Blue Drop Series
Book 1: Policy Makers

Rainwater Harvesting and Utilisation

UN-HABITAT

Foreword

Water is essential for the environment, food security and sustainable development. In 2000, at least 1.1 billion of the world's people - about one in five - did not have access to safe water. Asia contained 65 per cent of the population without safe water and Africa 28 per cent. Despite positive developments during the 1990s the number of urban dwellers lacking access to safe water increased by nearly 62 million. For this reason Millennium Summit set up target 10 to halve by 2015 the proportion of people without sustainable access to safe drinking water.

The increasing urbanization is a normal process of economic development and the challenge is to make this growth sustainable, efficient and equitable. Unfortunately, the positive role of urbanization is overshadowed by infrastructural deficiencies. Two million children die every year for the lack of water or for its poor quality. A billion people live in slums in overcrowded conditions without access to basic services particularly safe drinking water. The availability of water in the regions is constantly declining and health risks continue to rise. The poor pay more for water than the rich both within and between cities. Millions of girl children are forced to trade education for collecting water, or drop out from schools for the lack of even minimal sanitation facilities. Therefore, there is no better way to reduce child mortality or promote universal primary education than conserving the precious water resources for our cities especially for the poor.

Increasing access to safe water also requires addressing gender inequities. African women and girls spend three hours a day fetching water, expending more than a third of their caloric intake. Gender equality and empowering of women does require the unquestionable commitment of the policymakers to human settlements. The goals may be global but they need to be implemented locally in human settlements, where the people live and shelter and basic services like safe water are required.

Among the policy priorities for achieving target 10 of MDG 7, increasing resources and appropriate and affordable technologies for efficient water use are the important ones. Cost effective technologies are available to increase household and community access to safe water. Rainwater harvesting is one among such efficient but low-tech and cost effective technologies, which can help in meeting the challenge to provide fresh and safe water supplies. In order to harness local rainfall and local runoff to meet water needs, a variety of initiatives have been taken by some governments and communities around the world to promote water harvesting by urban households not only to encourage the use of rainwater for domestic use but also to reduce urban flooding and to increase ground water recharge.

In its pursuit to achieve the Millennium Development Goals relating to Water and Sanitation UN-HABITAT has been making an endeavour to strengthen the efforts of the cities and the communities by sharing knowledge and experiences, best practices and to help them use proven technologies for sustainable development. Hopefully a series of this UN-HABITAT publication on Rainwater Harvesting is another step in this direction, which may help undertaking rainwater harvesting programmes by communities, organizations and cities in the crisis regions of Asia, Africa, Latin America and the Caribbean.

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Preface

Rainwater harvesting is a technology which has been practiced for more than four thousand years. The rapid population growth, combined with industrialization, urbanization, agricultural intensification and changing life styles, is resulting in a global water crisis. UN-HABITAT in pursuance of targets 10 and 11 of MDG 7 has been working to promote technologies which may help water scarce cities and towns to meet the challenge on a sustainable basis. The current series on Rainwater Harvesting and Utilization has been brought out for the awareness and sensitization of the Policy Makers, for building the capacity of beneficiaries and developing the skills of Project Managers and implementing agencies.

Rainwater Harvesting has several policy dimensions. There are several conceptual and policy issues for community based rainwater harvesting. In order to encourage rainwater harvesting by city dwellers, there is a need for an appropriate fiscal and legal framework. Book - I has been mainly prepared for Policy Makers. Besides giving an overview of the concept of rainwater harvesting it has a focus on the legal and administrative framework for rainwater harvesting. There are many countries which have taken a variety of measures to promote water harvesting by urban households. Governments have used fiscal incentives to force households for water harvesting either for reducing urban flooding or for overloading of sewerage treatment plants. Subsidies have also been provided to promote urban water harvesting by the urban poor. Several case studies given in this Book - I share this knowledge and experience of many cities to be emulated by others.

The main objective of Book - II is to directly build the capacity of the beneficiaries. It fully explains the concept and technology of rainwater harvesting and water harvesting systems. In addition, the techniques for artificial aquifer recharging relevant for different topographies are explained.

UN-HABITAT would like to promote rainwater harvesting projects not only by the individual households but also by the industries, institutions like schools and encourage the communities to maintain and sustain underground water tables through artificial recharge. Book - III specially prepared for Project Managers and implementing agencies not only dwells on harvesting rainwater for direct use but also for rainwater harvesting for artificial recharge to groundwater and planning & monitoring of artificial projects. It is hoped that this attempt of UN-HABITAT in documenting rainwater harvesting experiences in technology and its use shall facilitate an extensive use of these techniques for harvesting rainwater and meet the challenge of achieving the Millennium Development Goal for Water and Sanitation.

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Acknowledgements

Water – being a precious item-rather a lifeline to the humanity – is getting scarce day by day. The more populous regions heading for rapid urbanization and fast depletion of water resources need utmost priority to act for conserving water and augmenting supply thereof. All this is possible through capturing rainwater. The most affected regions in the world are: Asia, Africa and Latin America & the Caribbean. Keeping in view the importance and urgent attention the subject of Rainwater Harvesting deserves, UN-HABITAT decided to undertake the task of preparing a generic guidebook on Rainwater Harvesting with a focus on rainwater harvesting and utilization in these most affected regions.

The preparation of the guidebook, called Blue Drop Series on Rainwater Harvesting and Utilization was entrusted to CITI Foundation, New Delhi, by the UN-HABITAT. Blue Drop Series was prepared under the overall supervision of Kalyan Ray, Senior Advisor, Office of the Executive Director, UN-HABITAT. Key substantive support in the form of concept and direction was provided by Andre Dzikus and design and coordination by Kulwant Singh of Water, Sanitation and Infrastructure Branch, UN-HABITAT.

An initial outline of the report was prepared by CITI Foundation in close consultation with UN-HABITAT. P.S. Mathur and Deependra Prashad did the field work and also desk-review of the available literature on the rainwater harvesting technologies as well as the best practices. Dilip Kumar Sharma together with Deependra Prashad through their commitment and professionalism did the writing and preparation of the draft guidebook. The CITI Foundation, apart from its own research, consulted, collected and collated huge information from various sources, which included available literature, contact with research institutions, experts, NGOs, discussions and other useful sources and also documented some of the case studies. The draft of the publication was circulated to experts for comments and suggestions.

The draft was extensively discussed in a workshop organized collaboratively by the Swiss NGO, the International Rainwater Harvesting Alliance (IRHA) and the Indian NGO, the Watershed Organization (WOTR) in India. IRHA also undertook the peer review of the guidebook and made useful recommendations of bringing out the guidebook in the form of Blue Drop Series in three volumes, each volume prepared for a separate target group. Based on IRHA's peer review, which analyzed the valuable information contained in the draft guidebook, the UN-HABITAT has brought out three Books on Rainwater Harvesting and Utilization under the caption "Blue Drop Series".

The report also benefited from the comments received from all the participants of the workshop organized in India. In particular those of Julie Perkins and Teshamulwa Okioga. Jogesh Kumar Arora provided valuable administrative and computer assistance.

CITI Foundation, New Delhi deserves special appreciation for completing the task of finalizing the three volumes on Rainwater Harvesting and Utilization.

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Introduction

Water forms the lifeline of any society. Water is essential for the environment, food security and sustainable development. All the known civilizations have flourished with water source as the base and it is true in the present context too. Availability of drinking water and provision of sanitation facilities are the basic minimum requirements for healthy living. Water supply and sanitation, being the two most important urban services, have wide ranging impact on human health, quality of life, environment and productivity. Despite the technological advancements, the global scenario still remains grim, as all the inhabitants of the world do not have access to safe water and adequate sanitation.

In most urban areas, the population is increasing rapidly and the issue of supplying adequate water to meet societal needs and to ensure equity in access to water is one of the most urgent and significant challenges faced by the policy-makers.

With respect to the physical alternatives to fulfil sustainable management of freshwater, there are two solutions: finding alternate or additional water resources using conventional centralised approaches; or utilising the limited amount of water resources available in a more efficient way. To date, much attention has been given to the first option and only limited attention has been given to optimising water management systems. Among the various technologies to augment freshwater resources, rainwater harvesting and utilisation is a decentralised, environmentally sound solution, which can avoid many environmental problems often caused by conventional large-scale projects using centralised approaches.

Rainwater harvesting, in its broadest sense, is a technology used for collecting and storing rainwater for human use from rooftops, land surfaces or rock catchments using simple techniques such as jars and pots as well as engineered techniques. Rainwater harvesting has been practiced for more than 4,000 years, owing to the temporal and spatial variability of rainfall. It is an important water source in many areas with significant rainfall but lacking any kind of conventional, centralised supply system. It is also a good option in areas where good quality fresh surface water or ground water is lacking. The application of appropriate rainwater harvesting technology is important for the utilisation of rainwater as a water resource.

Global Demographic Trends

The World population has more than doubled since 1950 and reached 6.15 billion in 2001. The most recent population forecasts from the United Nations indicate that, under a medium-fertility scenario, global population is likely to peak at about 8.9 billion in 2050.

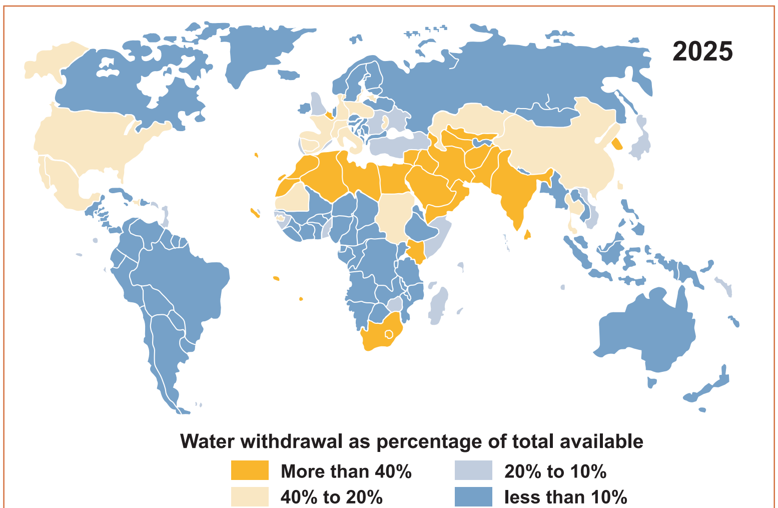
In parallel with these demographic changes, there have been profound demographic shifts as people continue to migrate from rural to urban areas in search of work and new opportunities. The number of people living in urban areas has jumped from 750 million in 1950 to nearly 2.93 billion in 2001. Currently, some 61 million people are added to cities each year through rural to urban migration, natural increase within cities, and the transformation of villages into urban areas. By 2025, the total urban population is projected to increase to more than five billion, and 90 per cent of this increase is expected to occur in developing countries. Sixty per cent of the global population is living in Asia. Urban population growth in Asia at 2.7 per cent per annum is 27 per cent higher than the global average. Asia's population living in urban areas is projected at 43.0 per cent for 2010 and will represent 50.8 per cent of world's total urban population. Asia is expected to double its urban population by the year 2020. By 2025, the majority of this region's population will live in cities. By 2015, there will be 153 cities of one million inhabitants, 22 cities with 8 or more million people and 15 with 10 to 20 million people.

The population of urban Africa is estimated to increase from 37.2 per cent in 2000 to 42.7 percent in 2010 and will represent 12.1 per cent of the world's urban population. The share of Latin America & the Caribbean is projected to increase from 75.4 per cent in 2000 to 79.0 percent in 2010, representing 13.4 per cent of the world's urban population.

The urban population of Africa, Asia and Latin America and the Caribbean is now nearly three times the size of urban population of the rest of the world. This population is growing so much faster than the rural population that 85 per cent of the growth in the world's population between 2000 and 2010 will be in urban areas and virtually all this growth will be in Africa, Asia and Latin America. Given that many natural resources (such as water, soil, forests and fish stocks) are already being exploited beyond their limits in some regions, significant effort will be required to meet the needs of additional people in the next 50 years.

The World Water Crisis

Rapid population growth, combined with industrialisation, urbanisation, agricultural intensification and water-intensive lifestyles is resulting in a global water crisis. In 2000, at least 1.1 billion of the world's people - about one in five – did not have access to safe water. Asia contains 65 per cent of the population without safe water and Africa 28 per cent. During the 1990s, there were some positive developments: about 438 million people in developing countries gained access to safe water but due to rapid population growth, the number of urban dwellers lacking access to safe water increased by nearly 62 million.



by the year 2025, two third of the world population may be subjected to water scarcity

Falling water tables are widespread and cause serious problems, both because they lead to water shortages and, in coastal areas, to salt intrusion. Both contamination of drinking water and nitrate and heavy metal pollution of rivers, lakes and reservoirs are common problems throughout the world. The world supply of freshwater cannot be increased. More and more people are becoming dependent on limited supplies of freshwater that is becoming more polluted. Water security, like food security, is becoming a major national and regional priority in many areas of the world.

Scenario in Selected Cities

In **Kolkata, India,** about half the population that lives in the slum or squatter settlements collect water from stand posts. The rest of the slum population do not have access to the municipal water supply and have to make their own arrangements – for instance relying on handpumps/drawing from tube wells. In **Bangalore, India** a city of some 6 million inhabitants, it is estimated that more than half depends on public fountains. Almost a third of the population has partial or no access to piped water. In **Dhaka, Bangladesh** it is estimated that in 2002 there were 2.5 million people in its 'slum' areas with most having very inadequate provision for water and sanitation. Tens of thousands of children die each year in Dhaka because of waterborne diseases and polluted water. In **Pakistan** more than half of **Karachi's** 12 million inhabitants live in *katchi abadis*. Only half the *katchi abadis* have piped water. In **Faisalabad, Pakistan** some two thirds of the city's two million inhabitants live in largely unserviced areas. Over half have no piped water supply.

In **Kampala (Uganda)** only inhabitants of affluent and middle-income districts in central and residential areas have private connections serviced by National Water & Sewerage Corporation. More than half the population in **Nairobi (Kenya)** depend on standpipe vendors for access to water; 30% of the population have a connection to the official network. In **Lima (Peru)** almost 2 million inhabitants have no water supply and 30% of those who do receive water (1996) is of dubious quality. The water shortage in **Tugucigalpa (Honduras)** is particularly acute as there is not even enough water to supply to consumers already having municipal water connections.

To further illustrate, **India's** population as per 2001 census is 1027.02 million. Over 60 per cent of households in India meet their drinking water requirements from underground water sources such as hand pumps, tube wells and wells. In urban areas while 68.7 per cent households use tap water, 29 per cent of the households directly use those underground water resources. Intense use of underground water has resulted in depletion of sub-terrene water resources in many parts of India.

Benefits of Rainwater Harvesting

Rainwater harvesting provides the long-term answers to the problem of water scarcity. Rainwater harvesting offers an ideal solution in areas where there is sufficient rain but inadequate ground water supply and surface water resources are either lacking or are insufficient. In hilly areas, rainwater can be used by humans, vegetation and animals. Rainwater harvesting system is particularly useful in remote and difficult terrain as it has the ability to operate independently. The whole process is environment friendly. There are a number of ways in which water harvesting can benefit a community – water harvesting enables efficient collection and storage of rainwater, makes it accessible and substitutes for poor quality water (Box 1.1). Water harvesting helps smooth out variation in water availability by collecting the rain and storing it more efficiently in closed stores or in sandy riverbeds. In doing so, water harvesting assures a continuous and reliable access to water.

A water harvesting system collects and stores water within accessible distance of its place of use. While traditional sources are located away from the community particularly in peri-urban areas, collecting and storing water close to households, villages or pastures greatly enhances the accessibility and convenience of water supplies.

Box 1.1 Rainwater Harvesting - Multiple Benefits

- Improvement in the quality of ground water
- Rise in the water levels in wells and bore wells that are drying up
- Mitigation of the effects of drought and attainment of drought proofing
- An ideal solution to water problems in areas having inadequate water resources
- Reduction in the soil erosion as the surface runoff is reduced
- Decrease in the choking of storm water drains and flooding of roads
- Saving of energy, to lift ground water. (One-meter rise in water level saves 0.40-kilowatt hour of electricity)

The rainwater collected can be stored for direct use or can be recharged into the ground water to improve the quality of ground water and rise in the water levels in wells and bore wells that are drying up as well as reduce the soil erosion as the surface runoff is reduced. Rainwater harvesting is an ideal solution to water problems in areas having inadequate water resources and helpful in mitigation of the effects of drought and attainment of drought proofing.

Water harvesting provides an alternative source for good quality water (rainwater is the cheapest form of raw water) seasonally or even the year round. This is relevant for areas where ground water or surface water is contaminated by harmful chemicals or pathogenic bacteria or pesticides and/or in areas with saline surface water. The rainwater harvesting systems can be both individual and community/utility operated and managed. Rainwater collected using various methods has less negative environmental impacts compared to other technologies for water resources development. The physical and chemical properties of rainwater are usually superior to sources of ground water that may have been subjected to contamination. Rainwater is relatively clean and the quality is usually acceptable for many purposes with little or even no treatment.

Rainwater harvesting technologies are flexible and can be built to meet almost any requirements. Construction, operation, and maintenance are not labour intensive. Predictions regarding global warming could have a major effect in significantly increasing water demand in many cities. At the same time increased evaporation from reservoirs and reduced river flows in some areas may decrease the available surface water supplies. A greater uncertainty regarding yields from major reservoirs and well fields is likely to make investments in the diversification of water sources, better water management and water conservation even more prudent in future. The role of rainwater harvesting systems as sources of supplementary, back-up, or emergency water supply will become more important especially in view of increased climate variability and the possibility of greater frequencies of droughts and floods in many areas. This will particularly be the case in areas where increasing pressure is put on existing water resources.

In urban areas, scarcity and accelerating demand of water is a major problem and it can be reduced by rainwater harvesting, using various existing structures like rooftops, parking lots, playgrounds, parks, ponds, flood plains, etc. to increase the ground water table, which saves the electric energy to lift the ground water because one-metre rise in water level saves 0.40 kilowatt hour of electricity. Subsequently it can also reduce storm drainage load and flooding in city streets.

As cities continue to grow in the future such problems are likely to become increasingly common. Since cities comprise numerous impervious surfaces designed to encourage rainwater runoff the scope for rainwater collection is substantial. Atmospheric pollution remains a major constraint as it contaminates both the rainwater and catchment surfaces making rainwater unsuitable for drinking in many cities around the world. Nevertheless, rainwater can still be used for non-potable uses such as toilet flushing, clothes washing and gardening. Furthermore, greater use of rainwater in urban areas could in future significantly strengthen the lobby to clean up the urban atmosphere entirely.

The Growing Global Interest in Rainwater Harvesting

With development of modern 'conventional' water supply systems in the first half of this century, many traditional water sources went out of favour. This was the case with rainwater harvesting technologies which came to be considered only as an option of last resort. While the exploitation of rainwater was considered appropriate in certain extreme situations such as on coral islands or at remote farms for which reticulated supplies were uneconomic, little serious consideration was given to the more general use of the technology.

Since around 1980, however, things have changed and there have been numerous grassroots initiatives supported by enlightened government and donor agencies promoting and implementing rainwater harvesting technologies. This has partly been a response to the growing technical feasibility of using roof catchment systems in the South due to the spread of impervious roofing materials in urban as well as rural areas. It has also been motivated by a paradigm shift regarding global attitudes to the environment and the growing realisation that water resource utilisation has to become more sustainable. In 1979 UNEP commissioned a series of regional case studies into *Rain and Storm water Harvesting in Rural Area*s. This included work from China, India, Mexico, the U.S., Africa, Australia, and the South Pacific. This was the first time a global overview of experiences with the technology was brought together in a single publication. Another even more influential overview by Pacey, A. & Cullis, A. 1986 followed soon after. At around the same time, UNICEF, several bi-lateral donor agencies (including DANIDA and SIDA), and many NGOs were promoting the use of household roof catchment tanks in East Africa and working on developing various low cost designs in Kenya. This work, much of which was done directly with community groups, led to rapid rates of adoption of roof tanks among rural communities. In a parallel development, the first conference on the use of rainwater cisterns for domestic water supply was held in Honolulu, Hawaii in 1982 attracting around 50 mainly academic participants. It was not envisaged at the time that the meeting would herald the beginning of a series of international conferences on the topic over the next 20 years which would include thousands of participants from a very broad cross-section of countries and professions.

The next three conferences took place in the U.S. Virgin Islands (1984), Thailand (1987), and the Philippines (1989) at which point the scope of the conference series was broadened to include other forms of rainwater catchment systems such as rainwater harvesting for agriculture. At the 1989 conference in Manila, it was also agreed to set up an Association to oversee the conference series and endeavour to promote the technology worldwide. Subsequent conferences took place in Taiwan (1991), Kenya (1993), China (1995), Iran (1997), Brazil (1999) and Germany (2001).

International Conferences on Rainwater Harvesting

- Hawaii (1982)
- U.S. Virgin Islands (1984)
- Thailand (1987)
- The Philippines (1989)
- Taiwan (1991)
- Kenya (1993)
- China (1995)
- Iran (1997)
- Brazil (1999)
- Germany (2001)

In addition to international conferences, many regional, national, and local meetings and initiatives took place during this period reinforcing the suggestion that the technology is now being given more attention globally than at any time prior to 1980. These have included the efforts by the New Delhi based Centre for Science and Environment to revive traditional rainwater harvesting practices in India (Agarwal & Narain 1997); the establishment of a rainwater harvesting forum in Sri Lanka (LRWHF 1999); setting up of People for Promoting

The Millennium Development Goal (7) of ensuring environmental sustainability has set out the target of reducing the proportion of people without sustainable access to safe drinking water to half by 2015.

It is generally believed that water and sanitation provision has been a serious constraint in urban areas in nations that have experienced the most rapid increase in their urban population as a proportion of their total population (i.e. urbanization levels) but this is not uniformly true. In fact some of the regions with the largest increase in urbanization levels have achieved much better levels of water and sanitation provision than some regions with smaller increases. Many of the world's most rapidly growing cities over the last 50 years have very good water and sanitation provision and many slower growing cities or smaller urban centres have very poor provision. It is surprising that such large cities do not face serious water shortages. In the case of Asia, however, the picture, by and large, is quite disappointing.

Rainwater Utilisation (PPRU) in April 1995 in Tokyo, Japan and new initiatives such as the promotion on rainwater utilisation in modern mega cities such as Tokyo (Murase 1994). The Vision 21 initiative also placed the use of appropriate technologies such as rainwater harvesting at the centre of its proposed strategies for providing clean water, adequate sanitation, and hygiene education for 95% of the population by 2025.

Rainwater harvesting/collection is considered among the most appropriate technologies for efficient use. In pursuance of the Millennium Development Goals, UN-HABITAT, therefore, has decided to bring out a guidebook on rainwater harvesting under Water for Asian Cities Programme in "Blue Drop Series" to encourage rainwater harvesting as part of the strategy for integrated water resource management in the Asian Region, Africa and Latin America & the Caribbean.

Objectives of the UN-HABITAT Guide on Rainwater Harvesting

In the hydrological cycle, rain is the first form of water that we know and hence is a primary source of water for us. Rivers, lakes and ground water are all secondary sources of water. In the present times, we depend entirely on such secondary sources of water and the primary source has been neglected to a great extent.

The purpose of the "Blue Drop Series" is to introduce the planners, decision makers, project managers, beneficiaries and others to the concept and technology of rainwater harvesting in urban areas and to show them where it fits into the overall picture of appropriate and sustainable community water supply development in urban areas. Just like other water resources, rainwater harvesting is an option to be considered when planning an improved water supply system with a community. Depending on local environmental conditions, water harvesting may provide a supplementary supply, an alternative supply or the only feasible improved supply, especially in urban areas which are heavily dependent on underground water. The information provided on technical issues is quite specific, as considerable experience is available, in particular in the area of construction technologies involved in rainwater harvesting.

The information on socio-economic aspects though less specific has also been provided as no tailor-made approaches can be recommended and much will have to be developed to cope with the differences in size, social organization, leadership and complicity of the urban community concerned. This "Blue Drop Series" has been prepared with the objective of presenting the basics required for undertaking rainwater harvesting. The three books under the series have been written in a simple form so that these can be used even by ordinary householders.

Apart from various methods and techniques for water harvesting, selected case studies of harvesting systems designed by various organizations working in the field of rainwater harvesting have been cited so that establishments with similar conditions can take up water harvesting on the same lines. This volume specifically presents methods suitable for singular building/establishment level – residences, institutions and industries. The scope of water harvesting can be extended to a locality/community level by incorporating various such singular units into a group. As one may learn through the "Blue Drop Series", broadly there are two approaches to harvesting water – storing of water for direct use or recharging of ground water.

The "Blue Drop Series" on water harvesting is comprehensive enough and incorporates useful information on various innovations in techniques that can be applied. This guide on water harvesting has been conceived as part of the broader objectives of the Water for Asian Cities Programme.

Rainwater Harvesting: An Overview

Water Harvesting

Scientifically, water harvesting refers to collection and storage of rainwater and other activities aimed at harvesting surface and ground water. It also includes prevention of losses through evaporation and seepage and all other hydrological and engineering interventions, aimed at conservation and efficient utilisation of the limited water endowment of physiographic unit such as a watershed. In general, water harvesting is the activity of direct collection of rainwater. The rainwater collected can be stored for direct use or can be recharged into the ground water. Rain is the first form of water that we know in the hydrological cycle, hence is a primary source of water for us (see figure).

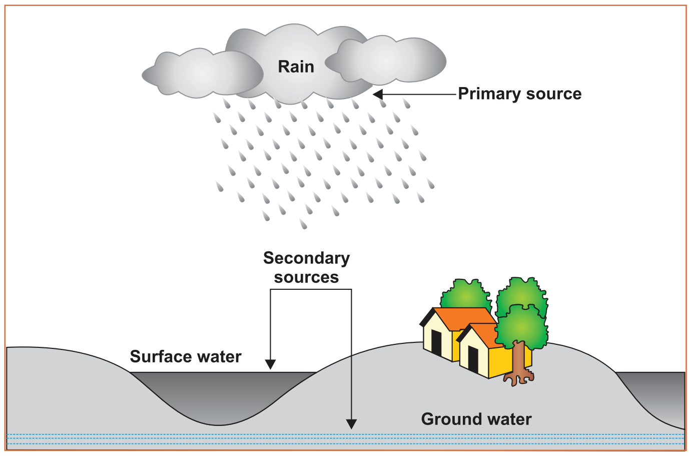
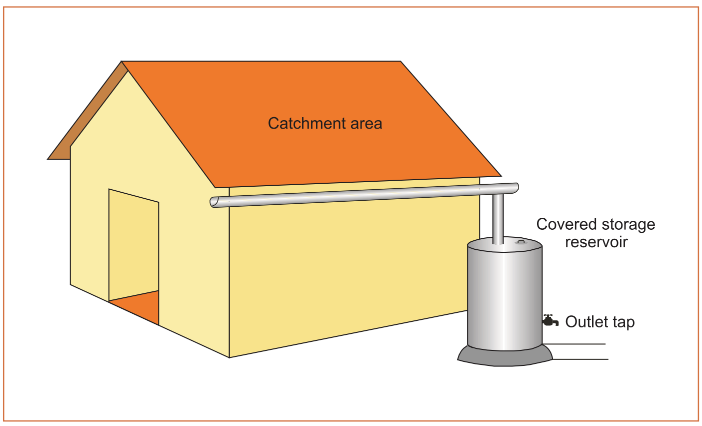


Figure: Where does all our water come from?

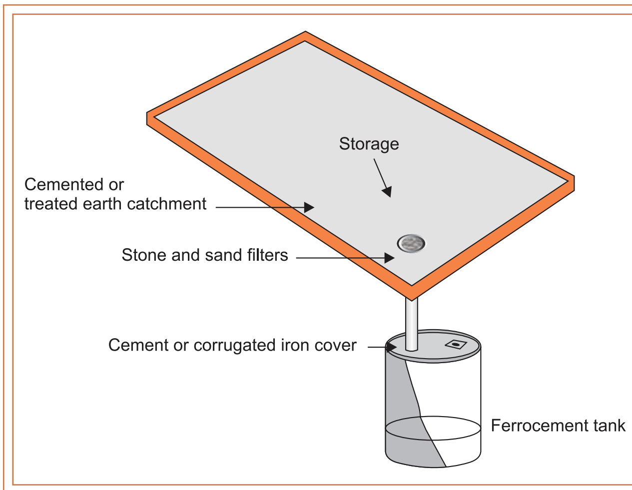
Rivers, lakes and ground water are all secondary sources of water. In present times, we depend entirely on such secondary sources of water. In the process, generally, it is forgotten that rain is the ultimate source that feeds all these secondary sources. Water harvesting means making optimum use of rainwater at the place where it falls so as to attain self-sufficiency in water supply, without being dependent on remote water sources.



Typically, a rainwater harvesting system consists of three basic elements: the collection system, the conveyance system, and the storage system. Collection systems can vary from simple types within a household to bigger systems where a large catchment area contributes to an impounding reservoir from which water is either gravitated or pumped to water treatment plants.

The materials and the degree of sophistication of the whole system largely depend on the initial capital investment. Some cost effective systems involve cisterns made with ferro-cement, etc. In some cases, the harvested rainwater may be filtered. In other cases, the rainwater may be disinfected.

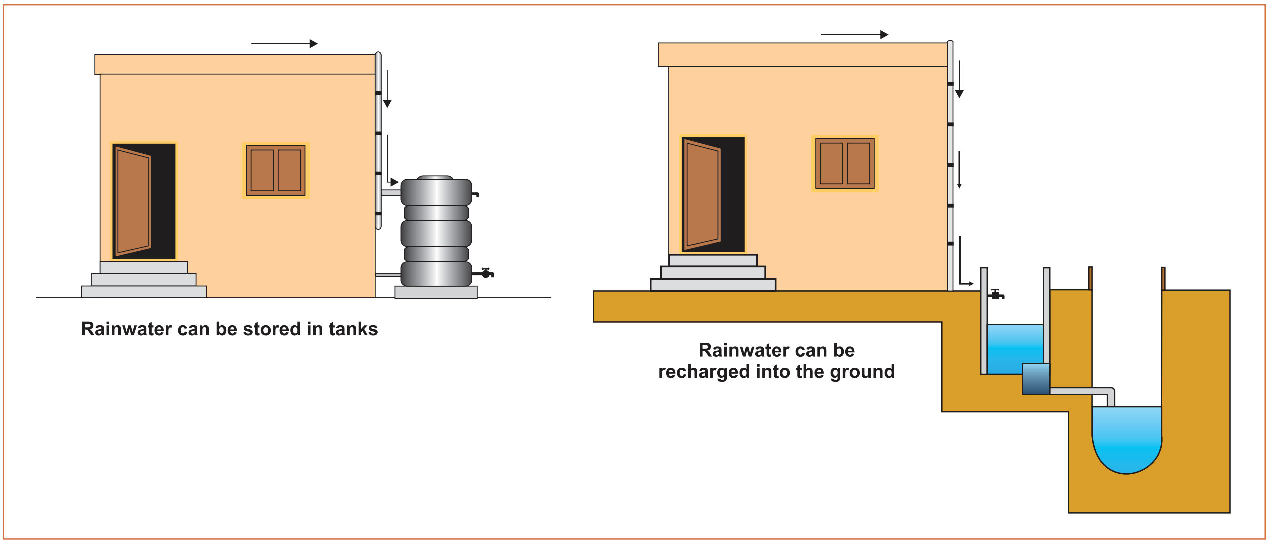
Rainwater harvesting using ground or land surface catchment areas can be a simple way of collecting rainwater. Compared to rooftop catchment techniques, ground catchment techniques provide more opportunity for collecting water from a larger surface area.



Harvesting System

Broadly rainwater can be harvested for two purposes

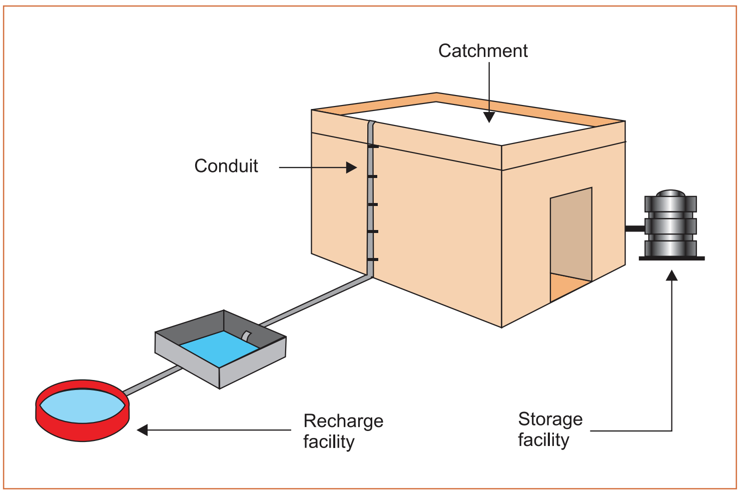
- Storing rainwater for ready use in containers above or below ground
- Charged into the soil for withdrawal later (ground water recharging)



Components of a Rainwater Harvesting System

All rainwater-harvesting systems comprise six basic components irrespective of the size of the system.

- **Catchment Area/Roof -** the surface upon which the rain falls; the roof has to be appropriately sloped preferably towards the direction of storage and recharge.
- **Gutters and Downspouts -** the transport channels from catchment surface to storage; these have to be designed depending on site, rainfall characteristics and roof characteristics.
- **Leaf Screens and Roof Washers -** the systems that remove contaminants and debris; a first rain separator has to be put in place to divert and manage the first 2.5 mm of rain.
- **Cisterns or Storage Tanks -** like sumps, tanks etc. where collected rainwater is safely stored or recharging the ground water through open wells, bore wells or percolation pits etc.
- **Conveying -** the delivery system for the treated rainwater, either by gravity or pump.
- **Water Treatment -** filters to remove solids and organic material and equipment, and additives to settle, filter and disinfect.



Elements of a Typical Water Harvesting System

Filters

Filter is an important part of the inflow structure of a RWH System. Once screens and roof washers remove large debris, other filters are available which help improve rainwater quality.

Charcoal Filter

Example of Artificial Recharge in Urban Settlements

Recharge Pits

Recharge pits are constructed for recharging the shallow aquifers. These are constructed generally 1 to 2 m. wide and 2 to 3 m. deep. After excavation, the pits are refilled with pebbles and boulders as well as coarse sand. The excavated pit is lined with a brick/stone wall with openings (weep-holes) at regular intervals. The top area of the pit can be covered with a perforated cover.

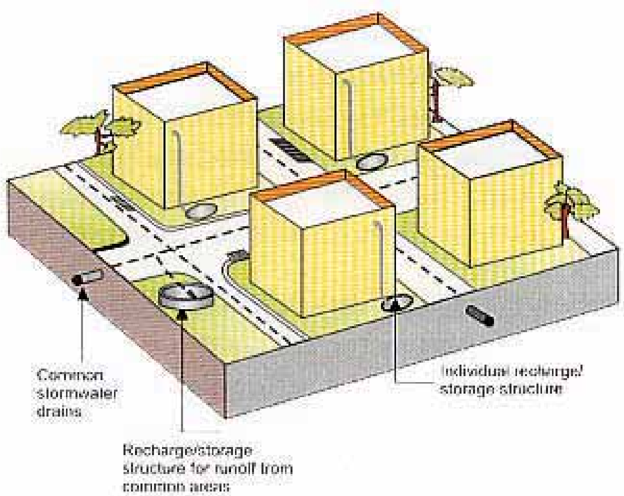
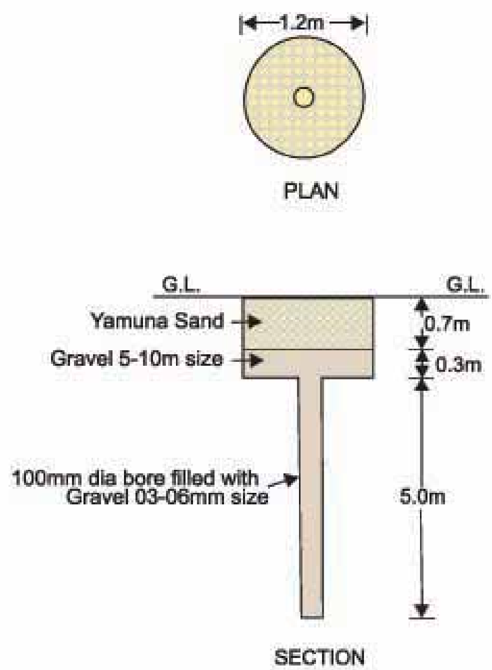


Figure: Trapping storm water drains in a community-level system



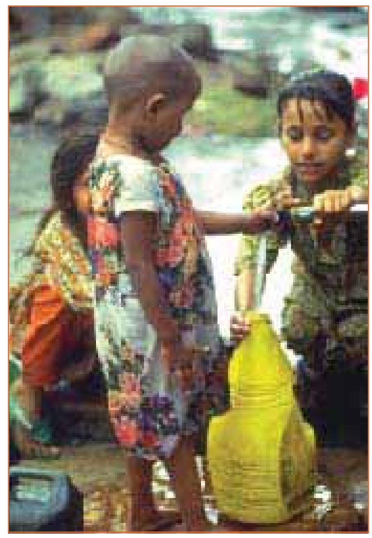
A locality-level water harvesting system illustrated in the figure above - shows how the runoff from individual houses can be dealt with at the building-level itself, while remaining runoff from the storm water drain (which drains water from roads and open areas) can be harvested by constructing recharge structures in common areas.

Water for Cities Programme

The objectives of the Water for African Cities programme and the Water for Asian Cities programme are to reduce the urban water crisis in cities through efficient and effective water demand management, to build capacity to reduce the environmental impact of urbanisation on fresh water resources and to boost awareness and information exchange on water management and conservation.

Water for African Cities Programme

A programme on Water for African cities was launched by UN-HABITAT in 1999 as a direct response to the Cape Town Resolution (1997) adopted by African Ministers addressing the urban water challenge facing the continent. This was the first comprehensive initiative to support African Countries to effectively manage the growing urban water crisis and protect the continent's threatened water resources from the increasing volume of land based pollution from the cities. The main objectives under the programme include:



- Development of water-related environmental education strategy for African cities.
- Establishment of water classrooms
- Schools water audit
- Water quality education
- Curriculum development and introducing water education in pilot schools
- Non-formal education with community initiatives
- Water health care education
- Information exchange and North-South twinning arrangements.

Water for Asian Cities Programme

To meet the Millennium Declaration Goal of halving the proportion of people without access to improved services by 2015, an additional 1.5 billion people in Asia will need access to adequate sanitation facilities, while an additional 980 million will need access to safe water. In urban areas, the corresponding figures are 675 million and 619 million respectively. Emphasis on urban water and sanitation has also been placed in the Millennium Declaration by setting a target of improving the living conditions of at least 100 million slum dwellers by 2020.

Following the New Delhi Consultation in April 2002, UN-HABITAT together with ADB launched this regional programme on Water for Asian Cities to promote pro-poor investments in water and sanitation in the region. The New Delhi Consultation made specific recommendations with regard to the implementation strategy and partnership arrangements for the proposed programme.

Programme Objectives

The Programme focuses on three inter-linked priorities.

(i) Introducing demand-responsive and demand management strategies to improve efficiency of water-use and give more influence to those currently deprived of water and sanitation

(ii) Scaling-up sanitation provision city-wide through innovative public-private-NGO partnerships, finance mechanisms and appropriate technical choices

(iii) New pro-poor investments in urban water supply and sanitation with emphasis on serving the urban poor with piped water and formal sanitation facilities

Key Programme Activities

- Monitoring of progress towards achieving Millennium Goal targets in the water and sanitation sector in Asian cities.
- Mobilization of political will through advocacy and exchange of information.
- Strengthening regional, country and city level capacities for integrated water and sanitation management. This requires human resource development in a focused manner, strengthening the capacity of existing institutions. Gender mainstreaming is an important crosscutting theme of capacity building at all levels.
- Creating a new ethic among children and community through Water, Sanitation and Hygiene Education. Interventions include: introducing value-based water education in schools; establishing water education classrooms in pilot cities; community education, training of trainers etc. Twinning of cities and schools is part of this initiative.
- Promoting pro-poor investments in the water and sanitation sector. This calls for the establishment of a pro-poor governance framework at the city level through stakeholder consultations, to facilitate the necessary policy and institutional reforms required for improving water and sanitation services for the urban poor. Investments in water supply and sanitation in Asian cities will provide the source developments, pipelines, treatment plants, reservoirs and distribution systems to bring water to those without direct access to piped water. It will also provide sanitation facilities in those cities, based on appropriate technology.

Partnership and Capacity Building for Pro-poor Investments

The programme commenced with a partnership development phase. The focus in this phase was on developing a framework for collaboration among city level actors as also with external support agencies and other ongoing programmes.

The central emphasis of the Water for Asian Cities Programme is on capacity building in the countries and cities in the region with a view to prepare the environment for pro-poor investments in the water and sanitation sector. While the Capacity Building Phase of the Programme is being directed to enhancing the willingness and commitment of the policy makers and creating the necessary institutional and human resource capacity to implement pro-poor policies and programmes, the investment promotion phase of the Programme shall be directed to creating the enabling environment for pro-poor investments.

Users of the "Blue Drop Series"

The "Blue Drop Series" on Rainwater Harvesting and Utilisation consists of three books and has been designed for policy makers, planners and all those involved in the implementation of urban water supply programmes. It has been prepared with a view to integrate the "state of the art" on Rainwater Harvesting to provide a handy, self-contained reference volume for use by all levels of functionaries in this sector in different regions of the world.

This volume, Blue Drop Series, Book 1, has been designed for Policy Makers. The book consists of three chapters including introduction about the Rainwater harvesting requirements, benefits and the role of UN-HABITAT in Rainwater Harvesting. The information contained in the Book provides useful information/data needed by policy makers/decision makers which include legal and administrative requirements for framing policies and programmes and giving proper directions. Also success stories/case studies around the world, as incorporated in the book, would provide valuable guidance for a pragmatic approach.

Chapter 2

Legal and Administrative Framework for Rainwater Harvesting

The fast rate of urbanization, resulting in rapid increase in demand for water, makes it scarce day by day. A growing number of cities and towns are, therefore, facing serious problems due to water scarcity. Whereas the water demand on one hand is increasing manifold, on the other hand state assured water supply is quite inelastic. These need to be addressed through mobilizing the people as well as enacting legislations that promote water harvesting on one hand, and regulate water extraction on the other. In urban areas water harvesting can be undertaken for a variety of purposes.

- To increase water supply for potable water needs;
- To increase water supply for low-quality household uses like gardening, washing clothes and for sanitary purposes;
- To provide water for institutional needs;
- To increase ground water recharge to improve the quantity and quality of ground water; and,
- To reduce storm water runoff and thus avoid flooding of urban areas and overloading of urban drainage and sewage treatment plants.

Policy Framework for Rainwater Harvesting

Many countries have national water laws. Most European countries have national water byelaws which put strict controls on Rainwater Harvesting (RWH) systems to prevent contamination of mains supplies by rainwater or inadvertent drinking of rainwater (of unknown quality) by individuals. As per law the mains and Rainwater (RW) plumbing systems are kept separate and RW taps are clearly marked. In India, however, there is no national law as such. There is, however, a national water policy. The National Water Policy (NWP) 2002 is a cogent and comprehensive document and can form a basis to be converted into a law. Water harvesting systems are diverse in their nature, size, number of users and ownership. People in South Asia, it is believed, evolved a water harvesting system based on availability of a resource, its geophysical conditions and local needs. The system is ancient. The need for a policy framework for water harvesting systems arises mainly because the prevailing policy statements do not touch upon the issue. The national water policy, national law policy, agriculture policy, national conservation strategies and policy statement on environment and development do not specifically touch upon the issues.

Box 2.1 **Initiatives for Promoting Rainwater Harvesting in Indore, India**

The local administration and various groups in Indore city are raising awareness and implementing rainwater harvesting to deal with the rapidly depleting ground water resources. The water supply to the town of Indore is 168 million litres per day as against the daily requirement of 320 million litres. Declining rainfall and the growing population has resulted in the gap increasing between demand and supply. This gap between demand and supply is met through tapping ground water. As a result, the ground water table is rapidly declining. "Energised pumps are working overtime to meet water needs".

When it comes to overexploitation of ground water, the story of Indore is no different from other big and small towns across India. What is different is the effort of the people to harvest rains. The Indore Municipal Corporation (IMC) and the city Mayor with the help of some media groups are involved in raising awareness and implementing rainwater harvesting. But rather than just complain, residents of the town are taking the matter into their own hands and are trying to alleviate the problem. Efforts to raise the ground water level in the area have started through rainwater harvesting programmes.

On the occasion of the 50th anniversary of the Nai Duniya newspaper group, a Nai Duniya Seva Trust was set up. The proprietors agreed to deposit a sum of five paise for each of the 1,30,000 newspaper copies sold every day. The scheme was launched on 23rd June 2000. So far, about Rs. 75 lakh have been collected and will be used for various development projects. Informs Ravindra Shukla, Senior Assistant Editor of the newspaper, "This fund is currently being used to finance organizations working to promote rainwater harvesting in rural and urban areas. So far, we have involved 12 organisations, six each in rural and urban areas. We have also sponsored satellite imagery of ground water resources in Indore so that rainwater harvesting efforts can be more effective".

A lot of effort is going into raising awareness. The group is spreading the message through advertisements and articles in their newspaper. The mayor is appealing to the citizens to adopt rainwater harvesting methods to raise the ground water level in the city. He informs, "I am planning a water march for water harvesting before the next monsoon. This water march will include a door-to-door campaign, public meetings, on the spot construction and exhibition of models.

The IMC launched its activities on 6th May 2000 with the theme, "If you protect water, water protects you". An exhibition was arranged at Rajwada, the palace of the Holkar kings, where models of different water harvesting methods, posters and filters samples were displayed and leaflets distributed. Rainwater harvesting is being implemented in residential colonies, institutes, clubs and gardens. Records of the IMC indicate that more than 2,000 houses in Indore have water harvesting structures The Nai Duniya office complex has a water harvesting structure that harvests rooftop rainwater from the roof area and recharges an old dugwell.

A rebate of six per cent on property tax has been announced for those who install rainwater harvesting in their house, bungalow or building. Three committees – technical, education and execution – were set up by the IMC for this purpose, the first of its kind in the country. For construction of new buildings on areas more than 250 square metres in size, rainwater harvesting is now compulsory. The Corporation has proposed to make rainwater harvesting mandatory for the existing buildings also.

The policy framework should respect people's right to free and easy access to water. The policy should also respect the right of people to clean and unpolluted water and a healthy environment. Further, the policy should also incorporate the principle of equity and distributive justice in the utilisation of water and to do so drinking water should get top priority followed by other domestic uses. The policy needs a law and for a possible law, a policy framework is a guideline.

In India, under the constitutional set up, water is a state subject. Institutions of local self-govt. have been established and steps are being taken to improve the existing law and to empower local institutions. In this regard, necessary efforts are also on to ensure that these institutions and local communities work together for the maintenance, use and survival of traditional water harvesting systems. The laws, however, should adopt a flexible framework for the management structure of water harvesting systems. There is, therefore, a clear need to evolve a decentralized legal regime which empowers people and makes them real managers of resources. For promoting urban water harvesting, a policy should include a mix of incentives and penalties. Measures that need to be undertaken include:-

- Provision of rainwater harvesting/recharge of ground water systems should become an essential town-planning requirement and be a pre-requisite for sanction of new colonies.
- Provision of rainwater harvesting structures in all building plans should be made before applications are accepted.
- Technical regulations should be in place to ensure that a certain distance of the pipes is maintained so that rainwater harvested is not contaminated by septic tanks.
- All the water carriers and bodies should be used as water storage through rainwater harvesting system.
- Creation of a national rainwater-harvesting fund.
- Creation/constitution of a single water authority or local body to control and regulate all water bodies.
- Granting rebate on property tax assessment and other fiscal incentives for effective use of rainwater harvesting system.
- Rainwater harvesting systems and conservation of water should be proclaimed as matters of national importance by the national Governments.

For implementing such policy measures the policy initiatives should be further strengthened through legislation. This apart, there is also a need to legally regulate ground water use.

Ground Water Rights: Legal Considerations

Ground water poses an extremely difficult legal problem. Unlike the case of surface water, it is often difficult to determine the source and rates of recharge, the extent and variation of quality in storage, and the direction of water movement. In **United States** three basic rules cover the use of ground water. **The first, or English, rule** is one of absolute ownership. It allows the overlying landowner to take ground water from the land at any time and in any quantity, regardless of the effect on the water table of a neighbor's land. Under this rule it would be possible for a landowner to exhaust the total ground water supply of an area by heavy pumping. This rule has been qualified in some areas to limit the malicious and wasteful use of the water. **The American rule**, or rule of reasonable use, recognizes that the landowner has rights to the water under the land but that these rights may be limited. The rights to water are limited to its reasonable use in relationship to the overlying land. **The third rule** covering ground water is the appropriation principle, whereby the water is allocated for specific uses. The growing intensity of water scarcity, however, calls for certain legislative, administrative and fiscal measures. Legislation is a source as well as an instrument of public policy.

Legal and Fiscal Measures to Protect Ground Water

A variety of measures have been undertaken by governments to promote water harvesting by urban households. In the city of **Chennai (India)**, urban authorities have made it mandatory under the city's building regulations for all new buildings to have water-harvesting mechanisms primarily to recharge the ground water aquifers. In **Bonn**, a fiscal incentive is provided to households through a municipal tax that forces households to pay for runoff producing areas like paved areas and the roof area, unless they unpave the paved areas or collect the rainwater from rooftops and paved areas for domestic use. The primary objective in Bonn is to reduce urban flooding and overloading of sewage treatment plants and to increase ground water recharge locally. **Sumida city,** a ward of **Tokyo**, provides a subsidy to all households interested in developing water-harvesting systems.

The main objective here is to promote the use of rainwater for low quality household uses, for drinking in emergency situations and to reduce urban flooding. If any subsidies are provided to promote urban water harvesting, it must be ensured that only the poor and lower middle classes benefit from them.

Legal and Other Measures Initiated in India to Promote Rainwater Harvesting

In order to ensure that the buildings that are erected in Delhi provide for water harvesting through storing of rainwater runoff to recharge underground aquifers, the Central Government in India has notified modifications/ additions to the Building Bye Laws of 1983. The modified Buildings Bye Laws have made water harvesting through storing of water runoff including rainwater in all new buildings on plots of 100 sq. mtrs and above mandatory. The plans submitted to the local bodies have to indicate the system of storm water drainage along with points of collection of rainwater in surface reservoirs or in recharge wells.

Secondly, buildings having a minimum discharge of 10,000 litres and above per day have to incorporate a wastewater recycling system. The recycled water would be used for horticultural purposes. Every time a building plan is submitted for approval, a certificate has to be submitted along with the building drawings stating that the building plans submitted for approval satisfy the water harvesting requirements as well as minimum anticipated discharge of waste water as stipulated in the revised Building Bye Laws.

Similarly, the Central Government has amended the Environment (Protection) Act 1986 to incorporate the following provisions relating to Rainwater Harvesting with a view to protect and improve the quality of environment in all the hill towns located in the Himalayan region.

- All buildings to be constructed in future in hilly urban areas to have provision for rooftop rainwater harvesting commensurate with its plinth area with minimum capacity of 5 Kl for plinth area above 200 sq.m, 2Kl for plinth area of 200 sq.m or below in case of residential buildings and minimum capacity of 0.01 cu.m per sq.m of plinth area in case of commercial and institutional buildings such as tourist complexes, hotels, shopping complexes and Government buildings.
- Where minimum standards have already been laid down by the State Governments, such standards shall take precedence.
- The institutional and commercial buildings not to draw water from existing water supply schemes which adversely affect water supply to local villages or settlements.
- In rural and peri-urban areas rainwater harvesting to be undertaken through such structures as percolation tanks and storage tanks and any other means.
- Spring sanctuary development to be undertaken in the spring recharge zones to augment spring water discharge.
- Rainwater collected through storm water drains to be used to clean the waste disposal drains and sewers.
- Ground water aquifer recharge structures to be constructed wherever such structures do not lead to slope instabilities.

The Govt. of India has also constituted the Central Ground Water Authority (CGWA) under section 3(3) of the Environment (Protection) Act 1986 for the purpose of regulation and control of ground water management and development. The CGWA has been vested with the powers under section 5 of the said Act for issuing direction and taking up such measures as may be deemed necessary to any authority and such person, officer or authority shall be bound to comply with such directions. The Authority has issued several Public Notices declaring areas/ complexes as “Notified Areas” for the regulation of ground water extraction. It regulates undertaking of any

Box 2.2 **Regulating Ground Water Use**

The city of Chennai (India) has resorted to legislative control to regulate ground water use

The Chennai Metropolitan Area Ground water (Regulation) Act 27 of 1987 envisages control, regulation, extraction and transportation of ground water in the notified area through (i) registration of existing wells; (ii) regulation of sinking of new wells; (iii) issue of licenses to extract water for non-domestic use; and (iv) issue of licenses for transportation by goods vehicles.

The term 'Ground water' mentioned in the Act means the water which exists below the surface of the ground and the term 'scheduled area' means the whole of the city of Chennai and the villages specified in the schedule. The Act, which came into force in February 1988, exempted from its purview wells used for purely domestic purposes, requiring a grant of permission regulated construction of wells for other uses. Extraction of water was, however, regulated on an annual basis.

The competent authority for the purpose of the Act:

- In the city of Chennai, the Metro Water Board;
- In relation to the villages specified in the schedule, the respective sub-collectors or revenue divisional officers of the taluks in which the villages fall.

In granting or refusing a license, the competent authority takes into account:

- Purpose or purposes for which ground water is to be used;
- Existence of competitive users;
- Availability of ground water;
- Effects on sources of water supply;
- Compatibility with existing water supply system; and,
- Availability of factors controlling or preventing pollution.

The competent authority has full powers to withdraw or cancel the license, if any of the provisions of the Act, or the rules made under the Act, or if any terms and conditions and restrictions, subject to which the permits or licenses have been granted, are contravened, or otherwise not complied with.

Punishment for first offence is a fine which may extend to Rs. 500, and for the second and subsequent offences with imprisonment for a term which may extend to six months or with a fine which may extend to Rs. 1,000 or both. Any offence punishable under the Act is a cognizable offence within the meaning of the code of criminal procedure.

operation connected with drilling, cleaning, construction or rehabilitation of ground water abstraction structures and related works including installation of pumps in the notified areas. The CGWA also promotes adoption of rooftop rainwater harvesting system by Group Housing Societies, Institutions, Schools, Hotels, Industrial Establishments and Farm Houses etc. This apart, the Authority also declares aquifers as **"Protected aquifers".**

A number of State Governments have made rainwater harvesting mandatory. Depending on the intensity of the problem, rooftop harvesting has been made compulsory on new buildings, old buildings and buildings according to their size in various Indian cities. **Fiscal incentives** like rebate in property tax and financial assistance for making provision of rainwater harvesting in the existing buildings are also available in a number of cities. Some of the important measures adopted in different states/cities are highlighted in Box 2.5.

Besides the steps being taken by the Central Ground Water Authority for adopting water harvesting compulsorily, several State and City Governments have resorted to legal and administrative measures for making rainwater harvesting mandatory. Andhra Pradesh has passed an Act titled "Water, Land and Trees Act", 2002, which came into force on July 1, 2002. The Act aims at regulating the exploitation and use of ground and surface water for protection and conservation of water resources. Under this Act, a Water, Land and Tree Authority has been established. This Authority regulates all ground water resources including prohibiting water pumping and sinking of new wells. Similarly Govt. of Tamil Nadu has issued an ordinance titled “Tamil Nadu Municipal Laws 2003” making rainwater harvesting mandatory for all the buildings, both public and private in the State. The state Govt. of Rajasthan, Gujarat and Haryana have also taken administrative/legal measures for making rainwater-harvesting mandatory for all public/government buildings. Several city governments, which include Indore, Kanpur, Hyderabad, New Delhi, Mumbai and Chennai, have also adopted similar measures.

Promoting Urban Water Harvesting: Some Guiding Principles

In urban areas, rooftop water harvesting has an enormous potential to reduce the demand on river and ground water systems, many of which are getting increasingly overexploited and polluted. In order to promote water harvesting in urban buildings, development byelaws need to be suitably formulated or modified. The following steps need to be taken:

- Every urban area should have a master plan; wherein water catchment areas are clearly demarcated and should be left undisturbed. Municipal corporations should demarcate such lands and utilize them as water catchment areas. These catchment areas can be used for afforestation by the forest department or can be transferred to the forest department as an urban sanctuary, so that its land use cannot be changed without government approval.
- Prior clearance before land acquisition to ensure that water catchment areas are not disturbed.
- A single water authority or local body, as the case may be, should be vested with the control and regulation of all water bodies including rivers / canals / waterways / ground water aquifers in urban areas.
- Town planners / local authorities should provide for surface water percolation along roads, pavements and other open spaces.
- All building plans must provide for water harvesting structures before applications are accepted, though provisions for exemptions should exist for those who cannot build water harvesting structures for genuine reasons like lack of space. Statutory provisions should be made for public buildings and large structures, making water audits essential.
- Provision of Water Harvesting (WH) systems in plans should be followed up by enforcement at the time of grant of water and / or sewer connections / assessment of property tax, etc.
- Builders and planners should be given clear technical guidelines on precautions to be observed in providing WH systems so that there is no contamination by septic tanks. The local authority in charge of water supply should be responsible for the maintenance of rivers and other water bodies with the specific aim of using them for water storage through WH systems. More efforts are needed to simplify approval procedures to reduce the overload on the existing administration.
- Master plans for rainwater collection and use for all urban centres should be made a pre-requisite for meeting eligibility requirements of national / international funding agencies like the ADB, the World Bank and others.
- The misuse of water bodies and waterways through sewage discharges should be restricted with provisions made for interceptory sewers and canals along waterways. This is an expensive proposition but can be taken up in a phased manner. At the same time, all new housing / commercial / industrial / construction activity by private or government agencies, should be allowed after a proper sewer system is laid and commissioned.
- WH systems should be promoted as a means of both providing water and preventing floods so that the message and the need are permanent.

- A central nodal agency in each country should provide technical and engineering advice on structures and systems to be used particularly in urban areas where the availability of non-paved areas is increasingly getting limited.
- Industrial houses should be encouraged, through incentives as well as town planning requirements, to provide for water harvesting on their premises and to maintain at least one WH community structure in an urban area.
- In the case of the **Singapore Changi Airport,** harnessing of runoff has been in operation for more than a decade. Since it has been successful even when the airport is very close to the sea, such projects should, as far as possible, be adopted in all airports. It should be made mandatory for all airports to utilize the runoff water on their land to recharge ground water and meet their requirements. Similarly, all highways and roads should construct structures to collect rainwater in order to sustain green strips on both sides.

Financial Assistance

Rainwater harvesting, like infrastructure, is an area in which government policy and finance have an important role to play because of its pervasive impact on economic development sustainability and human welfare. In recent decades, developing countries have made substantial investments in infrastructure, achieving dramatic gains for households and producers by expanding their access to services such as safe water, sanitation, electric power, telecommunications and transport. Water harvesting is, therefore, an area which needs to be governed by certain effective measures which could be mandatory, promotional, incentive related or others.

The governments should come forward to provide financial assistance to communities and households in addition to their contribution. Every household has something to contribute. The rich households have money to pay and the poor households have labour to contribute. People should also be urged to save and contribute money and labour for maintenance. As much as possible, people must be allowed to undertake construction themselves; at the least they must be involved in the supervision of the construction. They must be involved in the decision on what to construct. It is equally vital that people should know what money has been given to their community and for what purpose. All these are ingredients of a system of incentives meant to encourage community institutions to function effectively and take decisions.

- Generally a large number of urban local authorities are both water and cash starved. The government to extend financial assistance in the form of loans or grants should promote a Water Harvesting fund.
- Offering subsidies, rebates or a progressive water tariff should encourage individual and community participation.

Box 2.3 **Financial Incentive for Housing Societies in India Adopting Rainwater Harvesting**

The State Government of Delhi has introduced a financial incentive for adopting Rainwater Harvesting by the Resident Welfare Associations and Neighborhood Societies in the worst affected areas of South and South West district. Financial assistance is given up to 50 per cent of the total cost of the project or a maximum of Rs. 50,000/- on satisfactory completion of the project. The Housing Society takes the responsibility for proper maintenance of the structure at all times. The state water utility also disseminates information on Rainwater Harvesting (RWH) and provides technical assistance for its adoption.

A growing number of local governments in **Germany** today are supporting Rainwater Harvesting to save drinking water and for promoting decentralized seepage. Municipalities have developed different strategies to extend direct or indirect support to rainwater harvesting. The city of **Hamburg,** for example, initially gave money directly to house owners for constructing Rainwater Harvesting systems. Gradually, it stopped this direct support and gave indirect help by way of providing consultation, planning and change in the water fees system.

The city of **Bonn** has also changed its system of water fees in order to support decentralized rainwater retention and seepage. It has split the sewage charges into fees for wastewater and fees for rainwater. The latter is calculated in accordance with the area of sealed surface per household. If a household has taken measures for decentralized rainwater retention or seepage by building grass-covered roof, seepage facilities or rainwater harvesting system, the rainwater fee is reduced.

Another very important instrument to support rainwater harvesting is through proper planning. To empower municipalities to take appropriate steps, national statutes concerning the construction of buildings have been changed and now municipalities can lay down their own decentralized rainwater management plans.

Fiscal Incentives and Regulatory Mechanisms

Subsidies

In order to encourage people to install rainwater utilisation systems in some of the cities in **Japan,** residents and companies are given subsidies to install systems. **Sumida City** now offers subsidies up to ¥1 million (US $7,500) per rainwater utilisation project. Increasingly, local governments, including Okinawa Prefecture, Takamatsu City, Toyota City, Kamakura City and Kawaguchi City have begun subsidizing or loaning funds for installing rainwater systems. The **Indore Municipal Corporation** in India has proposed a rebate of 6% on property tax for those who install rainwater harvesting in their house, bungalow or a building.

There is clearly a need to study the possibility and feasibility of various fiscal incentives and regulatory mechanisms for promotion of water harvesting. In Arthshastra, Kautilya recommended tax exemption for those who constructed water-harvesting structures in their homes. Without appropriate pricing of water and electricity, households and institutions will have little economic interest to meet a significant part of their water needs through local water harvesting, and, thus, reduce the pressure on municipal water supply systems. The efforts made by **Frankfurt Airport** managers to meet a large part of their water needs illustrate the need for working in this direction. The system set in place was able to save them unnecessary expenses.

Box 2.4 **Regulating Ground Water Use through Legal Instruments and Financial Measures: Experiences of the Federal State of Hessen (Germany)**

In Hessen, 95% of drinking water is supply from ground water sources. The summers of 1992 and 1993 were very dry and the state experienced water scarcity and depletion in ground water levels. To overcome these problems, the government introduced a five-point programme including appropriate legal steps. These were

- Introduction of high charges for drawing ground water
- A ground water management plan for critical regions where the ground water levels were sinking
- Changes in the permission system of ground water based on the calculation of certain ground water measure-points
- Use of legal instruments to reduce water consumption coercively
- Construction of filter systems for rainwater.

As a result of these measures the withdrawal declined from 483 mcum to 432 mcum between 1992 to 1996. The money raised by the ground water extraction fees was used for supporting number of rainwater harvesting projects as well as a number of water protection projects in the industrial sector.

For effective utilisation of water resources, research is needed on pricing and legal rights of water while respecting social equity. There may be differential pricing of water for industry and domestic use. However, water should be priced keeping in view the overall social, economic and financial objectives in view for integrated water resource development.

One option is for government agencies to concentrate on the provision of clean water supply for drinking and cooking, leaving households and communities to develop their own water harvesting structures to meet other lower quality water uses. The project can be supported with appropriate fiscal incentives. Currently in urban areas, generally all household activities utilize potable water, regardless of its use. In Rajasthan (India), while the traditional *kundis* met potable water supply, tanks and other structures met other household needs.

Another option is to provide a certain minimum level of potable water at low prices which can be used for drinking and cooking while the price of the remaining water use by households can be sufficiently increased to discourage indiscriminate use and wastage.

Legal Empowerment

If existing government laws have legal provisions that prevent communities from undertaking water harvesting activities, these legal provisions need to be modified and replaced with provisions that support community and household efforts for water harvesting. There is an equally pressing need to develop and / or strengthen legal provisions that help to prevent destruction of existing water harvesting structures.

Institutional Mechanisms

There is also the need to develop and strengthen institutional mechanisms that are needed to promote water harvesting at various levels.

- User level;
- Village level;
- Urban neighbourhood level;
- City level;
- Province level; and,
- National level;

Each level should have a clear and defined role which helps to strengthen the role of other levels.

For integrated development, it is necessary that the national and the provincial governments should recognize and accept the need to rationalize planning and administration under a unified authority which should have representatives from the civil society, members of rural and urban institutions, and officials from relevant ministries, such as those dealing with planning, urban development, rural development, health and environment. This authority should function under the head of the government at various levels of Govt. The purpose of these authorities should not only be to promote water harvesting in different ecological regions of the country but also to promote efforts to protect existing water harvesting structures.

In **India** there is no institution today which deals with the protection of these water bodies. The National River Conservation Authority, for example, deals only with river pollution. These authorities could be empowered under the Environment Protection Act of the Central government to issue appropriate directives to relevant authorities for the protection of lakes and other urban water bodies. Otherwise a separate National Urban Lake and Water Body Authority may be created to protect urban tanks and various other water bodies. The Environment Protection Act provisions to protect water bodies and the catchment areas from encroachment or any activity which would pollute, impair, disturb or destroy them.

Legal support should be provided to the public to help fight cases where these bodies are being destroyed. Institutional mechanisms should be developed for the rapid settlement of disputes relating to water bodies.

Administrative and Planning Measures

One of the important aspects of the utilisation of urban catchment is the need to take an integrated approach towards planning. This involves a number of government, quasi-government and even private organizations for ensuring that water pollution should be avoided and minimized. Normally such coordinating efforts should be spearheaded by the water utility of the city. For the utilisation of urban catchments, there is a need for excellent control and coordination between many departments. The success of the utilisation of urban runoff largely hinges on the ability of the water authority to closely monitor the quantitative and qualitative characteristics of the raw water.

Steps Necessary for Promotion and Further Development of Rainwater Utilisation

A Systematic Approach

Rainwater utilisation, together with water conservation and wastewater reclamation, should be incorporated into municipal ordinances and regulations. Some standardisation of materials, at least at national/regional level, may be desirable from a maintenance and replacement point of view. It may be also appropriate to standardise the design of the rainwater utilisation system, at least at the national/regional level.

Implementation Policy

Various implementation policies should be established to make rainwater utilisation and other measures a part of the social system. Leadership is very important and local governments must take the initiative to promote the concept of water resource independence and restoration of the natural hydrological cycle. Consideration should be given to subsidising facilities for rainwater utilisation.

Technology Development and Training

Encouraging technology and human resources development to support rainwater utilisation is very important. It is also important to promote the development of efficient and affordable devices to conserve water, facilities to use rainwater and devices to enhance the underground seepage of rainwater. Together with this, there is a need to train specialists with a thorough grasp of these technologies and devices.

Networking

To promote rainwater harvesting and utilisation as an environmentally sound approach for sustainable urban water management, a network should be established involving government administrators, citizens, architects, plumbers and representatives of equipment manufacturers. It is essential to encourage regional exchanges amongst public servants, citizens and industry representatives involved in rainwater storage, seepage and use, as well as the conservation and reclamation of water.

Public awareness and education are essential to improve acceptance and implementation of rainwater harvesting and utilization

Box 2.5 **Legal, Administrative and Fiscal Measures Taken in Selected Cities of India for Promoting Rainwater Harvesting**

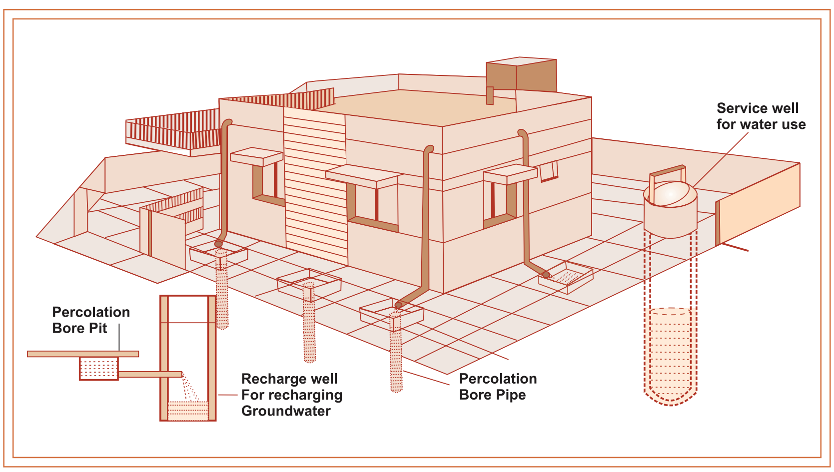
Cities/Authority	Measures Adopted
New Delhi Ministry of Urban Affairs & Poverty Alleviation, Govt. of India	Rainwater harvesting made mandatory since June 2001 in (i) all new buildings with a roof area of more than 100 sq.m. and (ii) all plots with an area of more than 1000 sq.m. that are being developed.
Kanpur State Govt. of U.P.	Rainwater harvesting made mandatory in all new buildings with an area of 1000 sq.m. or more
Indore City Municipal Corp. (M.P.)	Rainwater harvesting made mandatory in all new buildings with an area of 250 sq.m. or more Rebate of 6 per cent offered on property tax as an incentive for implementing rainwater systems.
Hyderabad and other City Municipalities in the State of Andhra Pradesh	Rainwater harvesting made mandatory in all new buildings with an area of 300 sq.m. or more (enforcing deadline was June 2001)
Chennai State Govt. of Tamil Nadu	Rainwater harvesting made mandatory in three storied buildings (irrespective of the size of rooftop area)
State Govt. of Haryana	Rainwater harvesting made mandatory in all new buildings irrespective of roof area.
State Govt. of Rajasthan	Rainwater harvesting made mandatory for all public establishments and all properties in plots covering more than 500 sq.m. in urban areas
Mumbai State Govt. of Maharashtra	Rainwater harvesting made mandatory for all buildings being constructed on plots more than 1000 sq.m. in size (deadline for this was Oct. 2002)
Delhi (South and South West Delhi and adjoining areas like Faridabad, Gurgaon & Ghaziabad) Central Ground Water Authority (CGWA)	Rainwater harvesting made mandatory in all institutions and residential colonies in notified areas (applicable for all buildings in notified areas that have tube wells). Deadline for this was March 31, 2002.
Central Ground Water Authority	Drilling of tube wells in notified areas of Haryana banned.
Chennai	New water and sewer connections provided only after implementation of rainwater harvesting systems.

Case Studies and Success Stories on Rainwater Harvesting

Adoption of rainwater harvesting systems is reflected through success stories the world over. The fast rate of urbanization followed by rise in demand for water has accelerated the pace of implementation of rainwater harvesting projects through various methods depending on the local requirement. The success stories bring to the fore the tales of truth whether it pertains to developed countries like Japan, Germany, Singapore, the Philippines, the USA or other developing countries of Asia and the Pacific, Africa, Latin America, the Caribbean islands and others. The stories of water harvesting serve as examples for the people facing and living in water scarce areas or the flood prone places, places encroached by water salinity or infected with the problem of arsenic or the areas needing recharge of aquifers. The case studies suggest adoption of a pragmatic approach towards methodology and techniques whether it is rooftop harvesting, water runoffs at the airports, commercial buildings, industrial areas or non-polluted plains. The future strategy could be based on the lessons learnt from these experiences.

Rainwater Harvesting Initiatives in Chennai, India

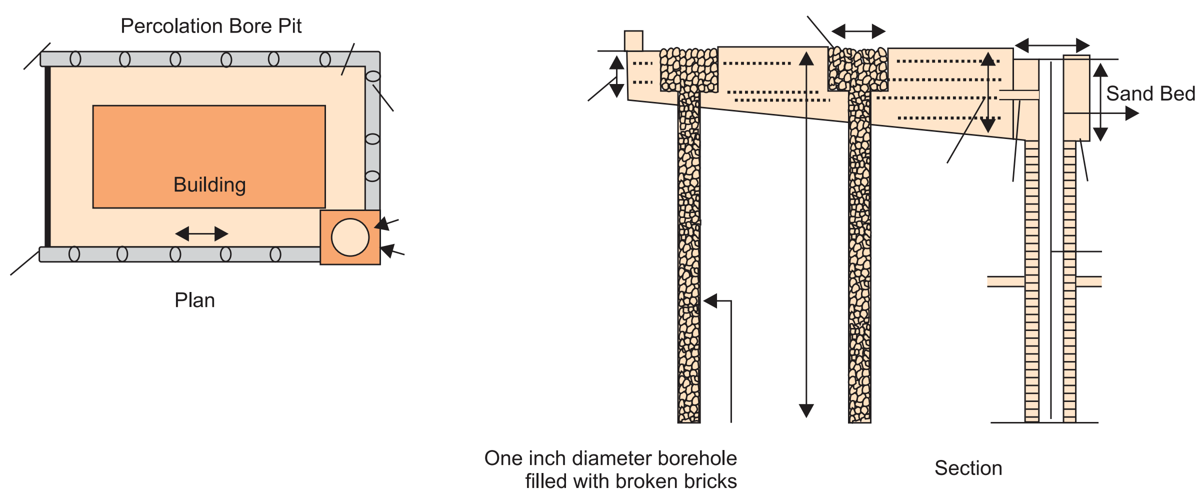
The city of Chennai faced a serious water crisis in the late 1980s. The need for effective ground water management along with the management of surface runoff became a necessity. Moreover, extraction of ground water started ringing alarm bells when ground water in the north-western coastal belt indicated that there was a rapid ingress of seawater which extended from three kilometers inshore in 1969 to seven kilometers in 1983 and nine kilometers in 1987. Ground water levels within the city also fell and brackish water began to appear even in localities which earlier had good quality ground water sources.



Practices in rainwater harvesting: Chennai receives an average annual rainfall of 1200 mm. It receives most of the rainfall from southwest and northeast monsoons. The geology of Chennai comprises mainly of clay, shale and sandstone (sand stone formation is the main water-bearing aquifer). Harvested rainwater is mostly used for recharging of aquifers, but in some places water is stored and used for non-potable purposes. Normally a building is constructed in the centre of the plot and an open area is paved with concrete. The runoff from these areas is collected through structures like percolation pits, trenches and collection wells.

Impact: In the southern coastal aquifer area, the ground water level in 1988 was around eight metres. A gain of 4.0 to 5.0 m was established in the 20 km stretch along the southern coast. In Anna Nagar, a significant difference was observed between areas where rainwater harvesting had been undertaken and where there were no such efforts. For the city as a whole, the average water level has increased from 6.8 m in 1987 to 4.55 m in 1998.

Civic Authority's Initiatives: In order to facilitate ground water management, the Chennai Metropolitan Area Ground water (Regulation) Act was passed in 1987. Metro water was identified as the enforcing authority for multistoried buildings/special buildings. They issued instructions that no new water connection was to be given unless water-harvesting structures provided in the approved plan were implemented. A series of investments were made by Chennai Metro water from 1991 onwards to harvest floodwaters along the course of the rivers bordering the city. Three check dams were constructed at Valliyur, Jagnathapuram and Melsembedu in 1991, 1992 and 1995 respectively. Moreover the government agencies are involved in implementing rainwater harvesting structures in public places like parks, roads, fly overs, and storm drains. Thus every possible catchment is being utilised for water harvesting. As of now 400 buildings, 216 schools and 56 parks owned by the corporation of Chennai have rainwater harvesting systems installed.



Sri Lanka

Sri Lanka receives abundant rainfall with mean annual totals ranging from 900mm to 6000mm with an overall national mean of around 1900mm per year. Due to the availability of alternative water sources in the past, there is no long tradition of roof water harvesting for domestic supply. Nevertheless, in many hilly areas lack of access to reliable wells or gravity fed piped supplies, water collection often involves a long trek to distant sources with a long uphill return walk carrying a full container. Following a study conducted in 1995, the Community Water Supply and Sanitation Project (CWSSP) first undertook a demonstration and pilot project involving the construction of about one hundred 5m 3-roof tanks for household water supply. Two designs were developed – a sub-surface brick tank and a surface ferrocement tank – costing about $100 and $125, respectively. For an average sized

Box 3.1 **Designing Rainwater Harvesting Systems in Urban Environment for Direct Use**

Using Bore wells

In the North East part of the city of Bangalore (India) is the residence of Mr. Namboodiri. Water lines have just reached the colony. The owner has dug a bore well to a depth of about 90 metres. The plot area for the site is 288 square metres and the roof area of the house is 121 square metres.

Approximately sloping roofs, locating down-pipes and providing filters at each down-pipe, guide clear water to a sump of capacity 8000 litres. Overflow from the sump is led to the bore well to recharge the underground aquifer. For the remaining plot area, ground slopes are worked and water is collected in a small water body. Overflow from the water body also recharges the ground water through percolation pits.

Every year it is estimated that on average 93,700 litres of rainwater is harvested and 32,400 litres of water is recharged.

Using Open Wells

Located in Sahakara Nagar about 13 km north of the city. City water lines are connected to the house. The twins, Prithvi and Purushottam, have an open well in their plot, which are about 6 metres deep. Water level in the dry season is at about 5 metres below ground level and in the monsoon it comes up to about 1 metre below the ground. The flat roof of about 60 square metres was gently sloped to a single point for the down water pipe, which would come down close to the Sump location. A first rain separator was provided to segregate the first 2.5 mm of rainwater. A drum filter designed by the owner was installed on the down pipe. After filtration the water is led into a sump of 6000 litres capacity. Overflow from the sump is led to the open well to recharge the unconfined aquifer. If the well water reaches ground level, provision is made for leading it out to a storm water drain outside.

Every year close to 54,000 litres are harvested and about 40,000 litres recharged.

Using Ponds

The Industrial unit of ESCORTS-MAHLE-GOETZE is located in Yelahanka a northern satellite town of Bangalore. The industrial unit has a site area of 20 Hectares.

Breakup of the area:

- Rooftop area: 29,961 sq.m,
- Paved area: 43,095.66 sq.m,
- Unpaved area: 129,286.98 sq.m

The total rainwater harvesting potential of the site is 185 million litres.

A pilot project was set up in May 2000 covering about 1280 sq.m of roof area for the administrative block and the canteen building. With storage capacity of 4200 litres, the unit collects about 1.05 million litres per year. The system is expected to pay back for itself in five years. The pilot system has received widespread publicity and is seen as a pioneering model for water harvesting by an industrial unit in Bangalore. The rooftop water harvesting is now being scaled up to cover 3000 sq.m of roof area.

Rainwater incident (harvesting potential) on the site was calculated to be 185 million litres of which it was estimated that 62 million litres could be harvested in a series of sumps and finally 3 ponds at the lowest contour of the site. A rooftop harvesting system for 2500 square metres of roof area has been put in place, which collects 2.40 million litres every year. Finally designing has been done to harvest the entire 62 million litres in the lined ponds. A payback period of about 3 years is expected for the Rainwater Harvesting System proving financial viability of the project.

roof of 60m, a household in the project area could expect a rainwater supply equivalent to between 150-200 litres/day or even higher during the wettest part of the year.

The end of 1997 had over 5000 grant applications for tank construction approved by the CWSSP in Badulla and Matara Districts and around 2800 tanks had already been constructed. The Lanka Rainwater Harvesting Forum was established in 1996 to promote the application of rainwater for domestic purposes throughout the country and to develop technology and establish guidelines for good rainwater harvesting practices.

Indonesia

In Indonesia, ground water is becoming scarcer in large urban areas due to reduced water infiltration. The decrease of ground water recharge in the cities is directly proportional to the increase in the pavement and roof area. In addition, high population density has brought about high ground water consumption. Recognising the need to alter the drainage system, the Indonesian government introduced a regulation requiring that all buildings have an infiltration well. The regulation applies to two-thirds of the territory, including the Special Province of Yogyakarta, the Capital Special Province of Jakarta, West Java and Central Java Province. It is estimated that if each house in Java and Madura had its own infiltration well, the water deficit of 53% at the end of the year 2000 would be reduced to 37%, which translates into a net savings of 16% through conservation.

Sumida City, Tokyo

Tokyo had been facing the problem of water shortages and floods alternately. The average yearly precipitation in Tokyo is about 1400 millimetres. Over two decades back, Sumida Ward (also called Sumida City), one of the most densely populated wards in Tokyo was inflicted with a serious flood causing heavy financial and health losses. Floodwaters inundated many buildings with sewage-contaminated water and for weeks people had no drinking water as the city's water tanks are installed underground.

Sumida City encompasses an area of 13.75 km^2, located in the eastern part of Tokyo and surrounded by the Sumida and Arakawa Rivers. The population of Sumida City is 225,935 (as of December 2001). Sumida City became involved in rainwater utilisation projects in 1982. Since then, Sumida City Government has been promoting rainwater utilisation in cooperation with its citizens. The Tokyo International Rainwater Utilisation Conference (TIRUC), organized by citizens and the Sumida City Government, entitled "Rainwater Utilisation Saves the Earth - Form a Friendship with Raindrops in Urban Areas", was held in Sumida City in August 1994.

Sumida City has since been actively promoting rainwater utilisation policies with the aim of developing water resources in communities, restoring natural water cycle and securing water supply for emergencies. Sumida City introduced the concept of rainwater utilisation in wrestling area in 1982. Since then the concept has been adopted in different facilities of the area. A simple rainwater utilisation system "Rojison" was constructed in many communities of the city hand-in-hand with the residents. The city's ward office boasts of the system that covers half of the building's water needs, apart from huge savings. Following the example of the area hundreds of buildings in Tokyo have introduced rainwater utilisation system. Thus Sumida City of Tokyo set the example for cities the world over.

Sumida City provided subsidy to residents and companies planning to install the rainwater utilisation system. The movement then started spreading nationwide. The government is planning water conservation policies for promoting the system and restricting ground water use.

A local Govt. Council was set up as proposed by Sumida City with the aim of utilizing rainwater to deal with the water shortage and flooding problems and has to improve the regional and global environment through measures such as the restoration of regional natural water cycle. The latter is exchanging information on policies, networking with local Govt. nationwide and spreading the network worldwide.

To date, 300 rainwater tanks have been installed in Sumida City, achieving a total rainwater reservoir capacity of 9000 m^3. In 1996, the Sumida City Government organized the Rainwater Utilisation Liaison Council for Local Governments. 104 local governments in Japan have joined this council in order to exchange policy ideas and experiences related to rainwater utilisation. Sumida City's rainwater utilisation projects were selected as an example of "best practice" by the G8 Environmental Futures Forum 2000, and also received an excellence award from ICLEI for "Local Initiatives" in 2000.

Profile of People for Promoting Rainwater Utilisation (PPRU)

PPRU was established on April 17, 1995 when the TIRUC Organizing Committee was re-organized as an NPO. The objectives of the PPRU are as follows:

- To promote autonomy of water resources by use of on-site rainwater.
- To promote regeneration of local water circulation by infiltration of rainwater.
- To promote policies which reduce air pollution so pure rainwater can be collected.
- To promote harmony with rainwater which has nurtured creatures and culture for millions of years.
- To create a global network for rainwater utilisation.

PPRU plans to create an International Rain Center to help solve the problems associated with the water crisis in the 21st Century and to promote a rain culture around the world. It will serve as the basis for an international network where information, ideas and experiences related to rainwater utilisation can be shared. Included in this international network will be citizens, businesses and public officials.

People for Promoting Rainwater Utilization

The promotion of rainwater utilisation and a rain culture requires acting locally, and thinking globally. In May 2001, the world's first Rainwater Museum was opened in Sumida City, Tokyo, Japan. City officials of Sumida City commissioned PPRU to create the museum in a vacant primary school in cooperation with the Japan Businesses Association for Rainwater Utilisation. The museum presents a wealth of information on rainwater and rain culture from around the world. In December 2001, PPRU published a Rain Encyclopaedia. PPRU has plans to translate this Encyclopaedia from Japanese into English and publish the English version. After its publication, PPRU is planning to initiate an International Rain Encyclopaedia project in cooperation with other countries.

Rainwater Museum in Sumida City

The Rainwater Museum is the first facility of its kind in the world. PPRU incorporated five key exhibit designs in the museum. The first is a pumpkin-shaped rainwater tank, which serves as the symbol of the Rainwater Museum. A symbolic message is written on this tank courtesy of the Lanka Rainwater Harvesting Forum (Sri Lanka): "Problem: Water, Solution: Rainwater". Another key exhibit is "Rainwater Crisis", which focuses on water shortages and flooding in urban areas in the 21st Century. The third exhibit provides an introduction to the study of rainwater utilisation not only in Japan, but also around the World. The fourth exhibit, "Rainwater Utilisation Systems", shows collection systems, various types of rainwater tanks, etc. Finally, the fifth main exhibit area is "Thinking Spots". This creative corner provides a space for thinking about the importance of rainwater.

Capiz Province, The Philippines

In the Philippines, a rainwater-harvesting programme was initiated in 1989 in Capiz Province with the assistance of the Canadian International Development Research Centre (IDRC). About 500 rainwater storage tanks were constructed made of wire-framed ferro-cement, with capacities varying from 2 to 10 m^3. The construction of the tanks involved building a frame of steel reinforcing bars (rebar) and wire mesh on a sturdy reinforced concrete foundation. The tanks were then plastered both inside and outside, thereby reducing their susceptibility to corrosion relative to metal storage tanks.

The rainwater harvesting programme in Capiz Province was implemented as part of an income generation initiative. Under this arrangement, loans were provided to fund the capital cost of the tanks and related agricultural operations. Loans of US$200, repayable over a three-year period, covered not only the cost of the tank but also one or more income generating activities such as the purchase and rearing of pigs, costing around US$25 each. Mature pigs can sell for up to US$90 each, providing an income opportunity for generating that could provide sufficient income to repay the loan. This type of innovative mechanism for financing rural water supplies can help avoid the requirement for water resources development subsidies.

Singapore

The Republic of Singapore has a land area of 61,000 hectares. Water availability is poor. In spite of 50 per cent of land area being used as a water catchment area, almost 40-50 per cent of water requirements are imported. After considerable research and development, schemes for abstraction of ground water in Singapore include utilisation of roofs of high rise buildings, use of run-off from airports for non-potable uses, integrated systems using combined run-off from industrial complexes, aquaculture farms and educational institutions.

A recent study of an urban residential area of about 742 ha used a model to determine the optimal storage volume of the rooftop cisterns, taking into consideration non-potable water demand and actual rainfall at 15-minute intervals. This study demonstrated an effective saving of 4% of the water used, the volume of which did not have to be pumped from the ground floor. As a result of savings in terms of water, energy costs, and deferred capital, the cost of collected roof water was calculated to be S$0.96 against the previous cost of S$1.17 per cubic meter. The catchment areas under utilisation are relatively clean and as a result the raw waters are of good quality. Singapore has earmarked specific locations where pollution-contributing activities are prohibited. The growing need for water led to establishment of Lower Seletar-Bedak Water Scheme in 1986. Control of Water Pollution and relevant technologies were the main priorities in the said scheme. Control of water pollution required great inter-departmental coordination which included government and quasi-government groups.

Besides inter-departmental planning for controlling water pollution, there are other important factors to be considered in the overall planning of such systems which include: hydrological simulation, water quality, trapping urban run-off, sediment removal etc. It has been established in Singapore that the utilisation of urban catchments is a reality that can be highly efficient if the system is well planned and is maintained and monitored. Additional research and development will help to optimize the reliable yield from such catchments and make the multiple uses of such catchments a truly working proposition.

A marginally larger rainwater harvesting and utilisation system exists in the Changi Airport. Rainfall from the runways and the surrounding green areas is diverted to two impounding reservoirs. One of the reservoirs is designed to balance the flows during the coincident high runoffs and incoming tides, and the other reservoir is used to collect the runoff. The water is used primarily for non-potable functions such fire-fighting drills and toilet flushing. Such collected and treated water accounts for 28 to 33% of the total water used, resulting in savings of approximately S$ 390,000 per annum.

The experience of Singapore shows that the concept of utilizing small catchments has to be accepted. The system of rainwater harvesting can be adopted in all the airports. The airports can provide both larger surface run-off and roof water. For utilizing urban catchments there is a need for proper coordination among various departments. This is very important to monitor qualitative and quantitative characteristics of the raw water.

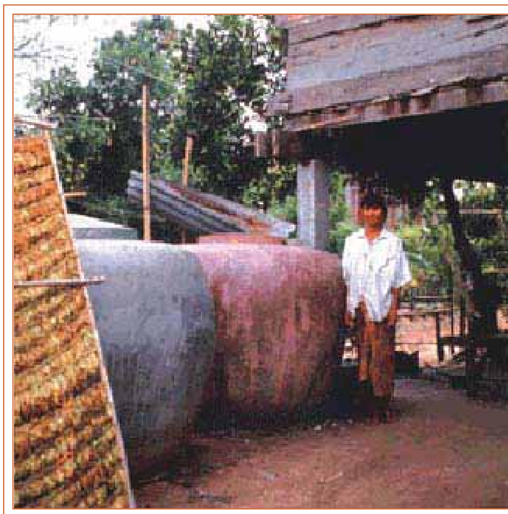
Thailand

Thai Rainwater Jar Construction Programme

The construction of over 10 million 1-2 cubic metre ferrocement jars for rainwater storage in Thailand between 1985-1991 has demonstrated the potential and appropriateness of rainwater catchment systems as a primary rural water supply technology. The unprecedented success of the programme was a result of several favourable factors all-encouraging the rapid spread of the technology. These included the following:

- The existing tradition of household rainwater storage in small jars;
- The relatively high rainfall and existence of large impervious roofs at most households
- The low price of cement;
- The availability of low cost skilled rural labour;
- The ongoing rapid rural economic development;
- The development of a durable and affordable tank design;
- The combination of a top down and bottom up approach;
- The combined public and private sector involvement;
- A willingness to adapt, modify and improve both the design and implementation strategies.

Although national, regional and local governments sponsored the programme through rural job creation initiatives to the tune of $64 million and both foreign and local donors provided some financial support, the recipients themselves contributed to most of the cost, estimated at between $250-350 million. The price of 1.8 cubic metre jars sold by entrepreneurs fell to just $20 making outright purchase affordable to most people and making the use of revolving funds unnecessary. By the early 1990's, most households in Northeast Thailand, a region previously dogged by inadequate rural water supplies, had year round access to clean water.



Example of the rainwater jar used in Thailand

Two approaches are used for the acquisition of water jars. The first approach involves technical assistance and training villagers on water jar fabrication. This approach is suitable for many villages, and encourages the villagers to work cooperatively. Added benefits are that this environmentally appropriate technology is easy to learn, and villagers can fabricate water jars for sale at local markets. The second approach is applicable to those villages that do not have sufficient labour for making water jars. It involves access to a revolving loan fund to assist these villages in purchasing the jars. For both approaches, ownership and self-maintenance of the water jars are important. Villagers are also trained on how to ensure a safe supply of water and how to extend the life of the jars.

Initially implemented by the Population and Community Development Association (PDA) in Thailand, the demonstrated success of the rainwater jar project has encouraged the Thai government to embark on an extensive national program for rainwater harvesting.

China

China's Gansu Province

Gansu province in China is one of the driest – and poorest – states in China. The loess (wind-blown soil) plateau in its central and eastern parts is the worst hit. Most of the river runoff is much too salty for drinking or irrigation purposes, and agriculture is rainfall-dependent. Ground water too is rare, and most of it is bad quality.

The Gansu Research Institute for Water Conservancy's (GRIWAC) four-year research findings suggested rainwater harvesting system (RWH) – tapping the only potential water source, the seasonal rains – as the answer. Its pilot program in the early 1990s helped 2,000-plus households set up RWH systems. They acted as true-life demonstrations of what could be achieved by harnessing water for supplemental irrigation and domestic use.

The provincial government in the wake of a drought of 1995 launched GRIWAC's successful project rather quickly. It provides each rural household with a $50 subsidy to build one rainwater collection field on their roofs or on a paved courtyard, two underground tanks, and a piece of land for courtyard economy. Design modifications in the structures were made to suit local conditions. Cement tanks were built instead of clay ones, as the latter are labour-intensive and prone to quality control problems. Rainwater collection efficiency was enhanced by adopting special measures of seepage control on the rainwater collection surface, or by using existing structure surfaces with less infiltration rates.

The impact of the project has been phenomenal. On an average, it has saved 70 water-fetching labour days per year per family. Supplemental irrigation yields have gone up by 20-40 percent for normal years, and is much higher for dry years. The cropping structure has undergone modification with farmers growing cash crops. Rainwater harvesting has, thus, become an indispensable option for Gansu Province to supply drinking water, develop rain-fed agriculture and improve the ecosystem in dry areas.

By 2002, the farmers in the area built 23,500 greenhouses and planted 40,440 hectare of fruit trees and 22,500 hectare of cash crops. The average per capita income has increased from $100 in 1995 to $182 in 2002. Food and livelihood security is finally a reality.

The Gansu success has caught the country's imagination as well as that of the international RWH community. By 2001, 12 million water cellars, tanks and small ponds were built throughout China with a cumulative storage capacity of 16 billion cubic meters, supplying water for domestic use to 36 million people, and providing supplemental irrigation for 2.6 million hectare of dry lands, helping 30 million people secure a relatively stable water source, a prerequisite for poverty alleviation.

The large-scale and quick replication of the Gansu experiment throughout the country is due to GRIWAC's step-by-logical-step research/experiment-demonstration-training-replication strategy.

The key success factors included motivation of and active participation in planning, construction and operations on the part of the farmers. Their labour and the donation of local construction materials provided two-thirds of the total cost. The springboard was the local government that recognized water as key to fundamental social and economic change and took it up in that spirit. They donated the subsidy money and spearheaded a hugely successful fund raising media campaign under this slogan: "Let us give our love to those suffering from thirst and poverty." Almost all government officials and employees of many enterprises, as well as donors from outside the provinces, contributed. Moreover, the participation of all sectors – universities, citizen groups, health departments, water and agriculture institutions – was sought.

Beyond this, setting up demonstration projects to showcase the benefits of this system, coupled with every household's ownership of it, are major reasons for success in engaging and motivating an increasing number of farmers.

Being is one of the driest provinces in China, Gansu's annual precipitation is about 300 mm, while potential evaporation amounts to 1500-2000 mm. Surface water and ground water is limited. Thus agriculture in the province relies on rainfall and people generally suffer from inadequate supplies of drinking water.

Since the 1980s, research, demonstration and extension projects on rainwater harvesting have been carried out with very positive results. In 1995/96, the "121" Rainwater Catchment Project implemented by the Gansu Provincial Government supported farmers by building one rainwater collection field, two water storage tanks and providing one piece of land to grow cash crops. This project has proven successful in supplying drinking water for 1.3 million people and developing irrigated land for a courtyard economy. As of 2000, a total of 2,183,000 rainwater tanks had been built with a total capacity of 73.1 million m^3 in Gansu Province, supplying drinking water for 1.97 million people and supplementary irrigation for 236,400 ha of land.

Rainwater harvesting has become an important option for Gansu Province to supply drinking water, develop rain-fed agriculture and improve the ecosystem in dry areas. Seventeen provinces in China have since adopted the rainwater utilisation technique, building 5.6 million tanks with a total capacity of 1.8 billion m^3, supplying drinking water for approximately 15 million people and supplemental irrigation for 1.2 million ha of land.

Contributed by: -Li Yuanhong, Project Director (gsws@public.lz.gs.cn), Gansu Research Institute for Water Conservancy, *China*

Gansu Province lies on the loess plateau in central China and is one of the driest and poorest areas of the country with annual per capita incomes of around US$70-80 in rural areas. Traditionally, people have depended on rainwater as their main source of water supply, excavating 20m^3 clay lined underground cisterns in the loess soil for storing surface runoff. In dry years, however, these could not always provide sufficient water and people were forced to trek long distances to rivers or to depend on government water trucks. In 1995 the region suffered its worst drought in 60 years. In response the Gansu Research Institute for Water Conservancy with the support of the Provincial Government launched the 1-2-1 projects which was based on test trials, demonstrations and pilot projects carried out since 1988.

The 1-2-1 projects were so named because each family was provided with 1 clay tiled roof catchment area, 2 upgraded cement water cellars and plastic sheeting for concentrating rainwater runoff on 1 field. Traditional clay lined water cellars (Shuijiao) were upgraded by lining them with cement or concrete and small metal pumps attached. Proper tiled roof catchments and cemented courtyards replaced the bare earth catchments and strong plastic sheeting was placed over the rills on fields to concentrate runoff onto crops. Some households also used spare plastic sheeting to construct temporary greenhouses using wooden frames. A trench dug around these was used to collect rainwater for watering the vegetables being produced.

Using these simple, effective yet inexpensive approaches, the project assisted over 200,000 families in 1995-1996 and ensured that around 1 million people were provided not only with sufficient water but also with food and through the production of cash crops, some limited income. For a total cost of around $12 million, half provided by the local government and half by community donations, the recipient families acquired upgraded water supplies and supplementary irrigation. The provision of labour and locally available materials by the community ensured that the total implementation cost for the project amounted to just $12 per capita.

Germany

Subsidies for Household Rainwater Systems in Germany

In Germany there is currently a growing interest in the promotion of household rainwater collection particularly at local government level. Due to serious industrial air pollution and strict regulations regarding drinking water standards, household rainwater supplies are limited to non-potable uses such as toilet flushing, clothes washing, and garden watering. In addition to reducing overall domestic water demand, benefits from rainwater utilisation include flood control and reduced storm water drainage capacity requirements. When used in conjunction with a seepage well to return any overflow to the ground, the systems also enhance ground water recharge. Most household tanks are constructed underground and one recent design incorporates a porous ring at the top of the tank so when it is more than half full, water seeps back into the ground.

The main advantage of designing rainwater collection systems in this way or in conjunction with seepage wells is that many German cities charge householders an annual rainwater drainage fee, which is waived if rainwater runoff is retained or returned to the ground, allowing significant savings. In Bonn, for example, current annual fees are \$1.80 per m^2 of roof area and sealed surround, respectively (König, 1998).

In many German towns and cities, grants and subsidies are available to encourage householders to construct rainwater tanks and seepage wells. In Osnabruck, Wessels, R. 1994 reported that a grant of \$600-\$1200 per household was available along with a further subsidy of \$3 per m^2 of roof area draining to any tank linked to a seepage well. On the basis of this subsidy, savings in water charges (\$0.56/m^3) and an annual rainwater drainage fees waiver of \$1.30 per m^2, the pay back period for investment in a tank seepage well system constructed at a new house was estimated to be 12 years. Even without the subsidy and constructing a system at an existing house, the investment would be recouped in 19 years. Costs and the return period on investments would be greatly reduced if householders were prepared to undertake some of the work themselves.

Berlin

In October 1998, rainwater utilisation systems were introduced in Berlin as part of a large scale urban re-development, the DaimlerChrysler Potsdamer Platz, to control urban flooding, save city water and create a better micro climate. Rainwater falling on the rooftops (32,000 m^2) of 19 buildings is collected and stored in a 3500 m^3 rainwater basement tank. It is then used for toilet flushing, watering of green areas (including roofs with vegetative cover) and the replenishment of an artificial pond.

In another project at Belss-Luedecke-Strasse building estate in Berlin, rainwater from all roof areas (with an approximate area of 7,000 m^2) is discharged into a separate public rainwater sewer and transferred into a cistern with a capacity of 160 m^3, together with the runoff from streets, parking spaces and pathways (representing an area of 4,200 m^2). The water is treated in several stages and used for toilet flushing as well as for garden watering.

The system design ensures that the majority of the pollutants in the initial flow are flushed out of the rainwater sewer into the sanitary sewer for proper treatment in a sewage plant. It is estimated that 58% of the rainwater can be retained locally through the use of this system. Based on a 10-year simulation, the savings of potable water through the utilisation of rainwater are estimated to be about 2,430 m^3 per year, thus preserving the ground water reservoirs of Berlin by a similar estimated amount. Both of these systems not only conserve city water, but also reduce the potential for pollutant discharges from sewerage systems into surface waters that might result from storm water overflows. This approach to the control of non point sources of pollution is an important part of a broader strategy for the protection of surface water quality in urban areas.

Frankfurt Airport & TU Darmstadt

Rainwater is being harvested at two huge complexes in Germany: Frankfurt Airport and the Technical University of Darmstadt. The combinations of huge catchment areas and simple technology have worked wonders. Frankfurt Airport is the biggest airport in the European continent. The city of Frankfurt is situated in the middle of Germany, where adequate quantities of water have been a problem. Most buildings in the airport have water saving installations.

In 1993, when a new terminal building was being constructed, a system for rainwater harvesting was installed. With an expectation of handling 13 million people every year, detailed studies were made on the future demands of water. For instance, toilet flushing was estimated at 20,000 litres per day. The rainwater system collects water from the roof of the new terminal which has an area of 26,800 square metres. The water is collected in the basement of the airport where six tanks have been put up, each with a storage capacity of 100 cubic metres (cu.m). This water is used mainly for flushing the toilets, watering the plants, and cleaning the air conditioning system with refined river water. In case of scarcity, this refined river water is also fed into the rainwater system. The rainwater harvesting system is one of the biggest in Germany and helps save approximately 100,000 cu.m of water per year. The costs of the system were 1.5 million DM (US $63,000). Some 50 per cent of the project was financed by the federal state of Hessen. The remaining investments will pay for themselves in approximately four years by reduction in the costs of water supply.

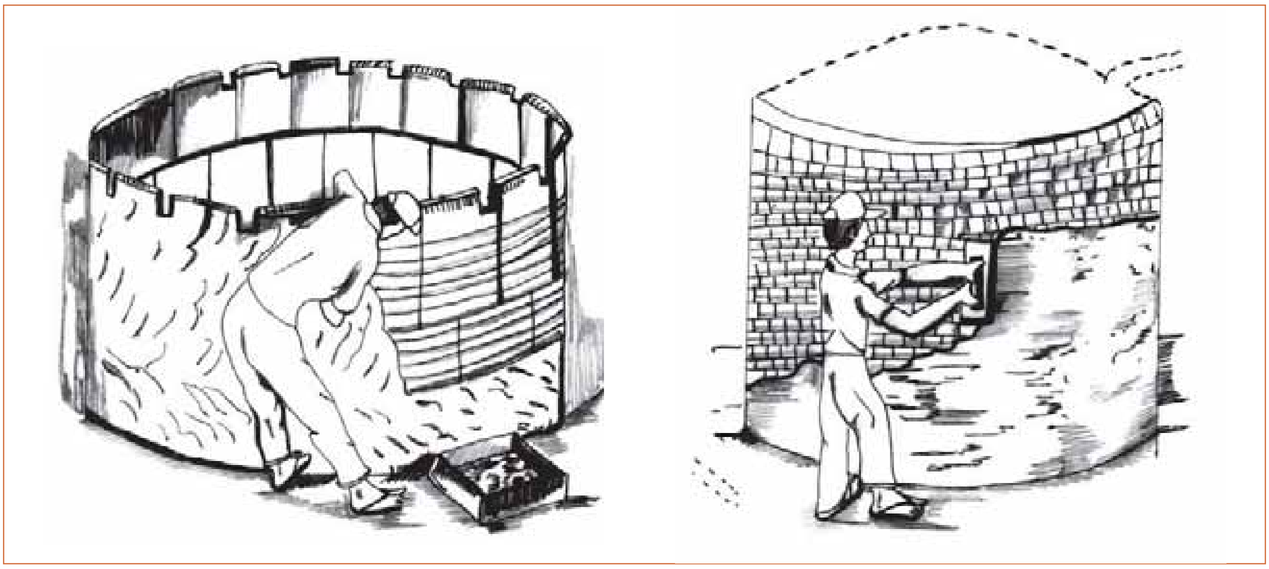
The Technical University of Darmstadt has another colossal rainwater harvesting system. Since 1993, a combination of rainwater harvesting and used-water is being supplied to the university. The water is used for flushing the toilets and is also supplied to the laboratories of the university for cooling and cleaning purposes, for which the water is cleaned prior to use. Ever since this system has been installed, only 20 per cent of the water demand is covered by drinking water, amounting to a saving of 80,000 cu.m of drinking water per year.

Bermuda

The island of Bermuda is located 917 km east of the North American coast. The island is 30 km long, with a width ranging from 1.5 to 3 km. The total area is 53.1 km^2. The elevation of most of the land mass is less than 30 m above sea level, rising to a maximum of less than 100 m. The average annual rainfall is 1,470 mm. A unique feature of Bermuda roofs is the wedge-shaped limestone “glides” which have been laid to form sloping gutters, diverting rainwater into vertical leaders and then into storage tanks. Most systems use rainwater storage tanks under buildings with electric pumps to supply piped indoor water. Storage tanks have reinforced concrete floors and roofs, and the walls are constructed of mortar-filled concrete blocks with an interior mortar application approximately 1.5 cm thick. A Public Health Act which requires that catchments be whitewashed by white latex paint regulates rainwater utilisation systems in Bermuda; the paint must be free from metals that might leach into water supplies. Owners must also keep catchments, tanks, gutters, pipes, vents, and screens in good repair. Roofs are commonly repainted every two to three years and storage tanks must be cleaned at least once every six years.

Brazil

Over the past decade, many NGOs and grassroots organisations have focused their work on the supply of drinking water using rainwater harvesting, and the irrigation of small-scale agriculture using sub-surface impoundments. In the semi-arid tropics of the north-eastern part of Brazil, annual rainfall varies widely from 200 to 1,000 mm, with an uneven regional and seasonal rainfall pattern. People have traditionally utilised rainwater collected in hand-dug rock catchments and river bedrock catchments. To address the problem of unreliable rural drinking water supply in north-eastern Brazil, a group of NGOs combined their efforts with government to initiate a project involving the construction of one million rainwater tanks over a five year period, with benefits to 5 million people. Most of these tanks are made of pre-cast concrete plates or wire mesh concrete.

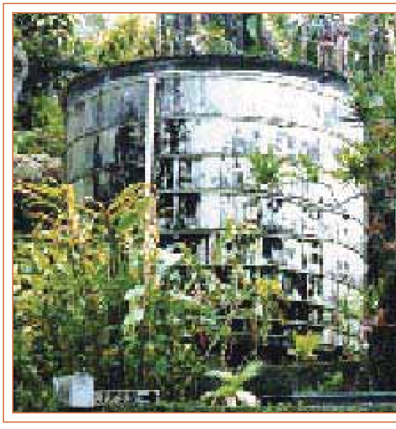


Tanks made of pre-cast concrete plates & wire mesh concrete

Rainwater harvesting and utilisation is now an integrated part of educational programs for sustainable living in the semi-arid regions of Brazil. The rainwater utilisation concept is also spreading to other parts of Brazil, especially urban areas. A further example of the growing interest in rainwater harvesting and utilisation is the establishment of the Brazilian Rainwater Catchment Systems Association, which was founded in 1999 and held its 3rd Brazilian Rainwater Utilisation Symposium in the fall of 2001.

Island of Hawaii, USA

At the U.S. National Volcano Park, on the Island of Hawaii, rainwater utilisation systems have been built to supply water for 1,000 workers and residents of the park and 10,000 visitors per day. The Park's rainwater utilisation system includes the rooftop of a building with an area of 0.4 hectares, a ground catchment area of more than two hectares, storage tanks with two reinforced concrete water tanks with 3,800m^3 capacities each, and 18 redwood water tanks with 95m^3 capacities each. Several smaller buildings have their own rainwater utilisation systems as well. A water treatment and pumping plant was built to provide users with good quality water.



A wooden water tank in Hawaii, USA

St. Thomas, US Virgin Islands

St. Thomas, US Virgin Islands, is an island city which is 4.8 km wide and 19 km long. It is situated adjacent to a ridge of mountains which rise to 457 m above sea level. Annual rainfall is in the range of 1,020 to 1,520 mm. A rainwater utilisation system is a mandatory requirement for a residential building permit in St. Thomas. A single-family house must have a catchment area of 112 m^2 and a storage tank with 45 m^3 capacity. There are no restrictions on the types of rooftop and water collection system construction materials. Many of the homes on St. Thomas are constructed so that at least part of the roof collects rainwater and transports it to storage tanks located within or below the house. Water quality test of samples collected from the rainwater utilisation systems in St. Thomas found that contamination from faecal coliform and Hg concentration was higher than EPA water quality standards, which limits the use of this water to non-potable applications unless adequate treatment is provided.

Dar es Salaam, Tanzania

Due to inadequate piped water supplies, the University of Dar es Salaam has applied rainwater harvesting and utilisation technology to supplement the piped water supply in some of the newly built staff housing. Rainwater is collected from the hipped roof made with corrugated iron sheets and led into two "foul" tanks, each with a 70 litre capacity. After the first rain is flushed out, the foul tanks are filled up with rainwater. As the foul tanks fill up, settled water in the foul tanks flows to two underground storage tanks with a total capacity of 80,000 litres. Then, the water is pumped to a distribution tank with 400 litres capacity that is connected to the plumbing system of the house.

The principles for the operation of this system are: (i) only one underground tank should be filled at a time; (ii) while one tank is being filled, water can be consumed from the other tank, (iii) rainwater should not be mixed with tap water; (iv) underground storage tanks must be cleaned thoroughly when they are empty; (v) in order to conserve water, water should only be used from one distribution tank per day.

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Glossary

Air gap: A vertical space between a water or drain line and the flood level of a receptacle used to prevent backflow or siphonage from the receptacle in the event of negative pressure or vacuum.

Aquifer: A porous geological formation which can store an appreciable amount of ground water and from which water can be extracted in useful quantities.

Artificial recharge: Any man made scheme or facility that adds water to an aquifer is artificial recharge system.

Backflow preventer: A device or system installed in a water line to stop backflow from a nonpotable source.

Backflow: Flow of water in a pipe or water line in a direction opposite to normal flow.

Backwater: The wastewater from toilets and kitchen sinks.

Bore well: Small diameter wells, which are generally deeper than open wells.

Buffer: To shift pH to a specific value.

Building footprint: The area of a building on the ground.

Catchment Area: The area from which runoff flows into a river, reservoir, etc.

Check Dam: Small dam constructed in a gully or other small watercourse to decrease the stream flow velocity, minimize channel scour and promote deposition of sediment.

Chlorination: The use of chlorine for the treatment of water, sewage or industrial wastes for disinfection or oxidation.

Cistern: An above or below ground tank used to store water, generally made of galvanized metal, fiberglass, ferrocement or concrete.

Contamination: To introduce a substance that would cause the concentration of that substance to exceed the maximum contaminant level and make the water unsuitable for its intended use.

Disinfection: A process in which pathogenic (disease producing) bacteria are killed by use of chlorine or physical processes.

Diverter: A mechanism designed to divert the first flush rainwater from entering the cistern.

Dug wells: Traditionally used large diameter wells. Defined precisely as pits excavated in the ground until the water table is reached, supported on the sides by RCC/Bricks/Stones/Walls, Diameters could vary from 0.6 metres onwards.

Erosion: The loss of topsoil that occurs as a result of run-off.

Filtration: The process of separating particles of 2 microns or larger in diameter from water by means of a porous substance such as a permeable fabric or layers of inert material housed in a media filter or removable cartridge filter.

First flush: Generally the first 50 litres of rainwater per 1,000 square feet of roof surface thatis diverted due to potential for contamination.

Flow rate: The quantity of water which passes a given point in a specified unit of time, expressed in litres per minute.

Force breaker: An extension of the fill pipe to a point 1" above the bottom of the cistern, which dissipates the pressure of incoming rainwater and thus minimizes the stirring of settled solids.

Greywater: The wastewater from residential appliances or fixtures except toilets and kitchen sinks.

Ground Water Draft: It is the quantity of Ground Water withdrawn from Ground Water Reservoirs.

Ground Water: The water retained in the intergranular pores of soil or fissures of rock below the water table is called ground water.

Hardness: A characteristic of ground water due to the presence of dissolved calcium and magnesium, which is responsible for most scale formation in pipes and water heaters.

Hydrologic cycle: The continual exchange of water from the atmosphere to the land and oceans and back again.

Katchi Abadis: Settlements/living colonies where people live in not so durable houses/shelters which may be made of mud, thatch, wood etc. or other non durable materials.

Leaf screen: A mesh installed over gutters and entry points to downspouts to prevent leaves and other debris from clogging the flow of rainwater.

Masonry: A wall or other structures made using building blocks like bricks or stone with binding materials like cement or lime.

Micron: A linear measure equal to one millionth of a meter, or .00003937 inch.

Nonpotable water: Water intended for non-human consumption purposes, such as irrigation, toilet flushing, and dishwashing.

Open Wells: Same as dug well. These wells were kept open in earlier days for manual withdrawal of water. Today, with electrical or diesel/patrol pumps, these can be fully covered.

Pathogen: An organism which may cause disease.

pH: A logarithmic scale of values of 0 to 14 that measure of hydrogen ion concentration in water which determines whether the water is neutral (pH 7), acidic (pH 0-7) or basic (pH 7-14).

Potable water: Water which is suitable and safe for human consumption.

Pressure tank: A component of a plumbing system that provides the constant level of water pressure necessary for the proper operation of plumbing fixtures and appliances.

Rainwater harvesting: The principle of collecting and using precipitation from a catchment surface.

Recharge: The process of surface water (from rain or reservoirs) joining the ground water aquifer.

Replenishable Ground Water: It is the portion of precipitation which after infiltration percolates down and joins the ground water reservoir.

Reservoir: A pond or lake built for the storage of water, usually by the construction of dam across a river.

Roof washer: A device used to divert the first flush rainwater from entering a cistern.

Runoff: Runoff is the term applied to the water that flows away from a surface after falling on the surface in the form of rain.

Sedimentation: The process in which solid suspended particles settle out (sink to the bottom) of water, frequently after the particles have coagulated.

Total dissolved solids: A measure of the mineral content of water supplies.

Water Pollution: The addition of harmful or objectionable material causing an alteration of water quality.

Water Quality: A graded value of the components which comprise the nature of water. Established criteria determine the upper and/or lower limits of those values which are suitable for particular uses (organic, inorganic, chemical, physical).

Water Table: The level of water within it granular pores of soil or fissures of rock, below which the pores of the host are saturated.

Wetlands: Areas of marsh, fen, peatlands or water, natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt including areas of marine water less than six metres deep at low tide.

Rainwater Harvesting FAQs

1. **What is Roof Top Harvesting?**

   To collect and store the rainwater which falls on the terrace of the buildings/houses. The water collected from the terrace is of good quality and it can be stored in tanks/sumps either for direct use or can be diverted to the existing bore well/open well for ground water recharge and storage.

2. **What are the precautions to be taken for roof top harvesting?**

   The terrace of the building should be maintained clean. A grill/mesh has to be fixed at the entrance of the rainwater pipe in the terrace to arrest large particles such as papers, leaves, etc. A filter chamber has to be provided to filter small/minute dust particles before diverting the rainwater into the storage tank or open well/bore well.

3. **How to harvest rainwater in the open spaces?**

   Rainwater collected in the open spaces, being relatively dirty in nature, cannot be used for direct recharge of the well and therefore used for ground water recharge, using appropriate recharge methods/structures. In the absence of open well, the roof-top water may also be harvested along with open space water.

4. **What are the precautions to be taken while harvesting rainwater from open space around the building?**

   A dwarf wall of (7.5 cm height) has to be constructed at the entrance/gate to avoid run off into the street/road. If man holes are present (sewerage/waste water line) the height has to be raised a little to avoid draining of rainwater through the manholes.

5. **What are the RWH methods used for ground water recharge?**

   There are various methods available for rainwater recharge into the ground which depend on the nature of sub-surface formation, extent of the area from where rainwater is collected. Some of the simple and cost effective RWH structure methods are:

   - Percolation Pit
   - Percolation Pit with Bore
   - Recharge Trench
   - Recharge Trench with Bore
   - Recharge well (shallow/small)
   - Recharge well (deep/large)

6. **What are the methods suitable for sandy sub-soil area?**

   As the sandy soil facilitates easy percolation of rainwater, shallow recharge structures such as percolation pits, recharge trenches and shallow/small recharge wells are enough for sandy sub-soil areas.

7. What are the methods suitable for areas with clay sub-soil and hard rock areas?

Since clay sub-soil formation is impervious in nature and is having poor permeability, deep recharge structures such as percolation pit with bore, recharge trench with bore and deep/large recharge wells are needed for deep percolation into the underlying sandy layer.

For hard rock areas it is advisable to construct recharge wells the size of which depend on the extent of the area/ building.

8. Can existing structures be used for RWH?

Yes. Existing structures such as defunct bore wells, unused/dried up open wells, unused sump, etc. can be very well used for RWH instead of constructing recharge structures to reduce the total cost.

9. Does RWH help to get immediate benefits?

Yes. In case of roof top rainwater harvesting where the water is collected in storage tanks/sumps after filtering, the water is available for use the moment it rains.

In case of ground water recharge where the quality of ground water is poor or moderate considerable improvement in quality would be observed from three to five years, if continuous recharge of rainwater is effected into an open well. However, slight improvement can be seen within weeks of rain if RWH structures have been installed. As far as improvement in ground water table is concerned, the improvement can be seen even during one rain fall season if large number of people have done RWH in a locality. In short, rainwater is relatively pure form of water and when it is added to the relatively poor quality of ground water, the quality of that water will improve due to dilution. More the water harvested better will be the result.

10. Is it necessary to construct all types of recharge structures in buildings?

Not necessary. In areas with alluvial sand, recharge structures would not be required unless the open spaces are covered with cement pavements. In other areas depending upon the area one or two recharge structures are enough to meet the requirement of an average sized house. Preference must be given to roof-top harvesting using existing open well. When roof-top harvesting using sumps and existing sumps and open well is practiced, it would take care of 60 to 75 percent of the rainwater recharge in an ordinary/normal house. In such cases, one or two simple structures would suffice to harvest the rainwater from the remaining open spaces around the building.

11. Is roof top water suitable for drinking and cooking?

Though the rainwater which falls on roof is pure but, still when it falls on roof and on the way to sump, some dirt, dust particles etc. are carried away with it. Therefore, it is advisable to filter this water and boil it before using for cooking and drinking.

12. What kind of catchment surfaces are most efficient?

The effective catchment area and the material used in constructing the catchment surface influence the collection efficiency and water quality. Materials commonly used for roof catchment are corrugated aluminium and galvanized iron, concrete, fibreglass shingles, tiles, slates, etc. Mud is used primarily in rural areas. Bamboo roofs are least suitable because of possible health hazards. The materials of catchment surfaces must be non-toxic and should not contain substances which impair water quality. For example, asbestos roofs should be avoided; also, painting or coating of catchment surfaces should be avoided if possible. If the use of paint or coating is unavoidable, only non-toxic paint or coating should be used; lead, chromium, and zinc-based paints/coatings should be avoided. Similarly, roofs with metallic paint or other coatings are not recommended as they may impart tastes or colour to the collected water. Catchment surfaces and collection devices should be cleaned regularly to remove dust, leaves and bird droppings so as to minimize bacterial contamination and maintain the quality of collected water. Roofs should also be free from over-hanging trees since birds and animals in the trees may defecate on the roof.

13. How can the runoff capacity be increased?

When land surfaces are used as catchment areas, various techniques are available to increase runoff capacity, including: i) clearing or altering vegetation cover, ii) increasing the land slope with artificial ground cover, and iii) reducing soil permeability by soil compaction. Specially constructed ground surfaces (concrete, paving stones, or some kind of liner) or paved runways can also be used to collect and convey rainwater to storage tanks or reservoirs. In the case of land surface catchments, care is required to avoid damage and contamination by people and animals. If required, these surfaces should be fenced to prevent the entry of people and animals. Large cracks in the paved catchment due to soil movement, earthquakes or exposure to the elements should be repaired immediately. Maintenance typically consists of the removal of dirt, leaves and other accumulated materials. Such cleaning should take place annually before the start of the major rainfall season.

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