Self Reliance in Water

(A practical manual for city and town dwellers)

Indukanth S. Ragade

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WATER! PRECIOUS WATER!

"A drop of water may spend 2 to 3 years in a river, 100 years in a glacier, between a few weeks and thousands of years in a lake. Some rains will evaporate off the ground at once. Some will soak into the ground, where it will be absorbed by the roots of the plants and then returned to the air through their leaves. And some may sink deep into the ground to form groundwater, where it may stay for thousands of years. It is always the same water that goes around in this cycle. Some of the water you shower in today may have flowed down the Amazon a year ago or may have washed the feet of an Egyptian Pharaoh 3000 years ago."

(Water, Water, Everywhere: Kingfisher Kaleidoscopes, Esley House, London, 1994, Ed. John Jamieson et al., 1994)

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"Life means water, soil and seeds. One holds no meaning without the other... Water is the life of the people.

(Car Oliviera, Co-ordinator for the Defence of Water and Life, Cuchambamba, Bolivia)

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In the beginning, to be sure, this world was water, nothing but water, nothing but a sea of water. The waters desired 'How can we be propagated?' They kindled their own ardour, performing this very action with fervour. While summoning their creative energy, they warmed up and a golden egg was produced.

(The Satapatha Brahmana)

***

Living beings originate from food and food originates from rain.

(The Bhagavad Gita, Chapter 3, Verse 19)

***

The rain cometh down and the snow from heaven and returneth not thither, but watereth the earth, and maketh it bring forth and bud that it may give seed to the sower and bread to the user.

(The Bible, Isaiah,, 55:10)

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Boxed Items

PROLOGUE

Every one of us would love to have ready access to good quality of water in adequate quantity to meet our daily needs. Paradoxically, in spite of all the technological progress the country has made in the 58 years after independence, ready access to good water for our daily needs is yet to become a reality in most of our cities, towns as well as villages. In thousands of villages, women still have to walk long distances daily to collect potable water. In cities and towns, groundwater levels are falling and potable water is increasingly being purchased. That there are many other countries in a similar situation is of little consequence to us. While the powers that be have taken various steps in these 57 years, their impact at the individual household level has been none too encouraging. Therefore it is important that we citizens should strive, in our own selfish interest, to alter this sad state of affairs. And *WE CAN MAKE A DIFFERENCE* if only we put in efforts at the micro level – *at the individual level, at the household level, at the neighbourhood level and at the community level* – to reduce our dependence for water on external sources.

The tremendous advantage in acting at the micro-level is that we have the maximum control and influence on any activity undertaken by ourselves and we can therefore be that much surer of achieving results and reaping the benefits of our efforts. And what are these efforts that can confer on us - town and city dwellers - that vital self-reliance in our daily water needs? In essence, they are three fold:

1 Harvesting rainwater i.e. tapping rainwater wherever and whenever it falls and diverting it to an appropriate storage for our use later.

2 Purifying used water and putting it back for reuse; and

3 Conserving the water available for our daily use.

Let us look at each of these in a little detail and see what is involved.

1 **Rainwater Harvesting:** Unlike many other areas in the world, our country is very fortunate in that it receives substantial rainfall from its two monsoons. If only this rainfall is tapped, it can meet fully our most essential daily need i.e. water for our cooking and drinking needs, in every town and city – even in areas where the annual rainfall is scanty. And what is more, it can meet from 20 to 100% of the total water needs of practically all towns and cities, depending on the rainfall in that place and its population.

Rainwater harvesting thus represents the first major step in our route to self-reliance in water.

2 **Used Water Recycling:** The water that we use for bathing, washing of clothes and cleaning the floors constitutes 50 to 60% of our total daily water usage. If only we clean this slightly contaminated water used for these purposes, it becomes available for fresh use again. Thus recycling of water represents the second major step in our path to self-reliance in water.

3 **Water Conservation:** Knowingly or unknowingly we use water wastefully in our daily activities. Conservation of water is nothing but realising the value of water and adopting simple techniques of using available water more efficiently for various uses in daily life, so that what is available can meet our needs for a much longer period. Its benefits would become obvious instantly to those who are facing acute water shortages.

Together these three are guaranteed to make citizens of every town and city self-reliant at least in their minimal water needs, if not their entire needs. And all three can be done at the micro-level without much expenditure or effort. But reliable and ready information has not been available on the methods involved. This book seeks to provide both from the author's first-hand experience in all the fields over more than a decade and a half. The language used is simple and jargon is avoided, so that all readers can understand and beneficially utilise the information and guidance provided.

Rainwater harvesting in urban areas has come into vogue only recently and among them, it was in Chennai that meaningful activity could be considered to have first commenced. The technology involved in it, although simple in nature, is still evolving. The techniques detailed in this book represent the results of the pioneering activity of the author in more than 200 apartment complexes in Chennai comprising over 4000 apartments. As for recycling of used water, the methods available till recently had been mainly chemical, requiring fairly large investments and regular maintenance efforts that are not convenient for operations in domestic environments. But alternate methods that are economic and user friendly were not so far available to city and town dwellers. For the first time, a method is presented in this book which is simple, easy to operate and maintain, and also eco-friendly. The method is the outcome of the author's efforts to meet the challenge of acute water shortages in many of the apartment complexes he was involved with in Chennai.

Efficient storage and distribution of water of various qualities available in any premises has an important role in the route to self-reliance. The guidance on this as also on conservation of water are both derived from actual experience on the field.

The water that we drink affects our health if it is not wholesome and free from harmful bacteria and viruses. How does one decide whether the water available in one's own premises or the water available while travelling is fit and safe for drinking? What is desalination? How relevant is Reverse Osmosis in residential complexes? What does one do when the ground water turns yellow and stains clothes because of iron salts? Why does sweet water turn saline in sandy coastal areas and what can be done about it? All these and many other such questions that city and town dwellers have to grapple with are answered in simple language.

Water and soil are intimately related, as it is the soil of Mother Earth that ultimately stores the water we need for our use and influences its quality. Therefore, the soil-water inter-relationship and the means of locating water sources below the ground are briefly presented.

Ironically, even while water is in short supply in our towns and cities, our streets invariably get flooded during the monsoon rains and our daily life is disrupted in many ways. And this happens in spite of the existence in many cases of a storm water drainage system. Some ideas have therefore been offered on how individuals and communities can tackle this problem with rich benefits not only in rendering streets water free but also in the process can get more water for their use. Some suggestions have also been added on what can be done at the macro level with only moderate outlays to mitigate the problem.

The sewerage system wherever it exists, was originally intended to carry human faecal matter to treatment plants for hygienic disposal. The system actually operates very inefficiently and is not only causing acute degradation of our precious waterways all over the country, but is actually the primary cause for the shortage of water experienced by our towns and cities as it carries away all the used water from them. In places that do not have a sewerage system, contamination of good water at shallow depths by the outflow from septic tanks is becoming a major problem. Both these warrant urgent and serious attention at both the individual and the governmental levels. The book not only offers some thoughts on corrective measures at the macro level but also concrete steps that individuals can take at the micro level to deal with the problem and have greater access to usable water.

In short, the book seeks to serve as a one-stop source for every aspect of water and its management that city and town dwellers would benefit from knowing and utilising. It is the author's belief that the information and experience shared in this book can be beneficially utilised by residents of most towns and cities of India. The water management techniques presented in this book are all economical and derived from first hand experience. Hopefully, architects will incorporate these techniques at the outset itself in their building designs so that Builders will readily install them in the homes and colonies that they construct and make life that much more comfortable and happier for those who will live in them. It is important to note that the techniques described in this book can be applied even in buildings that have already been constructed. The outlay needed to introduce rainwater harvesting systems or water recycling systems in buildings already constructed is likely to be more than what would have been enough if they had been incorporated during their original construction. But the resultant benefits would fully justify the expenditure.

India is rich in its diversity of climatic and topographical conditions. Given the natural ingenuity and enterprise of our people, it is quite possible that others may have developed techniques that are as good as those described in this book or are more appropriate to specific local conditions. The author will be happy to include them in future editions of this book with acknowledgements if details are sent to him.

While every effort has been made to ensure accuracy of language and content, all comments, suggestions and data that may add to or modify the matter presented in this book and enhance its utility are most welcome.

INDUKANTH S. RAGADE

ACKNOWLEDGEMENTS

This book would not have been possible but for my intimate association over two decades with M/s Alacrity Foundations Pvt. Ltd., and its founder, Amol Karnad. It was Alacrity's commitment to the healthy, hygienic and comfortable living of the residents of all the apartments that they constructed and delivered that offered me the freedom and the opportunity to focus on meeting the challenge of providing adequate water to city and town dwellers.

Involvement in writing a book distracts one no end from one's domestic responsibilities and impacts heavily on the spouse. The patience, understanding, tolerance and silent support that my dear partner, Jayanti, has unstintingly extended over the last two years and more is immeasurable.

Dr.Sekhar Raghavan, Director, Rain Centre, Mandavelipakkam, Chennai has been an unfailing source of encouragement throughout. His meticulous perusal of the manuscript in each of its many successive incarnations and the countless discussions that we have had on a subject dear to both of us have shaped this book in no small measure.

Dr.Y.E.A.Raj, Director of Research, India Meteorological Department, Chennai, not only graciously provided access to rainfall data for various towns and cities, but also enlightened me on various aspects of meteorology.

It was Tency Baetens, Chief Executive, Centre for Scientific Research, Auroville, Pondicherry, who in 1995 sensitised me to the vital need for sustainable development and was responsible for my entry into recycling of used water. He has been an interested and supportive friend since then in many ways.

Pioneering efforts are always tough but I had the advantage of having with me in those early days, my erstwhile colleague, Mr.P.D.Ratnakumar. Critical concepts in rainwater harvesting like the trench at the gate and making the almost extinct dug well a key element as well as the initial forays in used water treatment were the result of the many brainstorming sessions we had in those days.

I am beholden to my son-in-law, Manoj Gupta, Architect and Director, Design Academy, Delhi and Mr.Ashok Goel, Director, Academy of Interior Decoration, Delhi for familiarising me about the publishing field that emboldened me to venture into publishing this volume myself.

Conversion of thoughts into words is not easy unless the right ambience is available for doing it. I must thank my architect daughter, Lena Ragade Gupta who not only provided that ambience but also offered critical comments that have added to the clarity of the content in this book. Thanks are also due to her and Ms. Kirti Gupta of the Design Academy for preparing the drawings and sketches of this book.

I am thankful to my good friend and valued senior colleague of my Gujarat days, Dr. K. Aparajithan who readily agreed to go through my manuscript critically and offered comments and changes that have enhanced the readability of this book.

Some individuals are unobtrusive and silent sources of support. Two individuals who have played this role are my son, Navin and my daughter-in-law. Kirtana, who were always there when needed.

Being practically a computer illiterate, I would have really struggled to put the manuscript on to the computer. This task was rendered substantially easy because of the spontaneous assistance extended by my colleagues V.Murugaiyan and Mohan Karnad, and my erstwhile colleagues, A.Muralidharan and S. Ramanan. Friends in need are friends indeed!

My thanks go to the C.P.R.Environmental Centre, Alwarpet, Chennai for readily opening the doors of their excellent library for my referencing.

'A picture is worth a thousand words' goes the ancient Chinese saying. I am sure that the cartoons done by Mr.S.K.Ramanujam ('Rahnu') and Ms. Lena Ragade Gupta will make this book that much more enjoyable to read. My thanks go to them.

Last but not the least, Ramesh of The Ind-Com Press. The mere availability of a manuscript in one's hands, however good its content, does not guarantee that it can be made into an excellent book. My friend Ramesh took on that task of conversion readily and the result is there in front of you all to see.

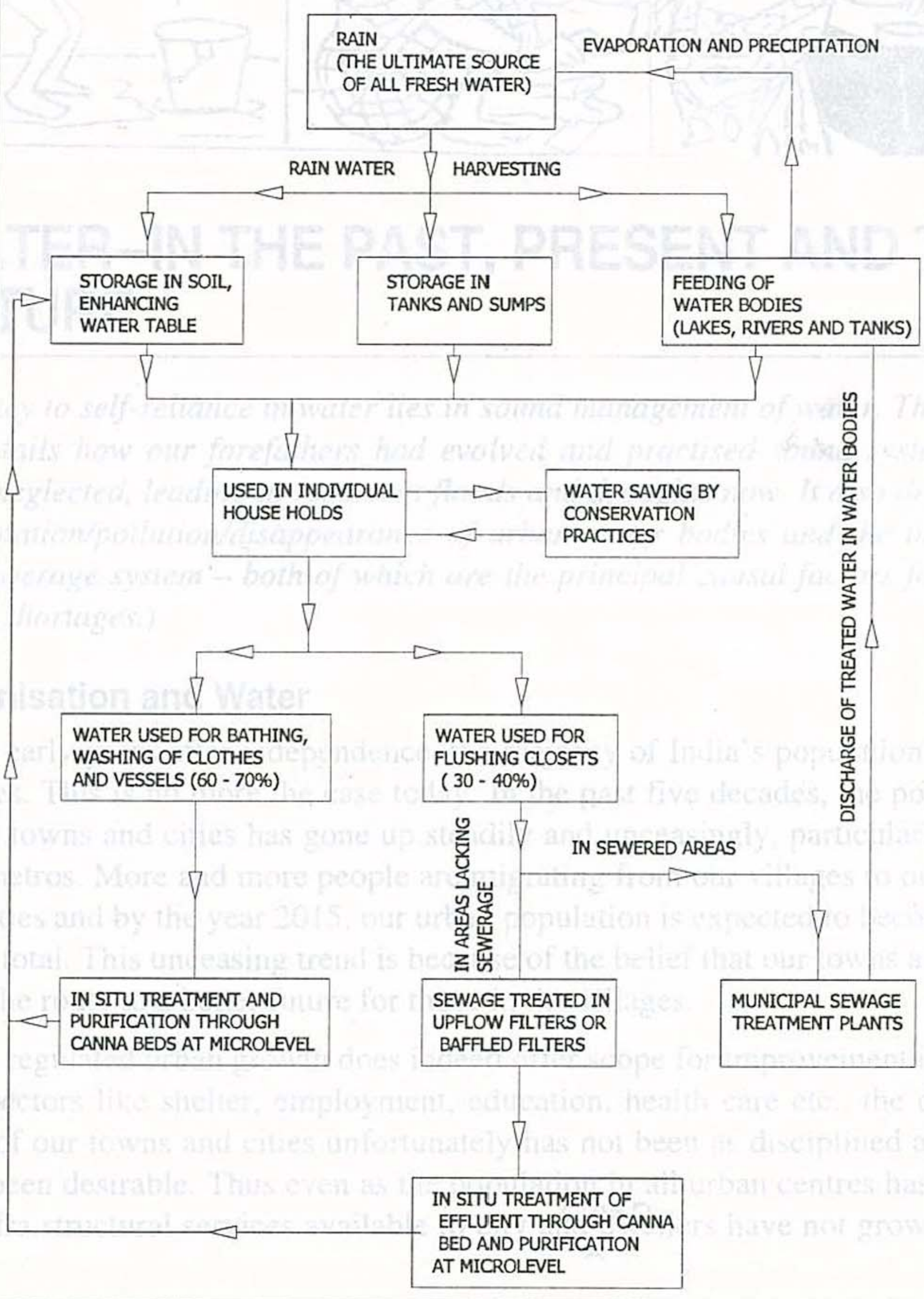
CHENNAI

NOVEMBER 2005 INDUKANTH S.RAGADE

Dear Reader,

If you and I are experiencing water shortages today, it is because we have not valued water and used it in an organised manner. All the water that we use and all the rainwater that falls on our homes and gardens is moving laterally away from our homes and cities, first into water bodies polluted by us and then into the sea. The situation will alter dramatically if only we make it move cyclically, as you can see it in the chart below. "Is it practicable?", you may ask. Yes, it is. To know how, turn the page and read on.

THE SUSTAINABLE URBAN WATER CYCLE



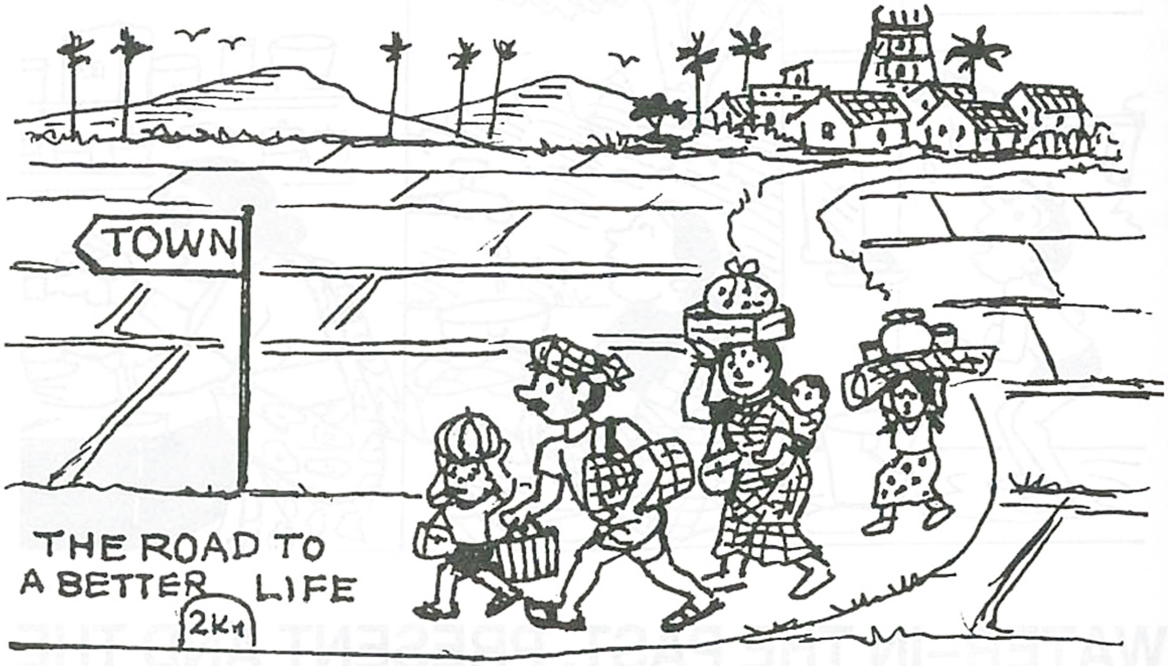
WATER–IN THE PAST, PRESENT AND THE FUTURE

(The key to self-reliance in water lies in sound management of water. This chapter details how our forefathers had evolved and practised sound systems that were neglected, leading to recurrent floods and droughts now. It also details the degradation/pollution/disappearance of urban water bodies and the impact of the sewerage system – both of which are the principal causal factors for urban water shortages.)

Urbanisation and Water

In the early years after independence, the majority of India's population lived in villages. This is no more the case today. In the past five decades, the population of our towns and cities has gone up steadily and unceasingly, particularly in the four metros. More and more people are migrating from our villages to our towns and cities and by the year 2015, our urban population is expected to become 60% of the total. This unceasing trend is because of the belief that our towns and cities offer the route to a better future for those in the villages.

While regulated urban growth does indeed offer scope for improvement in all the vital sectors like shelter, employment, education, health care etc., the development of our towns and cities unfortunately has not been as disciplined as would have been desirable. Thus even as the population in all urban centres has grown, the infra structural services available to city and dwellers have not grown correspondingly, whether it is the sewerage system or garbage disposal or water supply.



Having become dependent since long on the government for meeting all our basic infrastructure facilities, which often were being made available at subsidised rates, we, town and city dwellers have tended not to value them adequately. And when these facilities deteriorate, we feel helpless. Not knowing what to do, we assume that only the better functioning of the concerned authorities can rectify all these and blame them for their inefficiency. It is true that governmental authorities like the Water Supply and Sewerage Boards, the Electricity Boards, the Municipalities etc. are primarily responsible for making basic amenities available to citizens. When they are not able to fulfil their obligations for whatever reason, nothing prevents us at the micro-level from initiating efforts on our own to mitigate the situation and making life better for ourselves. This is particularly true in the case of access to water and its disposal. "Knowledge is Power" goes the saying. What we therefore have to do is to learn more about water that is one of the five primal elements that influence the quality of our daily life[1].

Rain – The Ultimate Source of Water

Many of us may not be aware of what is the ultimate source that supplies us all the water that we need and use. This source is RAIN. It is rain that nourishes and sustains all the water sources across the world except in the icy Polar Regions where water remains permanently frozen and in the high altitudes of the moun-

1. The five primal elements, known as Panchabhutas in the Indian tradition are: the Earth (soil), Water, Air (Oxygen) Fire (light & heat energies) and the ether (space). The vital role that these play in our daily lives is obvious.

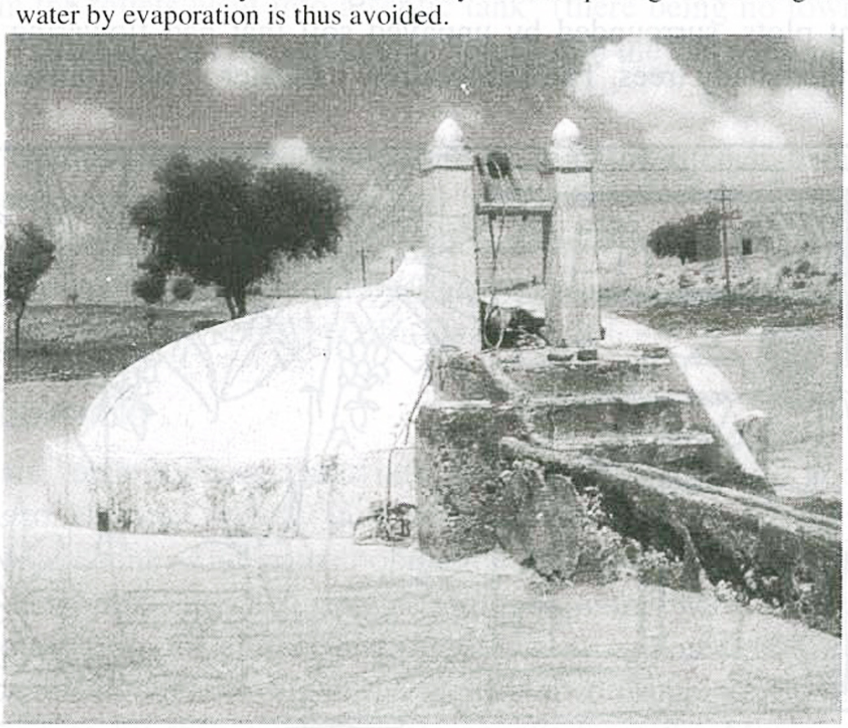
tains where glaciers supply water by melting and feeding the rivers. It is only rain that fills up the ponds, lakes, tanks and rivers and also the huge storage available below the ground.

India is one of the more fortunately placed countries in the world in so far as overall water availability is concerned. Whereas the world as a whole receives about 80 cm of rain annually, India receives about 110 cm. This rainfall however is not distributed evenly across the country. Areas like Kerala, Coastal Maharashtra, West Bengal, the North Eastern States and Orissa receive good rain that feed the water bodies and sustain them. Other areas like the Deccan Plateau receive only moderate rains. There are also areas like Kutch, Saurashtra and parts of Rajasthan, where the annual rainfall is very scanty.

Harvesting the Rain - Our Traditional Wisdom:

Over generations, our forefathers had developed marvellous systems to manage the water available to them in a very effective manner[2]. In the desert areas of Rajasthan where the rainfall was scanty and the climate was hot, they developed systems, which collected the rainwater and conserved it in storage in a manner, which kept loss of that precious water through evaporation at a very low level.

Picture 1.1 A typical storage tank called a "Kund" in the Thar desert region of Rajasthan. Note how the tank is fully covered with only a small opening for drawing water. Loss of water by evaporation is thus avoided.



On the other hand in areas where the rainfall was abundant, they established a system of tanks that not only stored enough water for their needs in the dry sea-

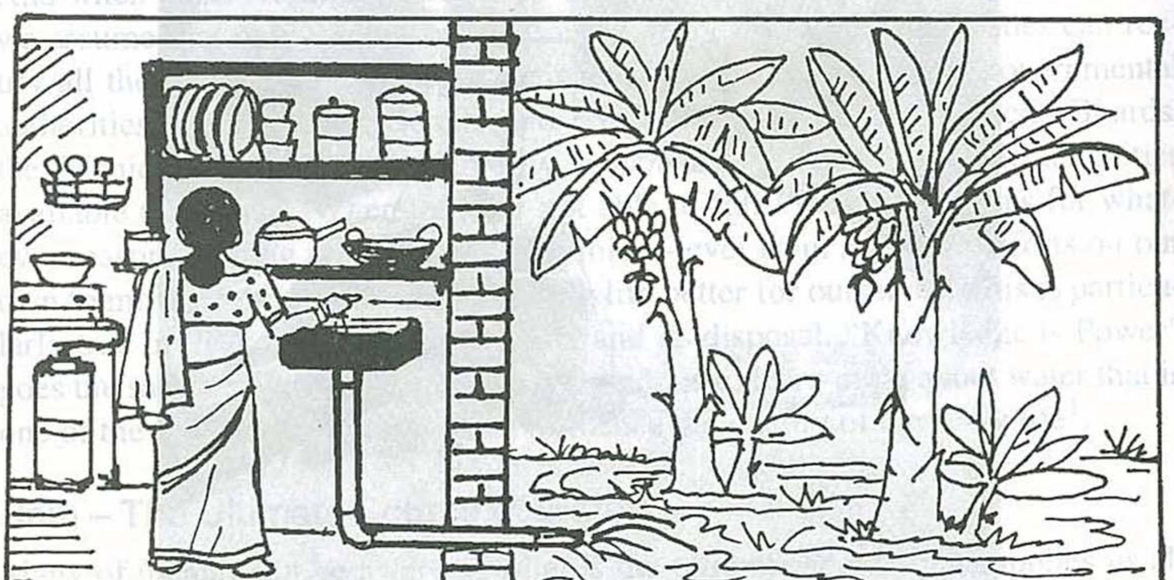
2. This is vividly portrayed pictorially in the book, "Dying Wisdom- Rise, fall and potential of India's traditional water harvesting systems", Ed. Anil Agarwal and Sunita Narain, Centre for Science and Environment, New Delhi, 1997.

son but also efficiently drained the excess into the sea in an organised manner. Thereby they minimised the occurrence of floods. Unfortunately, over the last three hundred years, due to historical reasons and changing social factors, these systems fell into disuse and neglect. And so, today, one sees frequent occurrence of devastating floods and droughts in various parts of our country in spite of having at our disposal, much more information, resources and technology. These traditional systems have been revived in some parts of Maharashtra, Gujarat and Madhya Pradesh in recent years with remarkable benefit. During the acute drought in these areas in 1999, while hundreds of villages were struggling even for drinking water, those villages, which had revived their traditional systems, had enough water not only for drinking and other daily uses but water for farming too. And the noteworthy aspect is that the revival of these traditional systems required only moderate outlays. The key factor behind their success was the villagers' own initiative and their determination to help themselves and work together.

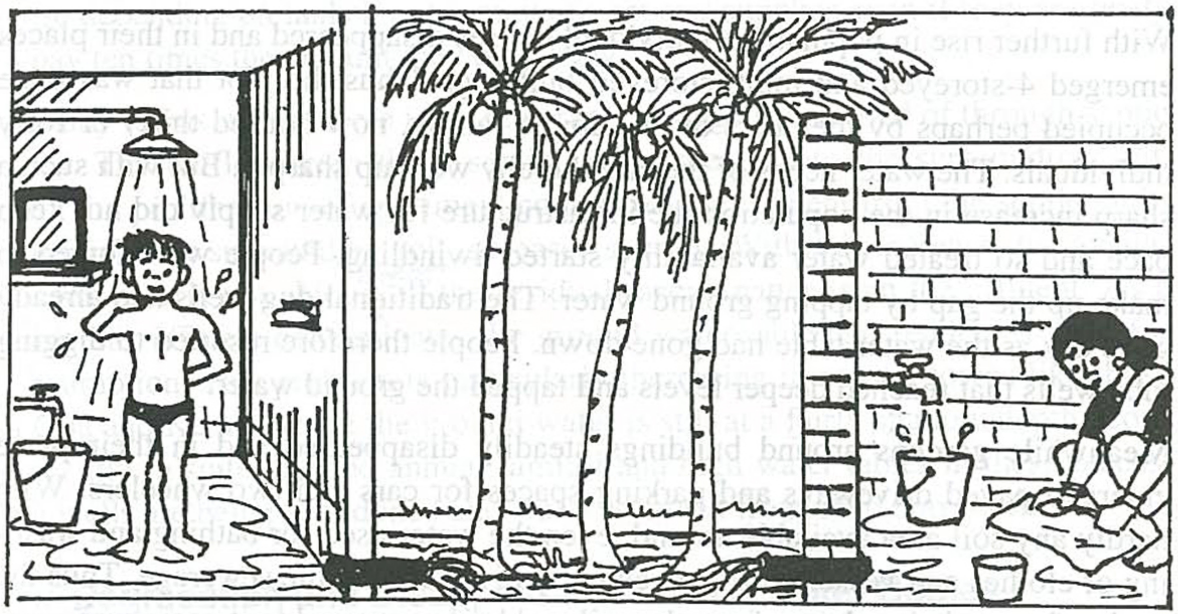
History tells us a similar story of decline in respect of urban centres as well.

Water Cycle in the "Good old days"

In the early years of this century, there were no apartment complexes in any of our four metros. Most households had single or double storeyed buildings on independent plots, surrounded by unpaved soil that had flowering plants, fruit trees and other shady trees. The family drew its water needs from a shallow open



well. The water used for bathing and washing of clothes and floors went to the garden, watered coconut palms and other trees and flowering plants. What the trees and the plants did not need, went into the soil. The water used for washing



the vessels in the kitchen nourished a clump of banana or colocasia plants. What the banana clump or colocasia plants did not need went into the soil. The sewage outflow from the toilets went into a septic tank[3] (there being no town sewerage then) and the effluent from the septic tank spread into the surrounding soil below ground level.[4]

The soil which thus received the water after use from the kitchen, bath and septic tank purified it with the assistance of soil bacteria and the clean purified water moved across the soil and reached the open well from where it was drawn again for use. Thus there was a beautiful cyclical movement of water that conferred self-reliance to the family in respect of its water needs.

Break of the Cycle

Over the years, town sewerage came into being in the four metros and the effluent from the toilets went directly into the sewerage instead of reaching the soil through the septic tank. And as the population increased additional houses were built on the same plot and water drawn from the ground increased. At the same time, more water from the closets went into the sewerage instead of returning to the soil. As a result, water levels in the wells started dropping. But this did not trouble anyone as by then treated water supply from the Municipality com-

3. See page -13 for a sketch of the septic tank

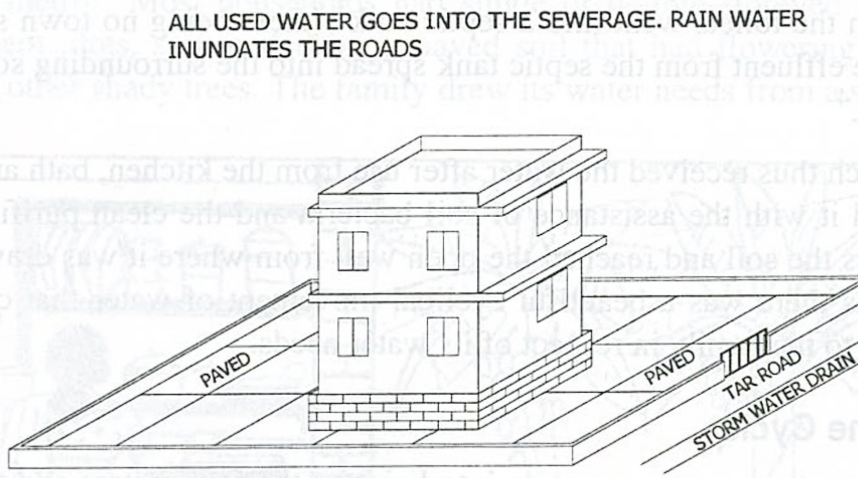
4. Rainwater also percolated into the soil to some extent. But the bulk of it went into the open drain on the road and reached a water body.

menced and water came in plenty and effortlessly at the turn of a tap. Availability of water thereby came to be taken for granted.

With further rise in population, individual houses disappeared and in their places emerged 4-storeyed and multi-storeyed buildings. Thus the plot that was once occupied perhaps by members of one single family, now housed thirty or forty individuals. The water needs of the city thereby went up sharply. But with such a sharp increase in the population the infrastructure for water supply did not keep pace and so treated water availability started dwindling. People were forced to make up the gap by tapping ground water. The traditional dug wells had already gone dry as the water table had gone down. People therefore resorted to digging tube wells that reached deeper levels and tapped the ground water.

Meanwhile gardens around buildings steadily disappeared and in their place emerged paved driveways and parking spaces for cars and two wheelers. With hardly any soil area available around, even the water used for bathing and washing of clothes and vessels was conveniently diverted into the sewerage. Thus the cycle of water being drawn from the soil and being returned to it again was completely cut and all the water drawn from the ground went from the premises into the sewerage **and away from the city itself**.

Sketch 1.1 Water Movement Now



Not surprisingly, water tables fell and continued to fall sharply. We now tap water from bore wells that are 200-250 ft in Chennai and other towns. In some areas like Coimbatore and Ahmedabad, water is now being "mined" with bore wells reaching up to depths of 400 ft, 600 ft. and even more. This is a dangerous trend as we are in the process of steadily using up a water stock built through geological processes over centuries and millennia - a stock that is not being replaced. Even this mining often yields highly brackish water and so we become helplessly dependent on external sources for water. When the water authorities are unable to respond, as is the case in many towns and cities, citizens spend substantial sums to buy water supplied in tankers. This water (presently used for agriculture) is itself drawn from the ground in less populated suburbs of the city where the water table has still not gone down. Such extraction of ground water from these areas on a continued basis is perilous, because it will result in a steady depletion of the water table in these suburbs. And a day would come soon when those depending on tanker water may not get any supplies even if they are ready to pay ten times the amount they pay today.

In many towns, where there is no sewerage, sewage is disposed of through septic tanks. The outflow from these septic tanks spreads into the surrounding soil. With the proliferation of apartment complexes the effluent from the septic tanks going into the surrounding soil increases sharply. With this increase, the available soil area is not able to all the residual faecal matter from the effluent. As a result this effluent contaminates the ground water table and renders it unfit for consumption. This problem is particularly increasing in coastal towns like those in Goa and Kerala where the ground water is still at a fairly shallow depth. Consequently in spite of good annual rainfall and high water tables in these places, dug wells are being abandoned and water is mined from deep bore wells.

The Degradation and Disappearance of Our Water Bodies

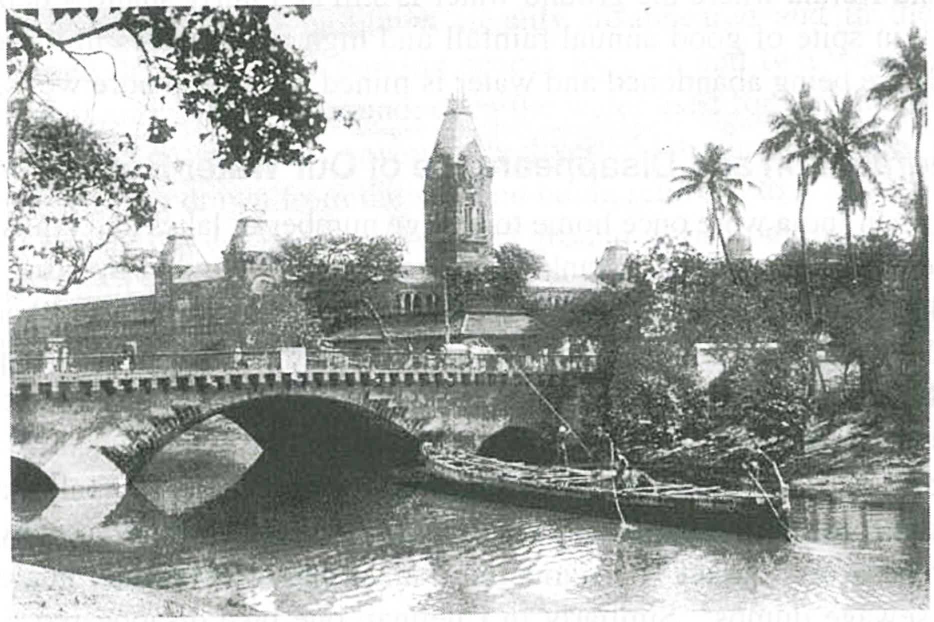
Most cities in India were once home to a large number of lakes and tanks. Bangalore once had as many as 170 tanks, many of which were dug by King Kempegowda 400 years ago. These served as catchment areas for rainwater and helped sustain the water table in the surrounding areas. As the cities grew in population, water tables started going down, the tanks became dry and got neglected. Thereafter they were filled up and used as construction sites. One tank in Bangalore has become the city's bus terminal, another has become a football stadium, a third has become partially a cricket stadium and the rest a housing colony. A fifth has become a big market.The remaining tanks, due to continued neglect, have become sewage dumps[5]. Similarly in Chennai, one lake disappeared and in its place, arose ironically a huge memorial for Poet Valluvar, who has in his works exhorted people to consider water to be sacred. A big school has emerged over another tank. Several lakes are shrinking due to neglect and encroached upon by people building houses. The story is the same in many other cities and towns and the degradation and disappearance of vital water bodies that can sustain the water needs of the citizens is relentlessly going on.

Rivers are being polluted either by sewage – as in the cases of the Ganga in Allababad and Varanasi, the Sabarmati in Ahmedabad, the Yamuna in Delhi – or by industrial effluents – as in the cases of the Palar, the Noyyal and the Bhavani rivers in Tamilnadu and the Daman Ganga in Vapi (Gujarat). Lakes have not been spared either (the Dal Lake in Srinagar, the Powai Lake in Mumbai and the Himayat Sagar in Hyderabad).

5. Happily, in recent times, thanks to a corporate-government-public joint initiative, several tanks have been cleaned up, freed from sewage inflow and revived excellently in Bangalore.

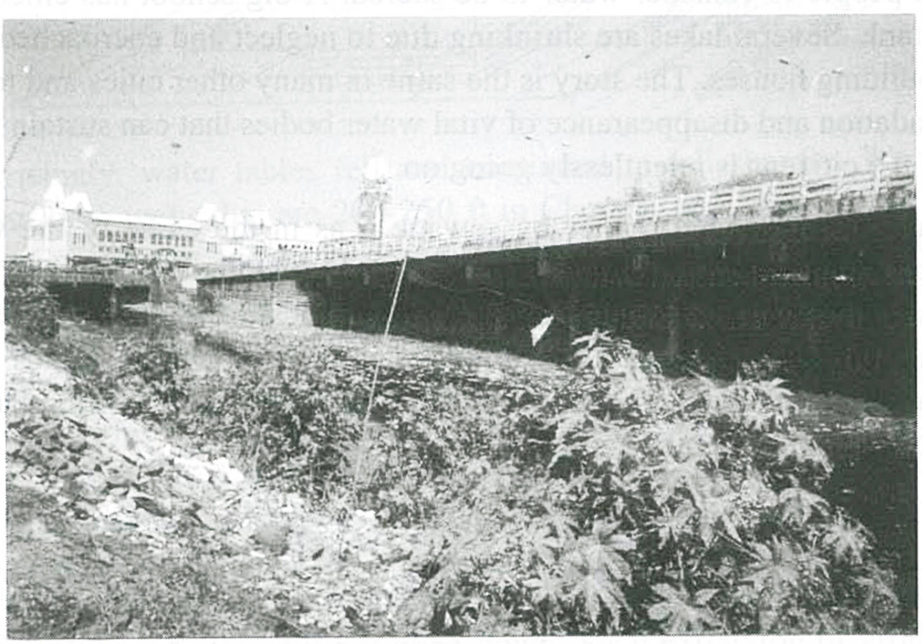
Treated water supply by the Municipalities is either erratic or inadequate or totally absent. We urbanites thus find ourselves helpless and blame the Municipalities. And we drink costly bottled water and buy water in tankers for our other needs, uncertain of what tomorrow has in store for us. Should we continue to remain so helpless in respect of a vital daily need that can make life comfortable and happy not only for our individual families but equally for the community in which we may be residing? "Is there a way out?" one might ask. Yes, the pages that follow venture to provide a pathway to break our dependence on water supply authorities, ***if only we decide to help ourselves..***

Picture 1.2 The Buckingham canal in front of the Central Railway Station in Chennai fifty years ago. It was then an attractive navigable water body. A variety of goods like sand, firewood, hay etc used to be transported using boats like the one in the picture.



Picture courtesy of Vintage Vignettes, Chennai-28

Picture 1.3 This is how the same canal looks today at the same spot: A narrow stinking sewage drain surrounded by weeds and all types of debris, mainly plastic.



CHENNAI — RAIN-RICH BUT WATER-STARVED!

Chennai is a typical example of a city that receives abundant water from the skies but still experiences chronic water shortage because of inefficient water management. The water authorities may find it convenient to cite frequent failures of the monsoon as the main reason but statistics present quite a different story.

Chennai gets its water from the two monsoons - The South West Monsoon and the North East monsoon - of which the latter is the major supplier. Records maintained meticulously over the last hundred years by the Meteorological Department show that the city receives from the two monsoons invariably more than 100 cm of rain every year which is enough to meet the city's present water needs. In the last 50 years, from 1952 to 2004, it was less than 100 cm in only 6 years. If only this bounty from nature is received and stored, Chennai will have enough water for all its needs. The problem for the water authorities however lies in the fact that all this falls only in about 60 days of the year!

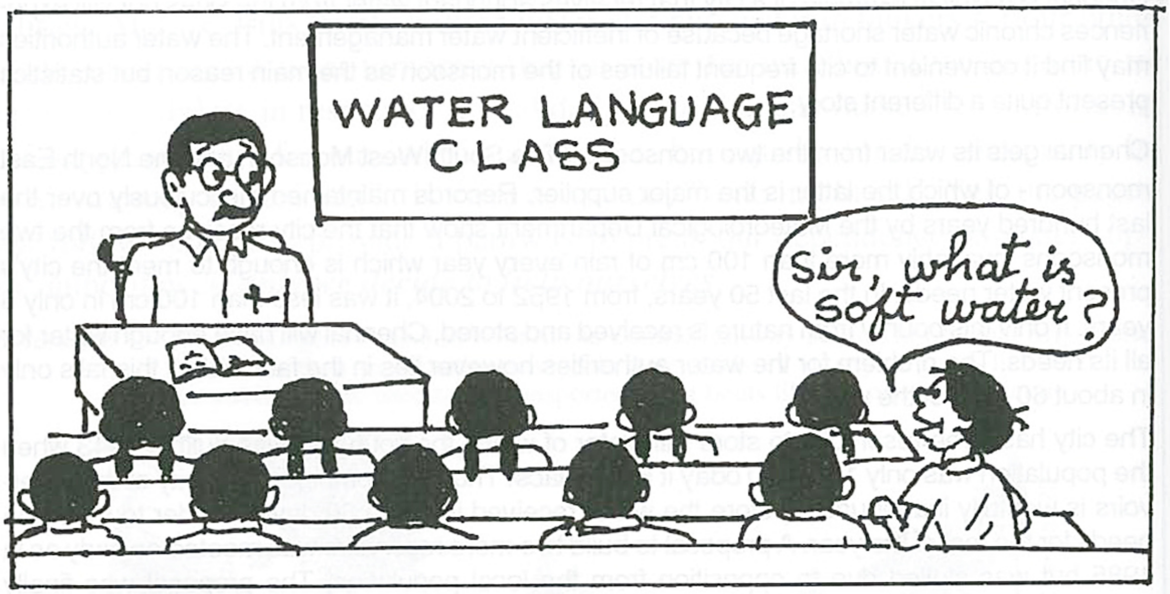
The city has three reservoirs to store rainwater of which the youngest was built in 1943 when the population was only 10 lacs. Today it is 43.2 lacs. Thus the combined capacity of the reservoirs is woefully inadequate to store the water received in those 60 days in order to meet the needs for the rest of the year. A proposal to build two more reservoirs was mooted as early as in 1985 but was stalled due to opposition from the local population. The proposal was finally dropped in 1998, unfortunately without any alternative being formulated. The major sources of water supply to the reservoirs are the Kortallayar and Araniyar Rivers that are located north of the city and flow eastwards reaching the sea. In a year of good monsoon, the reservoirs get filled up rapidly, and the excess water flows wastefully into the sea. But if the next monsoon is delayed or is somewhat deficient, the reservoirs get depleted. *In a year of normal rainfall, the excess water flowing into the sea from the Kortallayar River alone has been estimated to be more than a year's supply to the city*[1].

Since some years, very limited quantities of water have been brought from 600 km away from the Krishna River in Andhra Pradesh via an unlined canal[2]. In spite of crores and crores having been spent, the targeted quantity however has never come because of leakages in the canal, tapping by the farmers en route, absorption by soil and also occasionally due to 'deficiency of rain' in Andhra Pradesh. Such a system is not only costly to install and inefficient, but is also one that is exposed to the risk of being vulnerable to inter-state political compulsions. Recently, a scheme was implemented to bring water from the Veeranam Lake located 200 km from the city. The scheme had been opposed by the people currently using the water from this lake who fear that their water security will be badly affected by the diversion of the water from the lake to the city.

In the last few years, citizens have become increasingly aware of the value and potential of rainwater harvesting at the micro- level as a route to becoming self-reliant in their water needs. More and more people are going in for rainwater harvesting. The water authorities also are focussing on this and providing assistance to those interested. A law was recently passed making rainwater harvesting mandatory in all buildings – old and new. One therefore can look forward to the day soon when Chennai's citizens would have shed their helpless dependence on piped water supply, become self-reliant at least in their basic water needs through rainwater harvesting and shown to citizens of other towns and metros the value of rainwater harvesting.

1. Madras 2011: Second Master Plan – 1995, Chennai Metropolitan Development Authority.
2. It has been lined recently on the Andhra Pradesh side by a private charitable organisation called Sri Sathya Sai Organisation of Puttapurthi at a considerable cost involving crores.

CHAPTER 2



THE LANGUAGE OF WATER MANAGEMENT

(This chapter explains the meanings of the terms used in this book that enable the reader to reap the full benefit of the contents of this book.)

To understand water management and to practise it for your own benefit, you should get familiar with some terms that will be often used in the pages that follow: These are explained below:

TOPSOIL: The first 1.5m (5ft) layer of the soil. In the urban context, this layer is unlikely to be the original undisturbed soil. In flat complexes, more often than not, this layer of the soil is made up of construction debris.

SUB SOIL: The soil layer from 1.5 m (5 ft) downwards below ground level

SUB SOIL PROFILE: The composition of the soil at various depths in the subsoil in terms of the percentages of sand, silt, clay, gravel and rock. This is generally investigated up to 7 or 10 m before a building is constructed in order to decide the nature of the foundation to be provided.

GROUND WATER: Ground water is water that fills up the pores in the subsoil at shallow levels as also at deeper layers to saturation, which can drawn for usc through dug wells and bore wells.

AQUIFER: A layer of soil or rock below the ground level that holds water and also allows water to move within it, because of which it becomes a water source.

GROUND WATER TABLE: (OR WATER TABLE): The upper level of the water layer (aquifer) in the shallow subsoil. This is not necessarily the same in all parts of a locality. It is influenced by the nature of the subsoil in a particular spot and the quantum of water drawn from that spot for use.

DUG WELL (OFTEN CALLED SHALLOW WELL OR OPEN WELL): A pit excavated in the ground until the water table is reached. If the soil is clayey or sandy, the sides of the pit are lined with bricks or RCC rings to prevent the collapse of the pit. If the soil is rocky, such lining is not necessary. Generally the pit is circular, with a diameter ranging from 3 ft to 12 ft in urban areas and rarely deeper than 45 ft. In some urban centres like Coimbatore where the soil is of soft rock, there is no lining and well depths could be much more.

In general, the quality of water from dug wells will be better than that from bore wells that tap the deeper levels (except in rocky areas where the quality from deeper levels is likely to be excellent). The term "open" well is derived from the fact that before the advent of water pumps, these wells had to be kept open for the water to be hand-drawn through a wheel and pulley arrangement. Nowadays as the water is drawn up through pumps, there is no need to keep them open. They can be closed with a solid cover at the ground level itself so that there can be unhindered movement of men and vehicles above them.

BORE WELL: A small diameter hole (ranging from 4½" to 10" in diameter) drilled into the soil to much greater depths generally than dug wells. These can tap water from multiple layers of water under the ground. These holes are drilled either by hand operated augers or rotary rigs in non-rocky soils, and by using pneumatic drills called DTH (Down To Hammer) in rocky strata. The hole is prevented from collapsing by inserting a PVC pipe ("casing pipe") into it. If the hole is in a rocky layer, the pipe insertion is not necessary. The casing pipe may have slots or holes at various levels where the soil contains water or can contain water. In earlier years, casing pipes made of steel were used.

TUBE WELL: A tube-well is a bore well that is not very deep

SERVICE WELL/SERVICE BORE WELL: A dug well or bore well, from which water can be drawn for use.

RECHARGE WELL: (Also called **DRY WELL**) A dug well which for the time being is unable to yield water for use because the water table in the soil has gone below its bottom. So it is used only for receiving rainwater. Over a period, if the water table rises above the bottom of the recharge well, it becomes a yielding well.

PERCOLATION PIT[6] (Also called **BABY WELL**): A pit excavated into the ground until we reach a soil layer that is favourable for absorption of water i.e.

6. The author has no experience in lateritic soils that are found parts of Karnataka and Kerala. People in these lateritic areas therefore need to apply local knowledge about laterite to distinguish between a percolation pit and a dug well, if at all there is such a distinction.

soil that is not very clayey. Water led into a percolation pit thereby percolates downward and reaches the water table. A percolation pit is also lined with bricks or RCC rings as in the case of dug wells. If the diameter of the percolation pit is 3 ft or more, the pit can be deepened when desired, to reach the water table, using rings of diameter smaller than the existing diameter of the pit. Thereby it can become a yielding well.

RECHARGE BORE WELL: A properly constructed bore well whose main function is to charge rainwater into the sub-soil. Like the recharge well, this may be deep enough to reach either the water table itself or it may be up to a soil layer that is favourable for receiving water. Over a period, if the water table rises above the bottom of the recharge well, it becomes a yielding borewell.

PERCOLATION HOLE: A small circular hole (4½" to 10" in diameter) drilled with an auger up to a depth where the soil is favourable for absorbing water. This hole is filled with pebbles or blue metal. If water falls on it, it passes downwards through the gaps in the pebbles or blue metal.Instead of pebbles, a slotted PVC pipe can also be inserted into the hole. The first few feet can be 2 or 3 ft in diameter and filled with washed sand over the top 1 foot.

PATHOGENS: Organisms like bacteria and viruses that are capable of causing sickness in human beings if they enter our digestive system through consumption of contaminated food or water or through animals (e.g. bird flu, mad cow disease, Leptospirosis) or even by breathing contaminated air. Faecal matter excreted by human beings contains pathogens that can cause diseases like typhoid, amoebic dysentery and jaundice.

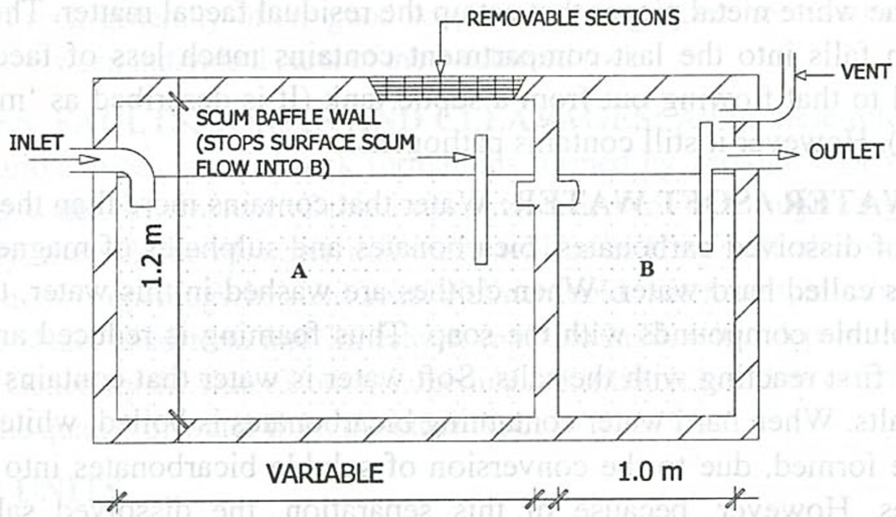
SEWAGE / BLACK WATER: The water flowing out of our closets and carrying with it faecal matter and urine is called sewage. In recent times, it is also being referred to as black water..

SULLAGE / GREY WATER: The water that has been used for bathing, washing of clothes, vessels, floors and vehicles is generally called sullage. In recent times, it is also being referred to as grey water. Sometimes the term is restricted only for water used for bathing and washing of clothes. Grey water is sterile i.e. unlike black water, it does not contain any harmful pathogens.

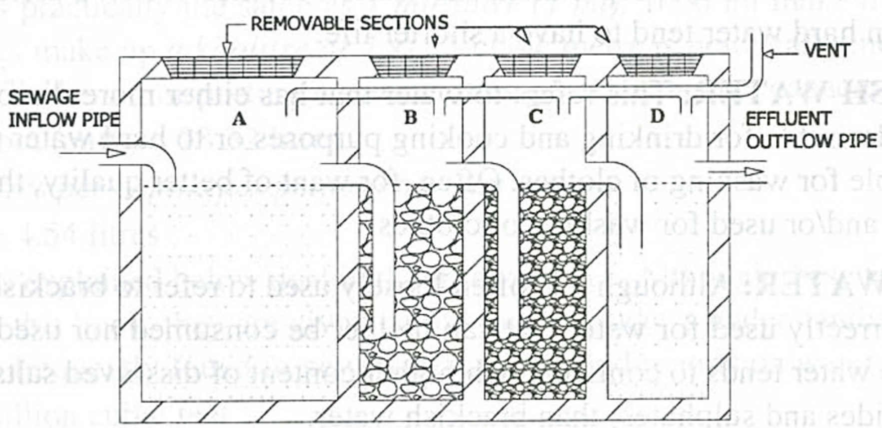
SEWERAGE: A system of pipe lines usually laid below the ground on roads to carry used water (particularly sewage) generated in households to a pumping station from where it is taken to a sewage treatment plant for purification and safe disposal. Nowadays sullage also ends up in the sewerage.

SEPTIC TANK: A device used for safe disposal of sewage into the soil in places where there are no town sewerage systems. In its simplest form, it consists of an underground tank made up of steel, ferro-cement or cement concrete, divided into two compartments. Sewage (i.e. water containing faecal matter and flowing out from the closets) is led into the first compartment where the bulk of the semi-solid faecal matter settles at the bottom. The outflow from this compartment ('effluent') flows into the second compartment where any residual faecal matter settles down. The flow from this compartment is dispersed into the surrounding soil. The soil bacteria in the soil consume any residual faecal matter. The harmful pathogens in the sewage die in a short period in the soil. If the soil area available around the septic tank is inadequate, the liquid in the second compartment can be pumped out in to a tanker and taken to the nearest sewage pumping station or sewage treatment plant for safe disposal. For more efficient clean-up of the sewage, the septic tank can also be provided with a third compartment for further settlement of residual faecal matter before the water leaves the tank. Over a period, the settled sludge in the first compartment will have to be removed physically or mechanically

Sketch 2.1 2-Compartment Septic Tank



Sketch 2.2 Upflow Filter



UPFLOW FILTER: This is an improved version of a septic tank and is made up of four compartments. In the first compartment, much of the faecal matter settles down as in the septic tank. In the second compartment, blue metal of size 40mm is put to about 3/4ths of the height. In the third compartment, blue metal of size 20mm is put similarly to about 3/4ths height. The fourth compartment is empty. The outflow from the first compartment is taken through a pipe to the bottom of the second compartment and similarly the outflow from the second compartment is taken to the bottom of the third compartment. The overflow from the third compartment falls into the fourth compartment. As the sewage fills up in the first compartment, much of the faecal matter settles down at the bottom. The overflow still contains some residual faecal matter. As the sewage flows upwards from the second and the third compartments, bacteria spontaneously build up on the surfaces of the white metal pieces that eat up the residual faecal matter. Thus the liquid which falls into the last compartment contains much less of faecal matter compared to that flowing out from a septic tank (It is described as 'much more polished'). However it still contains pathogens.

HARD WATER / SOFT WATER: Water that contains more than the desirable quantity of dissolved carbonates, bicarbonates and sulphates of magnesium and calcium is called hard water. When clothes are washed in this water, these salts form insoluble compounds with the soap. Thus foaming is reduced and soap is wasted in first reacting with the salts. Soft water is water that contains low level of such salts. When hard water containing bicarbonates is boiled, white salt sediments are formed, due to the conversion of soluble bicarbonates into insoluble carbonates. However, because of this separation, the dissolved salt content reduces and the water becomes softer. Sediments are also formed in our buckets and vessels over a period when they are used for storing hard water. This is because of evaporation of water and separation of the dissolved salts from it. However, because of this separation, the water becomes softer. Fabrics washed regularly in hard water tend to have a shorter life.

BRACKISH WATER: This refers to water that has either more dissolved salts in it than desirable for drinking and cooking purposes or to hard water that is not very suitable for washing of clothes. Often, for want of better quality, this may be consumed and/or used for washing of clothes

SALINE WATER: Although it is often loosely used to refer to brackish water, it is more correctly used for water that can neither be consumed nor used for bathing. Saline water tends to contain much higher content of dissolved salts (particularly chlorides and sulphates) than brackish water.

PPM: stands for **p**arts **p**er **m**illion. These are units used to indicate the extent to which dissolved salts are present in water. This unit is also expressed alternatively as mg / l or milligrams per litre. Thus, if a particular sample of water is stated to contain 200 ppm or mg/l of dissolved salts, it means that a million parts of that water contains 200 parts of dissolved salts.

WEATHERED ROCK: Weathered Rock is rock that has been affected at its surface by chemical processes, water movement and climatic conditions like heat, cold and sunlight. It is similar to what happens to the steel rim of a bicycle whose paint has peeled off. Because the paint has peeled off, the metal at the surface becomes exposed to water and air, and breaks down into tiny flakes that then get converted into oxides of iron or rust. Only a thin layer at the surface of the steel rim is affected while the bulk of the steel beneath remains intact. In a similar manner, the surface of solid rock, when exposed to water movement, heat, cold, sunlight and chemical processes occurring in nature, is broken down into boulders and gravel at the surface. Just as prolonged exposure to air and moisture would result in the steel rim losing all its rigidity and crumbling into bits of rusted iron, prolonged geological processes convert the boulders and gravel into finer products like coarse sand, medium sand, fine sand, silt and clay in that order. Weathered rock generally offers good scope for storing water because there will be large gaps between individual parts of the weathered rock.

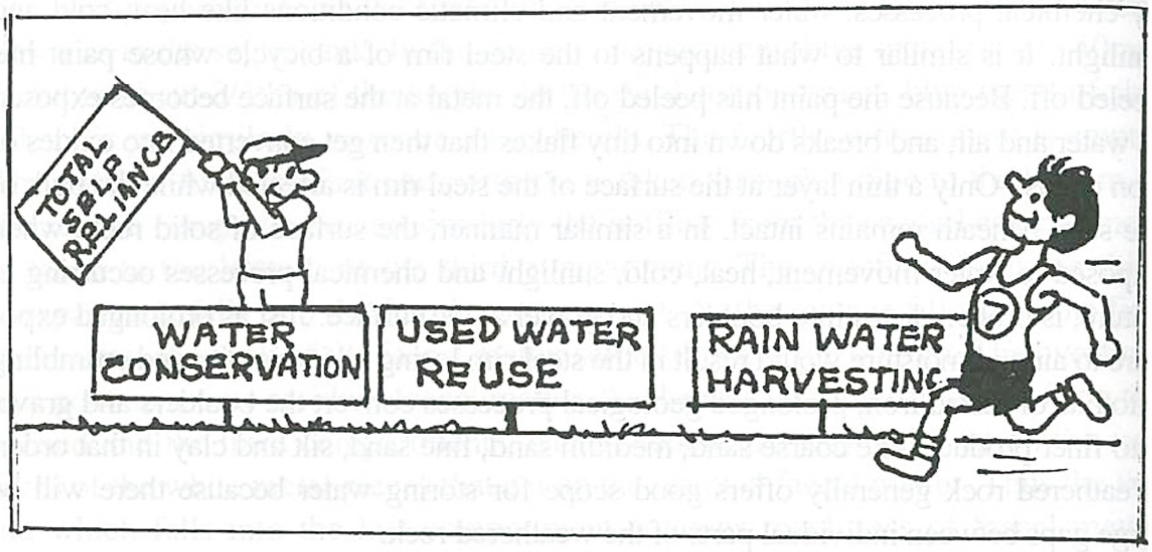
FISSURES, FAULTS, JOINTS AND CLEAVAGES: All of these refer to openings of various types in solid rock formations formed by geological processes that often hold water. The extent of these openings can vary over huge ranges. Correspondingly, the volume of water that these will be holding will also vary widely. Other than such openings in solid rock that can hold water, certain other types of rocks like shale, sandstone and limestone can also hold water depending on their make-up. Generally the water from the openings of solid rock will be of good quality, whereas the quality of water from the other types may vary.

WATER UNITS

Many terms relating to water appear in the media frequently in the papers. Those that are likely to appear frequently in this book are explained below:

1 cubic centimetre (1 cc) is the volume of a cube 1cm long, 1 cm wide and 1cm high. It is practically the same as *1 millilitre (1 ml)*. 1000 ml make *a litre (1 L)*. 1000 litres make up *a kilolitre or 1 kL*. 1 cubic metre is practically the same as a kilolitre. Tankers transporting water in cities generally have a capacity of 12 kL.
1 cubic foot (cuft.) = 28.32 litres.
lpcd = litres per capita(per person) per day
1 gallon= 4.54 litres
The terms explained below deal with large volumes. Although these terms do not appear in this book, they are given below for the reader's understanding, as these terms are frequently found in newspaper articles and reports on water.
mcft = million cubic feet
tmc = thousand million cubic feet
mld = million litres per day
cusecs = cubic feet per second (This is a rate of flow)

CHAPTER 3



THE FIRST STEP IN SELF-RELIANCE: RAINWATER HARVESTING

(Rain is the ultimate source of all the fresh water that we use. This chapter unfolds the enormous potential lying in harvesting the rain in our households on our path to self-reliance in water and how this potential can be harnessed economically for our benefit)

Fighting over water:

Of the total estimated stock of water in the world, 95-97% is in the form of sea water and therefore not readily usable for any of our daily needs. Of the balance of 3-5%, only 1% is in the usable liquid form, the rest being in the form of ice in the two Polar Regions. This usable 1% is itself distributed in rivers, lakes, ponds, and tanks and as ground water under the soil. Alarming forecasts appear in the media now and then of looming water shortages in the world and dire predictions are made that the wars that will be fought in the 21st century will be only over water[7]. However, these alarmist scenarios of the future are avoidable if only this usable 1% fresh water stock of the world is managed better.

In our own country, we have been witnessing neighbouring states fighting over sharing of the water from rivers that flow through them, during which passions

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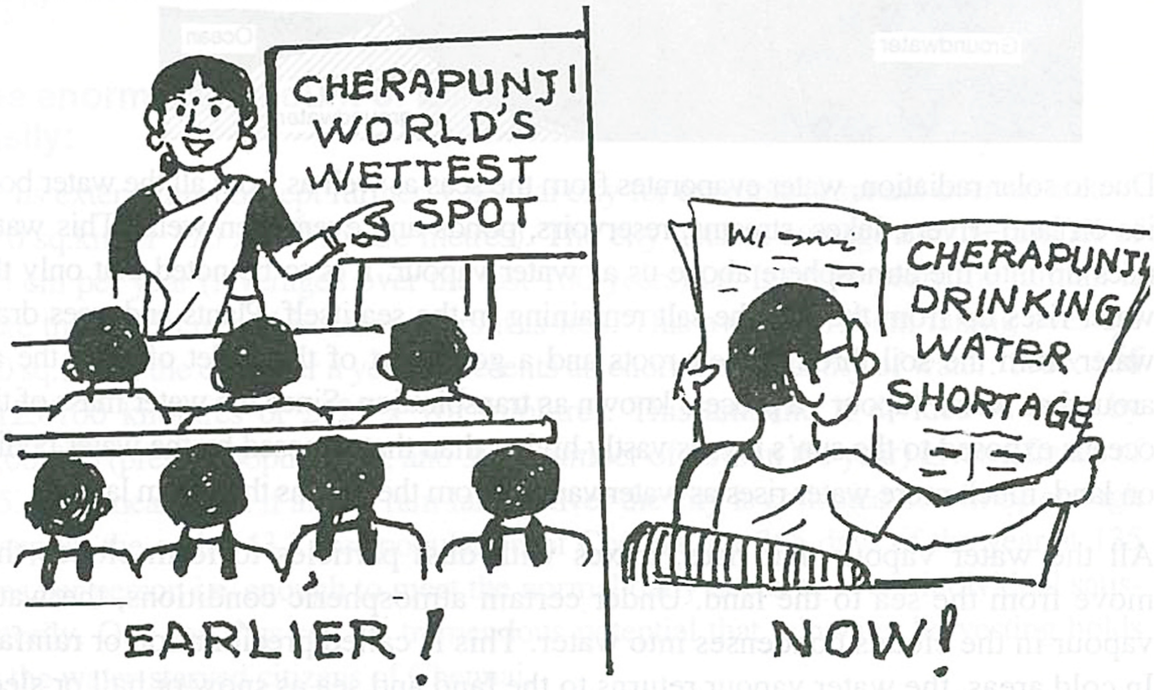
7. Ironically even Cherrapunji, which receives about 1100 cm of rainfall every year, suffers from acute shortage of drinking water today. This is because the rainwater is not conserved. It drains off rapidly down the slopes due to deforestation that has occurred over the years. Trees play a vital role in holding water around them and not allowing it to drain off rapidly.

are inflamed and otherwise peaceable people indulge in violent demonstrations, riots and arson. In recent years, disturbances have begun to occur even within the same state over water. In the year 2000 when Western Gujarat experienced acute deficiency of monsoon rains, villagers in Saurashtra opposed the diversion of water from a dam in their village to the nearby town. In the resultant disturbances, police resorted to firing and several villagers died.

Such unfortunate events are indeed avoidable; For, as stated earlier, our country receives much more monsoon rains than many other countries and all that we citizens of towns and cities have to do is to take advantage of the monsoons effectively and manage our water resources more efficiently at the micro level.[8] In order to do so, we urbanites need to know more about water and its behaviour both at the macro and micro levels.

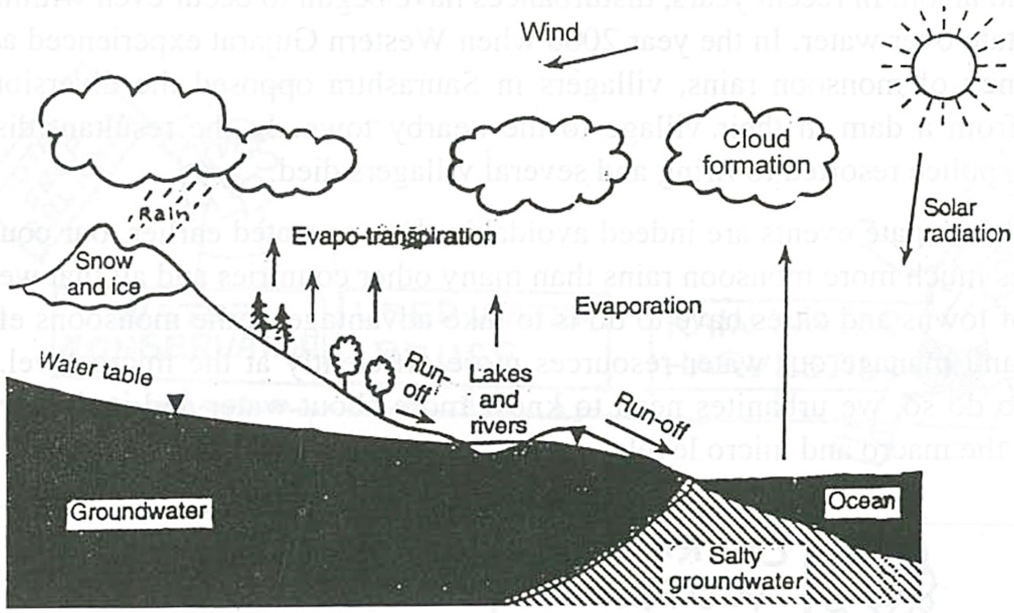


The Hydrological Cycle:

In the last chapter, we saw how the cyclical movement of water from and to the soil had sustained us at the micro level in earlier days. A similar cyclical movement of water between the oceans and the land that takes place at the macro level sustains all the water bodies on the land. This is illustrated in the picture below. This cycle is known as the hydrological cycle and the key players in this are the sun, the seas and rain.

7 'Fierce national competition over water has prompted fears that water issues contain the seeds of violent conflict.' – Kofi Annan, U.N.Secretary General, speaking on World Water Day, 23-2-2002; 'The wars of the next century will be about water.' – Ismail Seregaldin, Vice-President, World Bank, 1995.

Sketch 3.1 Hydrological Cycle



Due to solar radiation, water evaporates from the seas as well as from all the water bodies on land–rivers, lakes, streams, reservoirs, ponds and even open wells. This water rises up into the atmosphere above us as water vapour. It is to be noted that only the water rises up from the sea, the salt remaining in the sea itself. Plants and trees draw water from the soil through their roots and a good part of this is let off into the air around as water vapour - a process known as transpiration. Since the water mass of the oceans exposed to the sun's rays is vastly higher than that exposed by the water bodies on land, much more water rises as water vapour from the oceans than from land.

All the water vapour that rises, mixes with dust particles to form clouds that move from the sea to the land. Under certain atmospheric conditions, the water vapour in the clouds condenses into water. This is called precipitation or rainfall. In cold areas, the water vapour returns to the land and sea as snow or hail or sleet. Rainfall fills up tanks, lakes, ponds and wells and increases the water levels of streams and rivers. Whatever water is not diverted from rivers and streams for use on land ends up in the sea once again. The cycle thus goes on.

Measuring Rainfall — What is 15 cm of rainfall?

We often read in the papers or hear on the TV that the roads in some cities were flooded because of a heavy down pour of 15 cm (6 inches of rain) or that the total rainfall in that town in a particular year was 100 cm (40 inches). Rainfall thus seems to be measured and reported in terms of centimetres or inches. What does this mean in simple terms?

If you are living in a house or an apartment complex with a flat terrace, imagine the terrace to be fully water- proof i.e. no water can leak out through the parapet walls or seep down through the terrace floor. Assume also that the water that thus collects on the terrace is not allowed to evaporate. Then let us assume that on a particular day, the rain that fell in your locality was 15 cm. After this rainfall, what you will have on your terrace is a pool of water 15cm high. This would be the level of water irrespective of the area of your terrace. Suppose your neighbour had kept a wide mouthed drum on his terrace. After this 15 cm rainfall, the barrel would also have just the same level of water i.e. 15 cm from the bottom. Suppose your terrace area is 100sq.m. Then the volume of rainfall collected from a 15 cm rainfall will be 100 x 15/100[9] or 15 cubic meters i.e. 15 kilolitres. Suppose the total rainfall in your city in a particular year was 150 cm. Then your water proof and evaporation proof terrace of 100sq.m would at the end of the year have water standing up to a height of 150 cm on it This would be equivalent to a volume of 100 meters x 150/100 cubic meters or 150 kilolitres[10].

The enormous amount of rainwater that we can tap cheaply and easily:

Let us extend this concept further. Chennai city for example is spread over an area of (170 sq.km or 170 x 10^6 square metres). The city gets an average annual rainfall of 125 cm per year (Averaged over the last 100 years) i.e. In some years the rainfall is more than 125 cm and in other years it is less. This average 125cm falling over the 170 sq.km of the city over a year represents an enormous quantity of water: 170 x 10^6 x 125/100 kilolitres or 2125 x 10^5 kilolitres. This amount, if divided in turn, by 43,00,000 (present population), and 365 (number of days in the year) gives a figure of 135. This means that if all the rain falling over the city is collected, it will be enough to supply the entire 43.2 lacs population of Chennai for 365 days of the year at 135 litres per person i.e. enough to meet the normal daily needs of every individual satisfactorily. One can thus see the tremendous potential that rainwater harvesting holds for the water-starved citizens of Chennai.

Similar potential exists in greater or lesser degree in the case of any town or city depending on the rainfall it receives and the population it holds. Even in areas where the average annual rainfall may be low, the needs of safe drinking water, so vital for health and survival can be met from tapping and storing rainwater.

The question that naturally arises from these data and calculations is "How does one harvest all this water?" The answer is simple: If there is a waterway, a substantial part of the rainwater flows naturally into it and all one has to do is to divert the water into adequately sized storages instead of allowing it to run off into the sea. If there is no waterway, the rainwater can be diverted into lakes, ponds and tanks. Thus the water source for Delhi's citizens is the Yamuna River. For Hyderabad, the Hussainsagar Lake is the chief water source For Chennai's

9. 100 cm = 1metre. So, 15 cm = 15/100 meters.

10. For all practical purposes, 1 cubic meter = 1 kiloliter. 1 kiloliter=1000 liters

citizens, the two rivers, Kortalayar and the Araniyar are the main sources which feed the city's reservoirs The ground reality is that the available water has not been harnessed, stored and distributed by the water authorities in many towns to meet the needs of their populations that have risen with the passage of time with consequent shortage of water supply to the citizens. This is compounded by the fact that water bodies have been steadily eroded upon for the construction of residential or commercial structures.

Bangalore, for instance, once got all its water needs from its numerous tanks. Unfortunately, over the years, the major tanks have been taken over either for building residential colonies or for constructing bus termini, sports stadia and markets. Presently the water authorities are bringing water all the way from the Kaveri River, 90 km away. Not merely that but the city being at an elevation, this water has to be additionally pumped up 1000 meters, expending heavy electrical energy in the process.

However, even if the water authorities do not tap rainwater at the macro-level as efficiently as they could, nothing prevents us at our level to efficiently harvest rainwater in our houses, apartment complexes, office buildings, parks and school grounds. It is very easy to tap rainwater by you, your friend, your friend's friend, your apartment complex and so on – each of them in their respective premises – whether they be independent houses or apartment complexes or commercial complexes. In the following workings, one can see the enormous potential that micro-level rainwater holds for the water-starved citizens of Chennai:

AN INDEPENDENT HOUSE ON A 1 GROUND PLOT IN CHENNAI

Area of the plot = 2400Sq. ft (1 ground)

Occupancy assumed = 5residents

Daily needs ofthe household = 135litres per person $\times 5$ = 675litres

Average rainfall in a year = 50inches(125cms)

1 cu. foot = 28.32litres

Therefore volume of rain water falling on the premises in a year $= \dfrac{2400 \times 50 \times 28.32\text{litres}}{12}$

= 283.2kl or 283200 litres

Therefore the rainwater failling on the household premises is equal to $= \dfrac{283200}{675}$ or

= 420 days usage of the household

AN APARTMENT COMPLEX OF 8 FLATS ON A 2.5 GROUND PLOT

On a 6000sq.ft plot, an 8 flat complex can be accommodated comfortably.

$$\left.\begin{array}{r}\text{Assuming a total population}\\ \text{of 40 @ 5 individuals in each flat,}\\ \text{the daily water needs of the complex}\end{array}\right\} = 135 \times 5 \times 8 = 5400\text{litres or } 5.4\text{ kl}$$

$$\left.\begin{array}{r}\text{Average volume of rainfall in a}\\ \text{year over 6000 sq. ft.}\end{array}\right\} = \frac{6000 \times 50 \times 28.32}{12} \text{ or } 708\text{ kl.}$$

the rainwater falling on the premises in a year is equal to 708/5.4 or 131 days' total usage of the complex or 36% of the yearly needs. If the population is less than forty, this percentage increases pro-rata.

BIGGER APARTMENT COMPLEXES

The areas required for the construction of well designed apartment complexes can be assumed to follow a predictable pattern i.e. If an 8 flat complex is likely to be located on a 2.5 ground plot, a 16 flat complex can be assumed to be located on a 5 grounds plot, a 24 flat complex on a 10 grounds plot and so on. Therefore while we can work out the potential for tapping rainwater in the same manner as in the above two examples, one can assume that rainwater can meet approximately 131 days' water needs of the complex or 36% of the yearly needs at an average occupancy level of 5 persons per flat. If the occupancy is less, then this percentage will increase correspondingly.

COMMERCIAL/OFFICE COMPLEXES:

The total volume of rainwater falling on the premises can be worked out as in above cases. However, the usage per person here will be only about 135/3 or 45 litres or even less, as the offices will be working only for about 8 hr. in a day. Therefore the rainwater if harvested can meet the needs of the working population in the complex for a much bigger part of the year.

$$\frac{\text{Area of Plot}}{\text{No. of people working in plit}} \times \frac{51}{12} \times \frac{28.32}{45} = \left\{\begin{array}{l}\text{number of days' supply}\\ \text{available from rainwater}\end{array}\right.$$

In the workings above, rainwater harvesting even at 100% efficiency was found to confer only about 36% self reliance on apartment complexes. This appears to be contradicting the initial working where the rainfall over the entire city, if tapped, was found to be enough to meet the needs of the entire population. Actually there is no contradiction: When one divides the total volume of rainwater falling over the city by the total population of the city, one is implicitly assuming that the population is spread evenly over the entire area of the city. This assumption at the macro-level will give an average population density per square kilometer that will be much less than the population density at the micro-level of an apartment complex. Besides, we are taking into consideration in these cases only the water that is tapped within the confines of the apartment complex. But if we take the population density of the neighbourhood in which the complex is located, we will find it to be much closer to the city average because the neighborhood will include locations such as parks, play grounds and school buildings where the resident populations will be very low but the rainwater harvestable will be quite high. In other words, if rainwater harvesting were done in these places also, then the needs of the entire neighbourhood would be found to be available from rainwater harvest

As illustrated for the city of Chennai, you can work out the potential that rain harvesting holds for meeting the water needs of your town or city, from the average annual rainfall of your particular town or city, its geographical area and population, Given below is this potential for some towns and cities of India:

Table 3.1 Potential per capita(lpcd) water available from rainwater[1]

Sl. No.	City/Town	lpcd	Sl. No.	City/Town	lpcd	Sl. No.	City/Town	lpcd
1.	Agra	190	25.	Dharwar/Hubli	473	49.	Meerut	301
2.	Ahmednagar	95	26.	Gadag	401	50.	Mumbai	262
3.	Ajmer	816	27.	Gorakhpur	738	51.	Mysore	282
4.	Alapuzha	2540	28.	Gulbarga	187	52.	Nagpur	322
5.	Alwar	476	29.	Guwahati	1258	53.	Nasik	472
6.	Ambala	272	30.	Gwalior	960	54.	Nellore	404
7.	Amritsar	214	31.	Hyderabad	103	55.	Palakkad	881
8.	Anantpur	115	32.	Imphal	541	56.	Panjim	1917
9.	Aurangabad	313	33.	Indore	302	57.	Patiala	204
10.	Bangalore	98	34.	Jabalpur	588	58.	Patna	205
11.	Baroda	195	35.	Jaipur	159	59.	Pondichery	134
12.	Belgaum	1288	36.	Jamshedpur	369	60.	Pune	114
13.	Bellary	301	37.	Kanpur	238	61.	Raichur	576
14.	Bhopal	620	38.	Karwar	1751	62.	Ranchi	837
15.	Bijapur	546	39.	Kochi	1392	63.	Salem	79
16.	Bikaner	546	40.	Kohima	1484	64.	Shimla	315
17.	Chandigarh	250	41.	Kolhapur	422	65.	Surat	153
18.	Coimbatore	200	42.	Kolkota	182	66.	Thiruvanandapuram	797
19.	Cuddalore	658	43.	Kozhikode	3200	67.	Tiruchi	74
20.	Cuddapah	608	44.	Kurnool	111	68.	Udaipur	288
21.	Cuttack	921	45.	Lucknow	397	69.	Udhagamandalam	134
22.	Darjeeling	720	46.	Madgaon	1098	70.	Varanasi	213
23.	Dehradun	552	47.	Madurai	121	71.	Vellore	180
24.	Delhi	327	48.	Mangalore	982	72.	Ahmedabad	114

1. The formula applied is $\frac{\text{rainfall in meters} \times \text{area in sq.m} \times 1000}{\text{population in numbers} \times 365} = \text{lpcd}$. Rain fall data as in Appendix 4. Areas from Census 1991 except Delhi, Mumbai Baroda and Surat and population from Census 2001.

The rainfall pattern in these and a number of towns and cities of India is given in Appendix 4.

Is 100% efficiency possible in Rainwater Harvesting?

All calculations above assume a 100% efficiency in tapping all the rainwater. But is such efficiency practicable? And where can one find the receptacle to store all the rainwater? Would it not cost a fortune? And will it not be complicated also?

All these are legitimate questions, for which the answers are:

1. 100% efficiency may not be feasible but high efficiencies are certainly possible, even up to 98%[11]. Extensive studies by an Israeli scientist have shown that the efficiency of harvesting increases as the area of harvest reduces and efficiencies of 98% are quite achievable.
2. There is a ready receptacle available for storing all the rainwater tapped. This receptacle is nothing but the soil below the ground that has a huge capacity to store water and yield it back for our use later.
3. Tapping and storing water does not cost a fortune but it can save you a fortune in your life time not only in terms of the cost of the water you would not have to buy, but also in terms of the inconvenience and disruption to your daily life that it would avoid.
4. Tapping rainwater is simple both in the methods involved and in their maintenance.

Let us look at each of these aspects in more detail.

1. High Efficiencies can be achieved in tapping rainwater:

If you open a tap fully and hold an empty tumbler below it, very little water will fill into the tumbler. Most of it will bounce and flow out. This happens because the tumbler is incapable of receiving water at the high rate of flow from the tap. Instead if you hold a bucket below the tap, the situation alters dramatically: The bucket fills up rapidly. Alternately if you reduce the flow from the tap to just a trickle and then hold the tumbler below, you will see the water filling up the tumbler steadily. At a trickle, the bucket will also collect water efficiently, except that it will take a much longer time to fill up. These simple experiments show that the efficiency of collecting the tap water depends on adjusting the capacity of the receptacle to suit the rate at which the water flows from the tap.

An identical reasoning holds for rainwater harvesting also. If we have to tap the rainwater falling on our premises efficiently, we must have an idea of the pattern of rainfall in our area so that we can design the appropriate system to collect it efficiently and economically.

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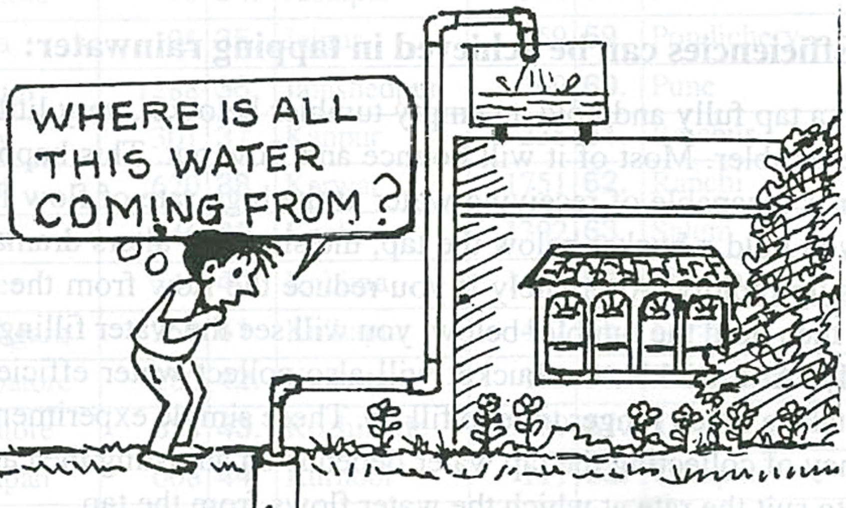
11. "The Negev: Challenge of a Desert', Michael Evenari et al., 1971, Oxford University Press, U.K.

2. Huge storage capacity readily available for storing rainwater in the soil below us:

Have you ever wondered how large quantities of water can be pumped out every day from a narrow bore well pipe? Have you ever considered why when rainwater falls into an open well it does not get filled up rapidly and start overflowing?

The answer to both is the same. Because the soil below and around both the bore well and the open well has spaces (pores) which not only holds large quantities of water which are drawn through the bore well pipe or the dug well but which can equally receive large quantities of water.



To understand this phenomenon, you can carry out a few simple experiments. Take a clean glass tumbler (about 4 ½ inch tall and 2 1//2 inch in diametre at the top and fill half of it with small washed stones (gravel). Mark the level of filling on the rim of the glass with a sketch pen all around. Take 100 ml of water and pour it into the tumbler in a slow thin stream. The water moves down quickly and fills up the spaces between stones. If after 1 hour, you tilt the tumbler carefully, most of the water comes back. Repeat the experiment with the tumbler filled up with sand up to the line marked earlier. Here too the water moves down fast and fills up the pores between the sand particles. But the water would have reached the top of the sand with less quantity of water being poured into the tumbler than in the case of gravel. If you tilt the tumbler after 1 hr., you will find more than half of the water can be drained out. Now fill the tumbler with powdered clay up to the line marked and repeat the experiment. Be sure to add the water in a thin slow stream, so that the soil at the top is not disturbed. The water level rises above the clay level with much less quantity being poured into the tumbler. When all the water has been added, you will find that the water remaining at the top of the clay is much more than in the two earlier cases. If you hold the tumbler in front of your face as you pour the water, you will see the water wetting the clay and moving downwards slowly. After 1 hr try decanting the water off. You will see very little water coming out. You will also see that the clay level at the top has gone above the marked line, indicating that the clay has absorbed the water and swollen. Such a rise in level does not take place in the other two cases because gravel and sand both do not absorb any water. You will also have noticed that when you drain off the water from the tumbler, the water flows out from sand and gravel much more easily than from clay.

What we learn from these three experiments is 1) that water moves downward and sideways in gravel and sand at a fast rate. This downward flow is known as infiltration or percolation and the rate of infiltration or percolation is high for sand and gravel. This rate of infiltration is known as permeability. 2) that the spaces between the individual particles in them are substantial enough to easily receive water and easily yield it back also, and 3) that clay does not hold much water but tends to absorb a considerable quantity and it yields back very little of water after it has been wetted to the saturation point.

Therefore, if the sub-soil in a particular area is sandy or gravelly in nature, huge quantities of water can be stored in the sub-soil of that area and this water can also be drawn for our use whenever necessary.

Table 3.2 Permeability of various types of soil[1]

Soil Type	Permeability (litres passing through one sq.m. area per day
Clay	0.50 to 100
Sand	5,000 to 1,50,000
Gravel	50,000 to 7,50,000
Gravel-Sand Mixture	10,000 to 2,50,000

1. Sourced from Groundwater, S. Ramakrishnan, TNHB Colony, Chennai 600 041, 1998.

In actual fact however the soil below us is not homogeneous in all places. In coastal areas, it is highly sandy. In other places it is gravelly or clayey or silty[12] or mixtures of two or more of them. Even in a specific area, the nature of the soil could change as we go down. Open wells (or dug wells) being shallow usually go only that much deep as to tap the water from one or at the most two favourable layers holding it. Bore wells on the other hand go much deeper and so can tap more than two favourable water- holding layers (or "aquifers"). This is dealt with in more detail in the next chapter.

3. Rainwater harvesting methods are simple and their costs are negligible if integrated with the building design:

As will be seen in the subsequent chapters, systems that harvest rainwater are simple in design and so their costs are very low. In fact, if they are installed at the time of the construction itself of any building a house or an apartment complex or a commercial complex the cost of the system is negligible in comparison with the total cost of the construction. If they have to be introduced in already developed plots – in existing buildings – the cost does increase but even the increased cost is not high and the outlay would be returned richly in terms of the recurring benefits that would accrue from it.

Rainwater harvesting systems can be installed at very low costs in large plots where public buildings, schools and colleges are located. So also can parks and play grounds be covered at low cost. Rainwater harvesting can be equally beneficial to industries, particularly to those requiring large quantities of water. While engineering industries can harvest rainwater easily, chemical industries and industries which use chemicals will need to take much greater care in their installations to prevent contamination of the tapped rainwater by any harmful chemical used by them. Municipalities too can with some imaginative means, charge the rainwater flowing through their storm water drains into the soil with very modest outlays. In areas where there are no storm water drains, inexpensive systems for ingestion of rainwater into the soil in a decentralised manner are feasible. These are detailed in Chapter 17

Apart from all these, rainwater harvesting offers one very significant benefit: It can provide us water for our drinking and cooking needs. There are many areas where potable water is not available either from ground water sources or from piped supply. In such areas, rainwater which is pure can be tapped and stored in containers above the ground, like pots, barrels and tanks or below the ground in sumps and used for that most vital daily need of ours i.e. for cooking and drinking. This aspect acquires great signifi-

12. Silt is fine mud whose particles are smaller than those of fine sand but larger than those of clay.

cance in areas where the ground water is contaminated with arsenic or fluoride.[13]

From all this, we see clearly the critical role that rainwater harvesting plays in our journey towards self-reliance in water. Let us shed our helpless dependence on others for our water needs and learn how to move forward in this journey through rainwater harvesting.

13. See Appendix 2 for more details on this.

CHAPTER 4

SOIL WATER INTER-RELATIONSHIP

(Water and soil are intimately related. This chapter shows how this influences the yield and quality we can expect from our dug wells and bore wells.)

In the last chapter, we saw how soil plays a vital role in water management and so we must learn a little more about soil and its behaviour vis-a-vis water. For our purpose, soil means the first few hundred feet of the earth below us. This is made up of rock of various types, gravel, sand, silt and clay. The earth as we all know, was once, geological ages ago, a ball of molten lava. The core of the earth today still is molten lava that comes out through volcanic eruptions. But as the outer most edges started cooling down, the lava solidified into hot hard rock and as this hard rock cooled down further, it was subjected to various forces like compression, chemical processes within the rock, movement of water, solar radiation etc. This resulted in the hard rock being modified in various ways and the modified rocks further disintegrating to smaller and smaller particles of gravel, sand, silt and clay.

Molten Lava → Hot hard rock → rocks of various types → gravel + sand + silt + clay.

Gravel, sand, silt and clay are today differentiated from one another on the basis of the size of their individual particles.

At the shallow depths that we are interested in i.e. up to a couple of hundred feet below the ground, these components are homogeneously present in some places (e.g.

Table 4.1 Sizes of individual soil particles

Coarse Sand	2 to 0.2mm
Fine Sand	0.2 to 0.02mm
Silt	0.02 to 0.002
Clay	Less than 0.002mm

highly sandy soil in coastal areas, highly rocky soil in mountainous areas) and in mixtures in various proportions in other places. Even in a specific area, the nature of the soil could change as we go down. Thus, in one part of a town, one may encounter rock at 15 ft and in another part of the same town at 60 ft and at 100 ft in a third. The ability of these various materials to hold water depends, as we said, on the spaces available between the particles in a specific layer of the soil. In terms of spaces between individual particles, gravel has the largest spaces, followed by coarse sand, medium sand, fine sand and clay, in that order. Solid rock obviously cannot hold any water. But due to geological processes, huge fissures could have occurred in the solid rock and these fissures are often found filled with water. The volume of water that a particular layer of fissured rock can hold depends on the extent of fissures present in the rock. But as a rock does not release any salts, water drawn from fissured rocks will generally be excellent in quality, although the available quantity may be uncertain. The water in some types of rocks like shale often does hold water but this water may contain dissolved salts.

Let us now look at Sketch 4.1 that represents the sub-soil profile in a particular premises up to a depth of about 23 metres (75ft) .

As we go downwards, we see that there are different soil layers but these different soil layers do not have uniform thickness. This is because of geological processes. While in this particular plot of land, the layers are distinctly clay or sand or gravel, more often than not, the layers are mixtures of these and silt in varying proportions. The predominant component of the mixture in each layer decides its affinity for storing and yielding water[14]. Let us now examine how the soil in this particular premises impacts on our ability to extract water from it.

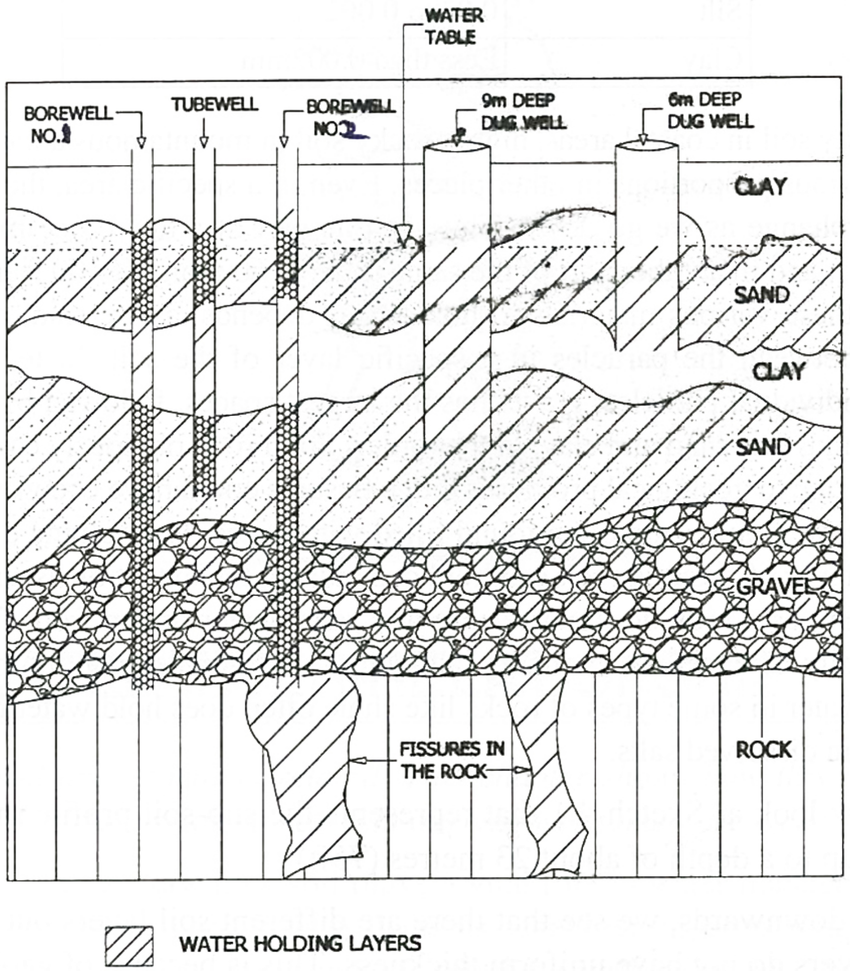
Two bore wells, one tube well and two dug wells are shown in the sketch. Let us now examine the water yields from these four water sources.

The 6 m. deep Dug Well No. 1 is able to tap only the first sandy layer whereas the 9 m. deep Dug well No. 2 is able to tap water from two sandy layers holding water. Thus if the upper sandy layer becomes dry due to excessive water extraction, Dug well No.1 will become dry whereas Dug well No. 2 will still yield water. The tube well which is only slightly deeper than Dug Well No. 2, is also

14. The question then arises as to how we can select the correct spot in any plot where we can dig a shallow well or drill a bore well. There is no sure shot method to locate such a spot in every case, but there are several ways in which we can get a reasonable idea of where to dig for a dug well or a bore well. These are detailed in Chapter 16.

tapping the water from the same two sandy layers through the slotted portions of its casing pipe at those levels. Therefore the yield from this tube well too may drop if the upper sandy layer becomes dry.

Sketch 4.1



Now, let us look at the two bore wells with identical depths. Bore well 1 with its three slotted layers taps water from three layers: the first and second sandy layers and the subsequent gravelly layer whereas Bore well 2, in addition to tapping these three layers, is able to tap a fourth water layer which is water held in a fissure in the hard rock. Unfortunately, Bore well No.1, with the same depth does not have this advantage of tapping this fourth layer, because there is no fissure in the rock at the point where the bore was drilled.

From this example, we can clearly see how soil and water are intimately related.

Incidentally, it is to be noted that the water level in the casing pipe of the two bore wells is somewhat higher than the water table. This is because of the pressure of the water in the lower layers.

In subsequent chapters (Chapters 6 and 16), we will learn more how to get information about the soil strata at various depths and use them for designing and installing appropriate rainwater harvesting structures.

CHAPTER 5

FREQUENTLY ASKED QUESTIONS ON RAINWATER HARVESTING

(When requested to introduce rainwater harvesting, people invariably raise three questions.. These three questions are answered here.)

Why should I harvest rainwater and put it into the soil when my neighbour is going to conveniently pump it out for his use?

The impression that your neighbour automatically has access to the rainwater harvested by you and put into the soil in your premises is erroneous. Very often he does not. Even if he does, it in no way negates the case for rainwater harvesting by you, irrespective of whether your neighbour goes in for it or not. To have a proper perspective on this, we must understand the dynamic behaviour of water in the subsoil. The basis for concluding that your neighbour automatically has access to the rainwater put into the sub-soil by you is the assumption that water flows *freely and quickly* both *laterally and vertically anywhere*. This assumption is valid, if all, only if there is no hindrance whatsoever for the movement of water. The water in the sub-soil is held in the pores between soil particles. Its vertical and lateral movement is therefore highly dependent on the nature of the soil in the place where it is and on the nature of the soil at the place where we assume it to move. Depending on this, there can be (and there often are) many an obstacle to the smooth movement of the water harvested by you either laterally or vertically to the layer from which your neighbour is drawing his water. Even if the soil nature is similar in both places, the lateral movement of water is not necessarily fast. If you have a dug well in your premises, you can observe this yourself during the rainy season.

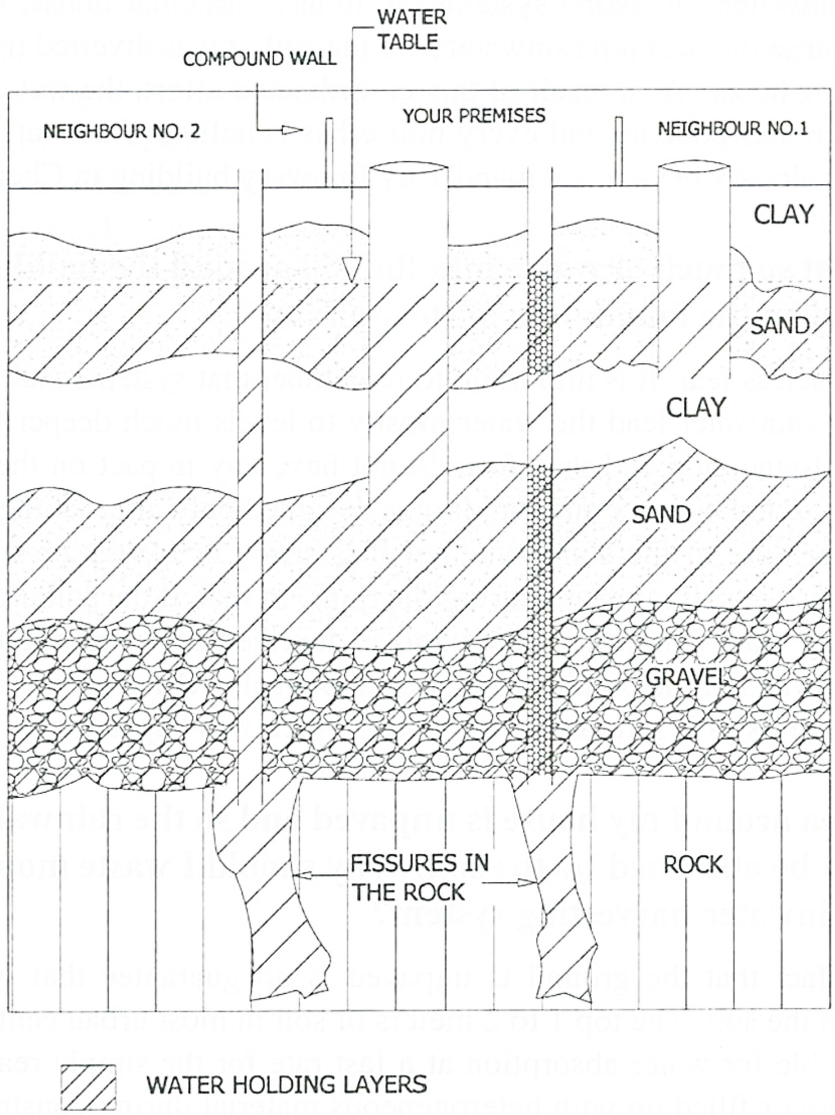
If there is a heavy downpour for sometime, then you will see a distinct rise in the water level in the well immediately after the rain stops. As the hours pass, this level goes down and the final level becomes much lower. This shows that the water takes some time to move laterally at the bottom of the well only because of which the level first rises after the downpour. Such a phenomenon may not be so clearly seen in very sandy areas because the movement of water laterally as also vertically is much faster in sandy soils. This phenomenon will be much more prominent in moderately sandy soils and in silty and clayey soils. Therefore, if you pump water from your well into your overhead tank immediately, you will in effect have cornered the water harvested by you before it has had the chance to move away from your premises. However, it is impracticable to corner all the harvested water in this fashion, for the simple reason that you won't have the capacity in the overhead tank to do so.

You can put up an impregnable compound wall all around your plot of land and thereby prevent outsiders from easily entering your plot or interfering with your legitimate activities on it. Your neighbours can do so equally on theirs. If you and your neighbours are drawing from a common water stock, you cannot unfortunately (or rather fortunately!) put any such impregnable barriers below the ground to prevent the water stock below your premises from moving laterally and being drawn upon by your neighbour. Equally, your neighbours too cannot prevent you from pumping out the water stock below their plots. While this is broadly true, the actual situation below the soil is not that simple in all cases. A lot depends on the sub-soil profile involved and the nature of the water sources you and he have. This will become clear if we examine a real life situation detailed below:

Let us assume that you have a shallow dug well and also a deep bore well reaching fissured rock in your premises. Let us assume that your Neighbour No.1 also has only a dug well but this is shallower than yours. Let us assume that your Neighbour No.2 on the other side has only a deep bore well reaching fissured rock. This situation is shown pictorially in Sketch 5.1.

Your dug well is seen to get its supply from two shallow aquifers (i.e. shallow soil layers holding the common stock of water) whereas your neighbour has access only to the upper aquifer. Thus the upper aquifer is common to both but the one immediately below it is not. If you have diverted the rainwater from your terrace say into your dug well, it reaches the first aquifer and Neighbour No.1 does have access to it, as both of you are drawing from the same aquifer. But if the water table has dropped and the upper layer has gone dry, then the water harvested by you reaches only the lower layer and Neighbour No.1 will have no access to it. Let us now look at Neighbour No.2. His bore well taps only the water in a fissured rock that is totally unconnected with any of the multiple layers that your bore well with the various slotted sections of its casing pipe is tapping. Therefore Neighbour No. 2 has no access whatsoever to any of the water layers that you are tapping. Even if his bore well had been provided with slotted sections, he would have been able to tap water only from those water bearing layers corresponding to the slotted sections and not the others. But he cannot, under any circumstances whatsoever, access the stock of water in the fissured rock connected to your bore well. And if you are charging the uppermost layer with rainwater, he can access it only if he has slotted sections in his casing pipe in this specific stretch.

Sketch 5.1



Apart from all this, even if your neighbour and you are already drawing water from the same aquifer, then merely because you are putting water into this aquifer, your neighbour is not going to increase his usage. Therefore you should continue to get the benefit of your initiative. This reasoning of course will not hold if your neighbour hitherto had been a single family and a flat complex is now coming up on the plot. The water extraction by the flat complex will certainly rise sharply. Even in such a case, if you go in for rainwater harvesting it will definitely be better for you in the long run, as the flat complex too would sooner than later be compelled to install rainwater harvesting measures to improve its self reliance in water [15]

Some people in Bangalore who had installed rainwater harvesting systems in their own premises found their neighbours were not convinced of the same and so were uninterested in following suit. These people however connected the terrace down take pipes of their neighbours to their own rainwater harvesting system with the approval of their relevant neighbours at a little additional cost and ensured greater water security for themselves. In a housing colony called Padmanabhanagar in Chennai, the residents of an entire colony of 200 houses have installed rainwater harvesting systems. If, in any particular house, there was no space to charge the roof top rainwater into the soil, it was diverted into soil in the neighbouring house. As a result of this co-ordinated effort, the water table in the entire colony has gone up and every house has benefited. Rainwater Harvesting (RWH) has already been made mandatory for every building in Chennai.

2. If we put so much of water into the soil around the building, will it not weaken the foundation of the building?

This is a baseless fear. It is important to remember that systems that harvest large volumes of rainwater lead the water mostly to levels much deeper than the bottom of the foundation and therefore do not have any impact on the foundation. Besides the foundation for any building is designed only after taking into consideration the nature of the soil - whether it is sandy or clayey or silty - and the likely increase in soil moisture during the rains. In fact, if the soil around a building is highly clayey and the clayey soil is deprived of water due to paving all around, the walls of the building may develop cracks. Often such cracks close up again if the dry soil is saturated with water, which will happen with RWH.

3. The area around my house is unpaved and so the rainwater will anyway be absorbed by the soil. Why should I waste money to put up a rainwater harvesting system?

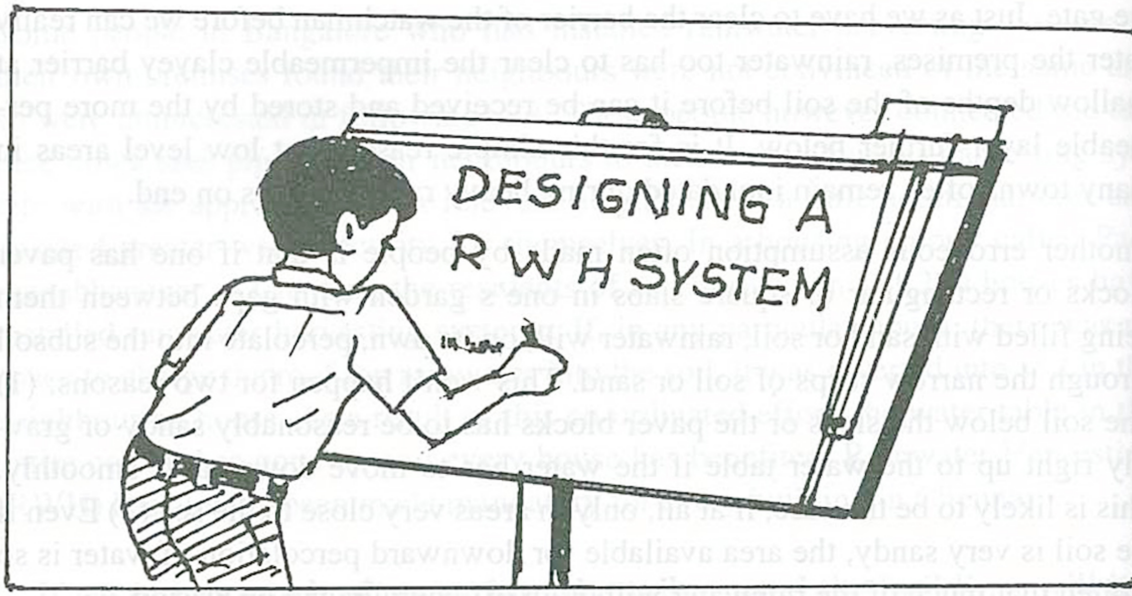
The mere fact that the ground is unpaved is no guarantee that water will be absorbed in the soil. The top 1 to 2 meters of soil in most urban centres is mostly not favourable for water absorption at a fast rate for the simple reason that it is either clayey or filled up with heterogeneous material during construction of the structures over it. This is no different from assuming we can enter a stranger's

15. RWH systems are being installed in schools, fly-overs, parks and play grounds. The impact of all these measures will be evident soon. RWH installations have also been made mandatory in all new constructions in Mumbai, Delhi, Nagpur and Indore. As the days pass, with increasing populations and increasing non-availability of treated water from the water authorities, more and more towns and cities will be making RWH systems mandatory. In the light of all this, it makes sound sense for us to go in for RWH irrespective of what our neighbours do or don't do

premises freely merely because the gate is open, without providing for the fact that there could be an alert watchman at the gate who will effectively stop us at the gate. Just as we have to clear the barrier of the watchman before we can really enter the premises, rainwater too has to clear the impermeable clayey barrier at shallow depths of the soil before it can be received and stored by the more permeable layer further below. It is for this simple reason that low level areas in many towns often remain inundated during heavy rains for days on end.

Another erroneous assumption often made by people is that if one has paver blocks or rectangular or square slabs in one's garden with gaps between them being filled with sand or soil, rainwater will, on its own, percolate into the subsoil through the narrow strips of soil or sand. This won't happen for two reasons: (1) The soil below the slabs or the paver blocks has to be reasonably sandy or gravelly right up to the water table if the water has to move downwards smoothly. This is likely to be the case, if at all, only in areas very close to the sea (2) Even if the soil is very sandy, the area available for downward percolation of water is so limited that much of the rainwater will drain off laterally and be wasted.

CHAPTER 6



DESIGNING A RAINWATER HARVESTING SYSTEM

(This chapter details the important factors that influence the designing of a rainwater harvesting system.)

The Basic Principle of Any Rainwater Harvesting System

Let us now get to know more about the actual make-up of a rainwater harvesting system.

We will hereafter refer to the phrase 'rainwater harvesting' by the abbreviation RWH.

RWH systems are somewhat like ready-made shirts! One adult size shirt does not necessarily fit all adults. It may fit a good number but for some, it may still have to be altered to fit the person concerned. And then there are half-sleeved shirts, full-sleeved shirts, T-shirts, kurtas and so on wherein the basic features remain the same but the final products are different. Again, a boy's shirt and an adult's shirt have obviously to be sized differently. In a similar manner, a single RWH system cannot be applied universally. While the basic principle influencing the design of all RWH systems is the same, the system appropriate for a particular plot or building would depend on a number of factors relevant to that plot or building. Nonetheless, rainwater harvesting is easy to practise and the technology involved in it is simple because the fundamental principle governing all RWH systems is a simple one:

CATCH RAINWATER WHEREVER AND WHENEVER IT FALLS

AND

DIVERT IT INTO AN APPROPRIATE STORAGE FOR LATER USE

Once this principle is kept in mind, the system appropriate to a particular place is only a matter of using one's ingenuity and the means available for doing so. The two examples cited below - one from a rural environment and the other from an urban environment will be illustrative:

Traditional houses in many towns of Tamil Nadu with scanty rainfall had sloping tiled roofing and these houses had, as seen in the picture, a central courtyard that was open to the sun. Rainwater coming down the sloping roof was diverted by semi-circular drains at the bottom of the sloped roof or by a cemented bund (See Picture 6.1) to the four corners of the sloped roofs. From this junction, the water fell down straight down through air on to the ground. The initial rainwater was rejected as it might contain mud or leaves from the roof and the clean water coming down thereafter was collected in large pots, stored and used later for cooking and drinking. Nowadays, four vertical pipes are fixed at the four corners to bring down the rainwater.

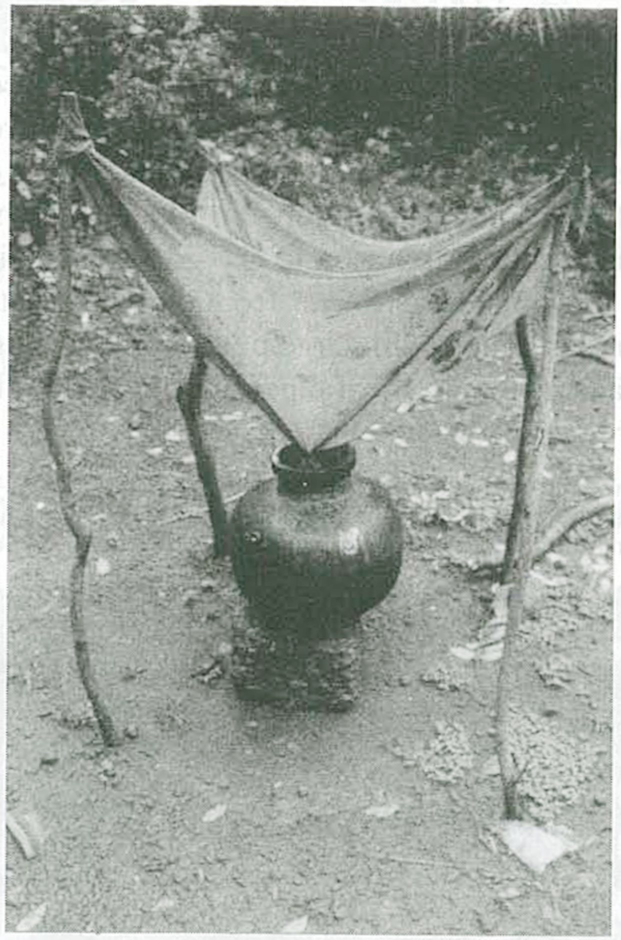
Picture 6.1 A typical courtyard in the Karaikudi district of Tamilnadu. A cemented bund directs all the rainwater to the junction of the sloping roofs. The water falling down the projecting drain section at the junction was collected in large pots kept below it.

Picture courtesy of Madras Craft Foundation, Chennai-90

In a different environment, a poor farmer's wife in a remote hamlet on the hills of Kerala had to trudge quite a long distance to collect some potable water for her family's daily use. The task became even more arduous during the monsoon because of the rains. She eliminated the monsoon problem in an ingenious manner: She just stretched an old sari of hers on four poles (See Picture 6.2 on p.38).

When rain fell on the sari, it automatically assumed the shape of a funnel and the rainwater falling over it flowed down as a single stream from the centre. She collected this water in a couple of pots, thus saving herself of the need to go a long distance for water in the rainy season at least. [16]

Picture 6.2 The simple ingenious arrangement set up by an illiterate housewife in a remote hamlet in Karnataka. The sari with its four ends tied to four poles takes up a pointed shape when rainwater falls on it. The rainwater falling down at this place is collected by her in pots.



These two examples show the application of the fundamental principle enunciated above:

CATCH RAINWATER WHEREVER AND WHENEVER IT FALLS

AND

DIVERT IT IN TO AN APPROPRIATE STORAGE FOR LATER USE.

The three components of any rainwater harvesting system:

A little reflection will show that any RWH system derived from this fundamental principle above must have three components:- (1) A catchment area or a collection area over which the rain falls; (2) An appropriate storage that can receive

16. For details of this interesting story, see Appendix 9: 'How Janaki stopped going down the hill to fetch water'.

and store the rainwater falling over the catchment area; and (3) A conveyance mechanism to transport the water from the catchment area to the storage unit. In the first example the sloping roofs of the house formed the catchment area, the large pots were the storage units and the semicircular drains and the vertical pipes comprised the conveyance mechanism.

In the second example, the catchment area was the sari stretched on four poles, and the pots kept below were the storage units. As the storage units were right below the cone shaped sari, the water fell directly into the pots and no specific conveyance mechanism was necessary.

1. Catchment Areas

In towns and cities, catchment areas are of three types (1) The flat terraces of apartment complexes and recently constructed houses, (2) The sloping tiled or tin/AC sheeted roofs of older houses and (3) the open spaces around buildings, roads, parks and playgrounds[17]. Harvesting the rain falling on flat and sloping roofs is called ***Roof-Top Rainwater harvesting*** whereas tapping the rain falling on the open spaces around buildings, on parks, playgrounds and other open spaces is called ***Surface Run-Off Harvesting.***

2. Storage Units

The type of storage unit required for receiving the collected water would depend on the scope of the harvesting planned. If say, rainwater is tapped in a house only for cooking and drinking needs the storage unit can be a large pot, a barrel or a drum, a tank above the ground made of cement and brick or of plastic or ferro-cement or a sump below the ground. However, for apartment complexes, the daily requirement of water even for cooking and drinking would be quite high. If rain occurs only over a limited number of days in the year, the rainwater has to be tapped in those limited number of days and stored for use for the rest of the year. Thus, the size of the sumps that can hold large quantities of water has to be quite large. The cost of constructing such sumps within the premises of the complex would not only be exhorbitant but could also be often impractical due to space constraints. For such complexes, the simpler and cheaper alternative would be to store all the tapped water in the soil below and draw it for later use through bore wells or dug wells

3. Conveyance Mechanism

Any urban RWH system must necessarily have a conveyance mechanism by which the water falling on the catchment area is transported to the storage unit. This is invariably done through pipes that can be of different materials (stone-

17. In row housing or continuous building areas, such open spaces do not exist.

ware pipes, GI pipes, rigid PVC pipes, asbestos cement pipes, polythene hoses[18]). The pipeline may be located fully above the ground or fully below the ground or partially above and partially below the ground, depending on the system to be introduced. The choice of the piping material also would depend on the particular system selected, the volume of water to be transferred and also affordability. Thus if roof top rainwater is to be diverted into a ferro-cement tank above the ground, the pipeline necessarily has to be above the ground and so stoneware piping cannot be used. If the pipeline has to cross a vehicular pathway and reach an underground sump, the pipe can cross the pathway at a height if it is not too wide. This has to be done only by using PVC or GI piping. Otherwise it has to go below the ground to enable smooth vehicular movement on the pathway. Either stoneware piping or rigid PVC piping has to be used here. While stoneware piping is cheaper, a mason is required to place it in position. PVC piping is costlier but can be laid in a much faster time by a plumber. As will be seen in the pages that follow, polythene hoses or unlined or cemented channels on the ground (open or closed) can also act as conveyance mechanisms in certain cases.

The size of the piping has to be adequate to handle the volume of rainwater to be passed through it during a good shower. In places where the rain tends to fall in short heavy spells, 4 or 6inch stoneware piping or 110mm PVC piping can be used. In places where the rainfall is light generally, 75mm piping should be adequate.

Factors Influencing the Design

A well-designed RWH system should integrate the above three components in an economic manner and at the same time, it should be capable of efficiently collecting and storing for later use, the quantity of water that one needs or that one can collect and store in the place involved. It should also be user-friendly. This integration and the designing of such a system are influenced by a variety of factors. The important ones among them are detailed below:

1.Average Annual Rainfall and Catchment Area

The total quantity of water that one potentially can tap from rainwater harvesting in a specific premises in a year is simply a product of the average annual rain fall in the place concerned and the catchment or collection area available for its collection.. Thus if the average annual rain fall in Town A say is 50 cm and the collection area available in a particular premises in this town is 100 sq.m., the maximum of rainwater that can be collected in that premises in a year is 100 sq.m x 0.5 m or 50 m^3 i.e. 50 kilolitres. If all of this quantity is to be collected then the entire catchment area has to be included in the design. If only a part of it is needed, only a part of the catchment area needs to be included in the design.

18. Even bamboo pipes are used in the northeastern states of India to harvest rainwater!

2.Distribution of Rainfall Over the Year

Let us assume that there are two identically designed houses in two towns A and B occupied by the same number of individuals. Let us also assume that the total annual rainfall in both the towns is the same. But in Town A, the rainfall is spread over eight or nine months of the year whereas in Town B the rainfall occurs in only two months of the year. If the rainwater is to be collected and stored in a tank or a sump, obviously the size of the tank or sump in Town A can be much smaller than their size in Town B. The pattern of distribution of rainfall in various urban centres of India (Average monthly rainfall and the number of rainy days in each month)are given in Appendix 4.

3.Intensity of Rainfall

The intensity of rainfall in a particular place is the amount of rain occurring in that place in an hour (mm/hr or inches/hr). The rainfall on a particular day may be heavy but light on the next day.

The maximum amount of rainfall that can be expected to fall in that place in one hour is called the peak intensity of rainfall per hour. Therefore, if we aim to tap all the rain that may occur in that place, we must put in place a system that ideally will be able to collect all the water even at the peak intensity of rainfall in that area The peak intensity of rainfall for 1 hr over a ten-year period in various places is given in Table 7.1 on page -50.

4.Daily Consumption Rate

Let us consider three identically sized plots in Town A which have respectively:- (a) a family of five individuals, (b) an apartment complex housing 30 individuals and (c) an office complex where 30 individuals work daily .The plot area being the same in all the three cases, the total harvestable rainwater is the same in all the three plots. However, the daily water needs of the three are quite different. The apartment complex has the maximum number of occupants among the three, and so it may have to harvest all the rain falling over the premises to meet its needs, whereas the needs of the family of five may be met by harvesting only a third of the total rain. The office complex may need to harvest a quantity in between. Generally it is accepted that every individual requires about 135 litres of water per day for healthy and hygienic living (135 litres per capita per day or 135 ***lpcd***). This is approximately allocated for various need as follows: 2 - 3 l for drinking; 10-15 l. for cooking, 20-25 l for bathing, 20 l for washing of clothes, 50 l for flushing of closets through cisterns, 10 l for washing of vessels and 15 l for other sundry uses. However, the actual per capita consumption would depend on the climatic conditions in the place concerned (hot/cold, dry/humid) and the facilities available in the habitation concerned. Thus, for example the water needed to flush by hand an Indian Water Closet is much less than the water needed to flush a European Water Closet[19]. Besides, the quantity of water needed by a family of five say is not necessarily five times the quantity needed per individual, except in the case of the usage for bathing and flushing of closets.

The usage of water in an office building/shopping complex bank/school is generally taken to be a third of a resident over 24 hours.

5.Run-off Co-efficient

Rainwater that falls on soil, a cemented floor or a metal sheet or sand or any other surface can take two routes:

1) Move vertically downwards through the surface involved wherever possible and

2)Move laterally along the surface. The vertical movement obviously depends on the permeability of the material forming the surface and is called 'percolation' or 'infiltration. The lateral movement of the water along the surface is called 'Run Off'. For instance, most of the water falling on a paved cemented surface around a building will move only laterally. Hardly any water will be absorbed by the surface.

In apartment complexes where the driveways are paved, most of it will flow towards the gate, as the paving slopes towards the gate. Therefore a very high portion of the water falling over, say 100 sqm. of such a paved surface will be collectible at the gate. If, say a kilolitre of rainwater falls on a particular day, as much as 80 - 90 % of it (0.8 to 0.9 parts of the total quantity) can be collected at the gate. This ratio is called the Run off Coefficient of cemented surfaces. Similarly, the run-off co-efficient for a metal sheet will be quite high. If the same 1 kl of water falls, say on 100 sqm of unpaved soil area around a house, the water collectible at the gate will be much less because the soil(if clayey) would either have absorbed a part of the water or(if sandy) would have allowed it to move downwards. The run-off co-efficient of the surface or surfaces involved in a specific plot would therefore have an impact of the efficiency with which rainwater can be harvested in that premises.

Table 6.1 Run-off co-efficient of surfaces

Nature of Catchment Area	Run-off Co-efficient
1) Tiled Roofs	0.8-0.9
2) Corrugated metal sheeted roof	0.7-0.8
3) Concrete Driveways	0.6-0.8
4) Brick Pavements	0.5-0.6
5) Compacted and smoothened soil	0.3-0.5
6) Plastic sheeting	0.7-0.8
Source: Rainwater Harvesting: The Collection of Rainfall and Run-off in Rural Areas, Arnold Pacey and Adrian Cullis, Intermediate Technology Publications, London,U .K., 1986.	

19. Some recent models of European water closets use much less water than older models, but these are expensive.

6. Availability of Piped Water Supply

If you are getting treated water from the municipal or the local water authorities, you in all likelihood will be having an underground tank or sump to receive and store the water. Generally, treated water supply improves during the rainy season and it is in that very season that you will have to harvest and store the rainwater. And there may be no space in the tank to store the harvested rainwater. In such a case, you can divert all the rainwater into the soil (through a well or a percolation pit or a bore well.) If the tank is not filled up by treated water inflow even in the rainy season, you can divert the rooftop rainwater first into the sump and the overflow from it can be diverted into a dug well or a bore well or a percolation pit. You could even have two lines: one going to the sump with the overflow going into the soil and a second line going directly to the soil, with a valve arrangement to choose the path desired.

7. Quality of the Ground Water Available

If the ground water quality is not good, it will be advantageous to divert the rooftop rainwater into a sump or a tank first to cater to cooking and drinking needs first and divert only the overflow from the tank to go into the soil. Surface run-off can also be charged into the soil. Both will improve the quality of the ground water progessively.

8. Financial Constraints

The quantity of cloth available to a person decides the maximum size of the shirt that he can stitch from it. Similarly, the budget allocated to rainwater harvesting often decides the quantity of rainwater that can be harvested. Suppose in a particular plot, the terrace area of the building is 50 % of the total plot area. Harvesting of the rainwater falling on the terrace alone may need a smaller investment than harvesting of the rainwater falling over the entire premises and roof top harvesting may be enough to meet the major needs of the residents. In such a situation, there may be reluctance to spend more and harvest the surface run-off even if it offered total self-reliance in respect of water. It is also possible in some of these cases that an integrated plan for tapping both the roof- top as well as the surface run-off may be feasible with only marginal increase in the outlay need. Therefore when financial constraints are involved, more efforts at the design stage may well yield an economic but comprehensive system. Alternately, it may be possible to work out a system that enables the comprehensive system to be implemented in stages. While considering the outlays for any RWH system, the long term should be kept in mind and not the short term.

9. Sub-soil Profile and Depth of Water Table

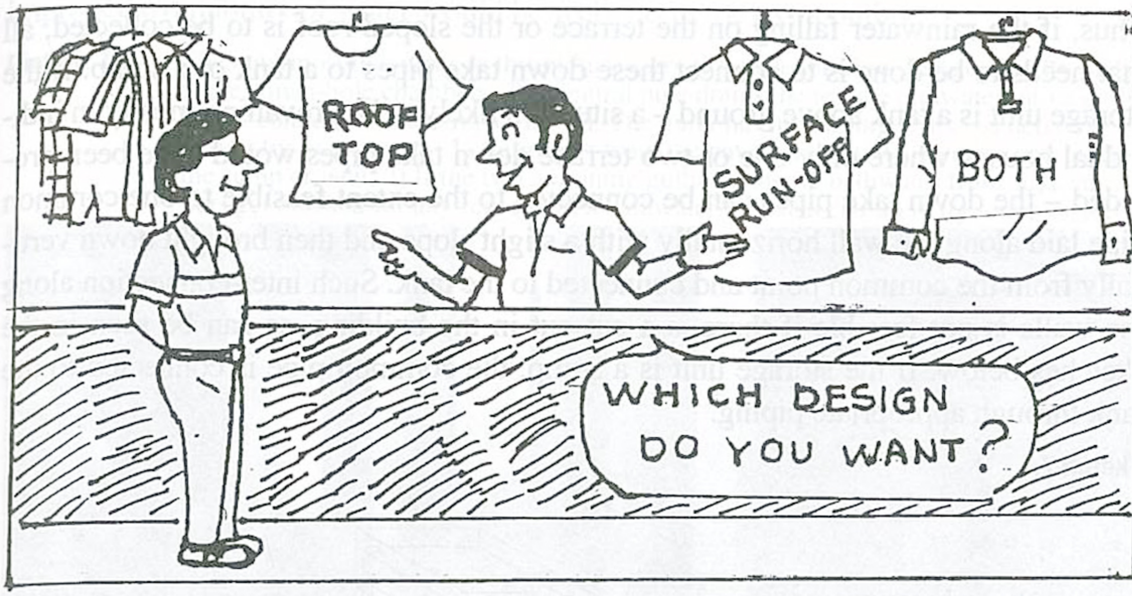
If rainwater si to be stored in the soil, the soil has to be favourable for hloding it. Generally, before any biulding is constructed, the nature of the soil at various depths upto 7.5 – 10 meters is ascertained in order to design the foundation. These data give valuable information on the scope for providing dug wells, percolation pits and bore wells (both service and recharge bore wells) for providing slots in the favourable soil stretches in order to store rainwater at shallow/deep levels. When the borewells are dug, samples of the soil at reqular depths must be examined and assessed by a simple thumbrule (see "Assessment of Soil Samples Set Aside on Site During Drilling/Digging" on page -137). If soil data are not available, one or two test borewells can be drilled in the premises to get an idea of the sub-soil profile (see "The Deep Bore Well" on page -135).

Groudwater maybe encountered during routine soil investigation. The depth at which it is encountered is a valuable addition to our data.

10. Overview

While all these factors do influence the design of a RWH system, all the factors may not be relevant to your particular situation and need. It is also possible that for some factors like the peak intensity of rainfall or the pattern of rainfall, precise data may not be available for your particular town. Nevertheless, a reasonable idea about them would be available from living in that area and from information about the weather reported in the newspapers. Besides, if the objective were only to store the water in a sump or a tank, the most critical factor would be the sizing of the tank or sump, availability of adequate space to locate them and the cost of constructing them. From a practical experience of the pattern of rainfall and the intensity of rainfall, the capacity of the tank or sump can be decided. However, it is simpler and cheaper to design systems to store the harvested water in the soil in addition to its storage in sumps or tanks. The sizing of the storage thereby acquires lesser importance. In the pages that follow, some typical rainwater harvesting systems are presented. These are systems that have been tested and found effective in Chennai, where the average annual rainfall is considerable (125 cm) but all of it tends to occur only in 50-60 days of the year. These are therefore designed to trap large volume of water in short periods. These designs can be adapted to the local conditions in other towns and cities depending on the specific factors involved.

C H A P T E R 7



RAINWATER HARVESTING SYSTEMS TO SUIT YOUR NEED

(Details of different types of RWH Systems to suit different situations and different needs are presented in this chapter. This is an important chapter. To get the full benefit of the information and guidance provided in this chapter, readers are strongly advised to refresh themselves, if necessary, with the meanings of the various terms listed in Chapter 2.)

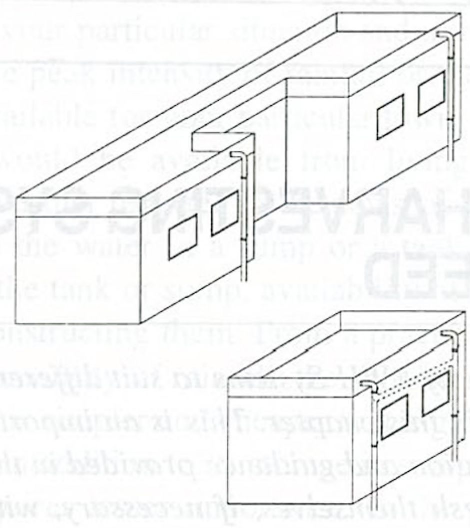
ROOFTOP RWH

1: Storing Rooftop Rainwater in Tanks Above Ground and in Underground Sumps

The most critical purpose for which we all need water is for cooking and drinking. This water should have a low salt content. In places where the available ground water is brackish or the municipal supply is poor, this need can be met by harvesting the rain falling on the roof or terrace and storing it in tanks above ground or in sumps underground. The roofs may be flat terraces as in the case of most apartment complexes or sloped with tiles or with A.C. or tin sheets as in many individual houses. In every well-constructed building with a flat terrace, an adequate number of vertical pipes are provided from the terrace down to the ground level so that the rainwater falling on the terrace does not stagnate on the terrace but is put in the open spaces around the building. In the case of building with sloped roofs, semi-circular drains are provided below and along the bottom edges of the roofs that are then connected to vertical pipes at the corners.

Thus, if the rainwater falling on the terrace or the sloped roof is to be collected, all that needs to be done is to connect these down take pipes to a tank or a sump. If the storage unit is a tank above ground – a situation likely to be prevailing mostly in individual houses where only one or two terrace down take pipes would have been provided – the down take pipes can be connected to the extent feasible to one common pipe laid along the wall horizontally with a slight slope and then brought down vertically from the common point and connected to the tank. Such inter-connection along the walls is not feasible if there is a cut-out in the building, as can be seen in the sketches below. If the storage unit is a sump, the common pipe is connected to the tank through appropriate piping.

Sketch 7.1

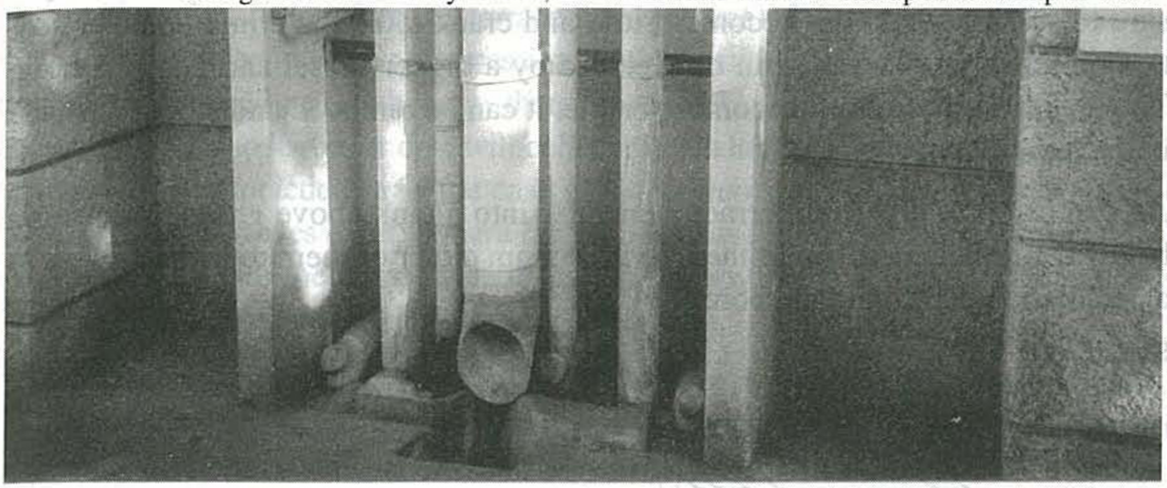


Connecting the Downtake Pipes to a Sump

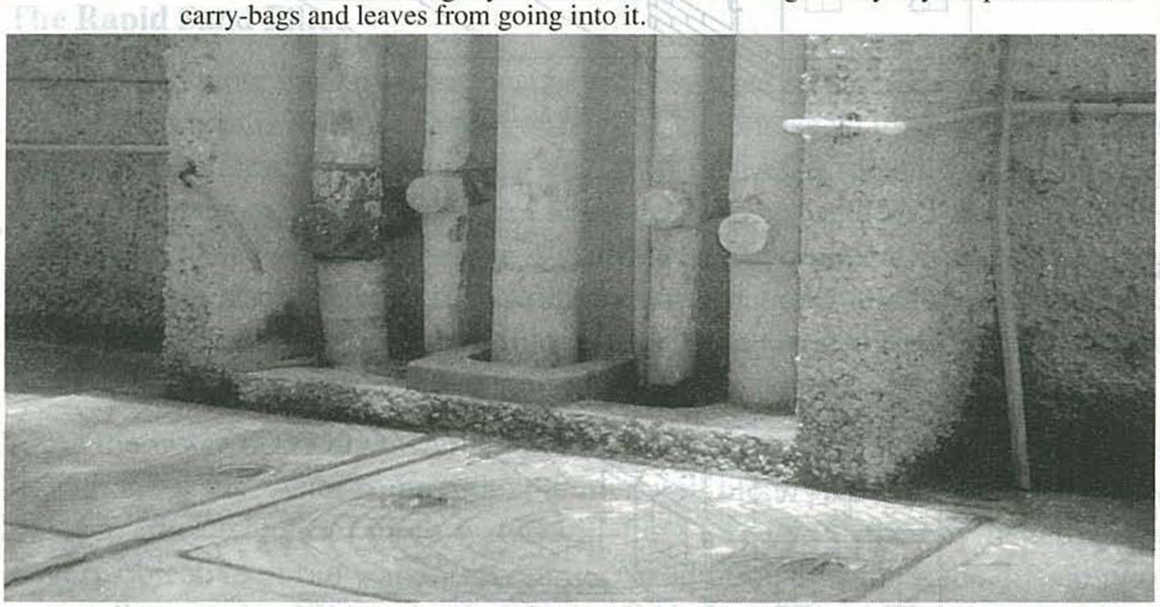
For apartment complexes, the rainwater will necessarily have to be diverted to an underground sump. If the area between the terminal point of the down-take pipes and the sump is not traversed by the residents or by vehicles, the piping can be laid above ground. If, however, it crosses a pathway with either pedestrian or vehicular movement above it, the piping necessarily has to be laid below the ground level using either stoneware pipes or PVC pipes· In fact, at the design stage itself, architects can fix the slopes of the terrace floors of buildings to be constructed in such a manner that as many rainwater down take pipes as possible from the terrace are located on the side where the sump or the dug well or the bore well is located. This would not only keep the length of the concealed piping to the minimum, but also enable the laying of the piping below the ground economically before the pathways are paved.

If the system is to be introduced in complexes already constructed where the open spaces around the buildings would have already been paved, one has no option but to dig the paved areas to lay the pipes and restore them again. The outlay for introducing the system increases because of this. But the resultant benefit in terms of the improved availability of water would be well worth the extra outlay.

Picture 7.1 The outermost two pipes in this picture carry the closet outflow and go direclty to the nearest man-hole chambers. The central pipe drains the terrace rainwater into a gully below connected to a sump or a well. The gully has no curbing. This is a defective design for two reasons: 1) Rainwater from the paved areas will also enter and reach the sump or well; 2) If the two adjoining gullies draining bathwater from adjacent flats get blocked for any reason, then bathwater will also end up in the sump or well



Picture 7.2 Here too, the two outermost pipes carry the closet outflow directly to the two manhole chambers seen in front of them. The rainwater gully here, as provided, does not allow any surface run-off of rainwater to come in. Note that the curbing of the rainwater gully here is higher than that of the bathwater gullies on either side. Therefore any overflow from the adjoining gullies will go on to the paved area and not to the sump or well. The rainwater gully should be covered during the dry days to prevent mud, carry-bags and leaves from going into it.

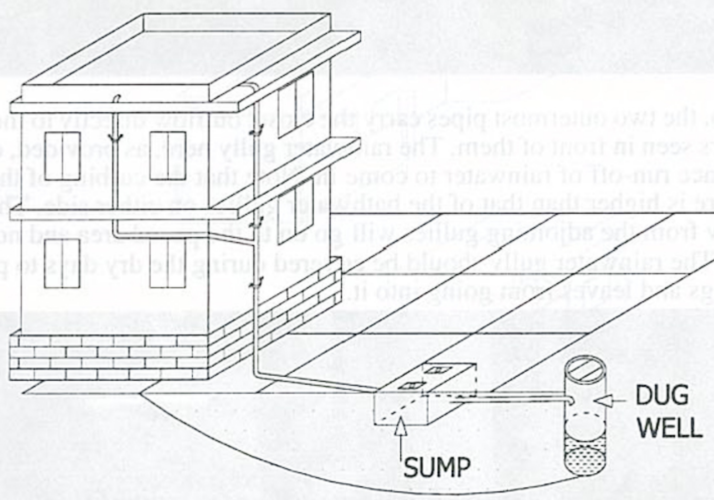


Direct connection of the downtake pipes to the sump assumes that the terrace will be maintained clean and free of leaves and carry-bags during the rains. If this be not the case then the downtake pipes can drain the rainwater into a gully which is connected to the sump. The different methods by which this can be done are shown in ~~Sketch 7.2 and Sketch 7.3~~ Pictures 7.1 and 7.2. Two other methods are shown in Pictures 12.5 (page -96), 12.6 and 12.7 (page -97). A simple ad-hoc method would be to utilise the mug and hose arrangement shown in Picture 12.8 in Chapter 12 for grey water treatment.

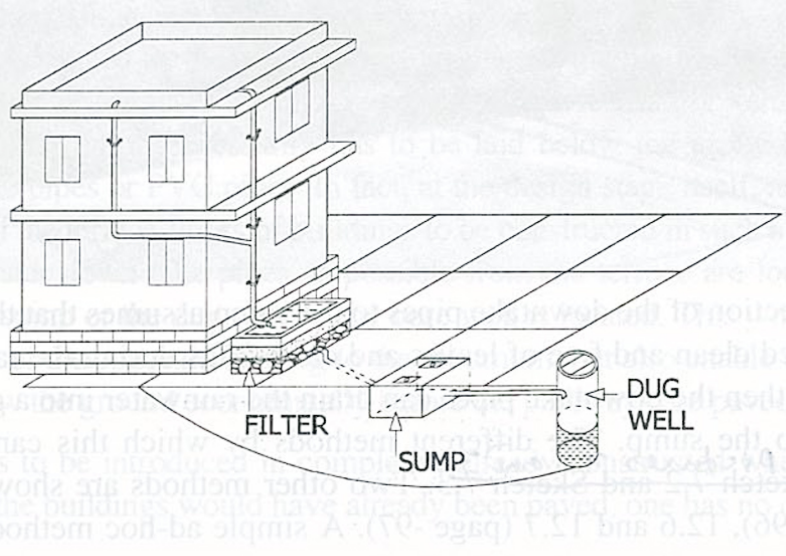
While this mug and hose arrangement is no doubt inexpensive, its disadvantage is that (a) it can be connected only to one terrace down take pipe. Multiple hoses will be required to connect multiple down take pipes; and (b) it needs some amount of human intervention unlike the other conveyance mechanisms which are self-operating; and c) the hose is subjected to hardening from continued exposure to sunlight and may become brittle and crack after sometime If the collection area is high, the mug can be replaced by a bigger vessel and a bigger hose. To prevent the hose from becoming brittle, it can be removed and stored in shade in the dry season.

An extension of diverting terrace rainwater into a tank above ground or a sump below the ground is to divert the overflow from either of them to a dug well or to a percolation pit around the bore well.

Sketch 7.2



Sketch 7.3



Is It Safe To Divert Rainwater From Terraces To Storage Tanks Or Sumps And Use It For Cooking And Drinking?

This is a question that is frequently raised by people wanting to harvest rainwater for meeting their cooking and drinking needs. The answer is 'Yes, it is safe ***if the roof or terrace is maintained clean***.' The sloped A.C./asbestos/tin-sheeted sloped roofs as well as the flat terraces of apartment complexes will have some fine dust on them. If there are any tall trees nearby, dry leaves may also be present. There should generally be nothing else. If therefore the terrace is swept free of dust and leaves before the rains, direct diversion from terraces into tanks would be quite safe. In the case of multi-storied buildings with more than four storeys, *even this cleaning would be unnecessary* as no leaves or dust will collect at such heights. Sweeping away the dust and leaves is impracticable in the case of sloped roofs, but sloped roofs would not normally retain leaves except where curved tiles have been used. Even if some dust and leaves go into the sump, they do not cause any harm as long as the water is boiled, cooled (and filtered) before being consumed.

While filters are often advocated on-line between the terrace and the storage, till now, no user-friendly designs for such filters have been presented by anyone. The filter generally recommended is a vertical filter (i.e. a filter where the water flows downwards).In this filter, there is a layer of pebbles or blue metal or brick-bats at the bottom and above this, there is either a layer of washed coarse sand alone or sand with an intermediate layer of charcoal (to remove any odour). Such a filter, called a 'rapid sand filter', is widely used in municipal water treatment plants.

The Rapid Sand Filter

It is common sense that any filter must be suitably sized so that it can handle the volume of water that is expected to pass through it. Unfortunately though, most of those who advocate filters simply propose a sand filter of size 2ft square and 2 to 3ft deep without any reference to the volume of water that is to be handled. The filter with the dimensions given in the figure above is stated to handle between 5 and 8kL of water in an hour. It is also stated that such a filter removes not only turbidity and sediments but also 98% of the bacteria. Such a filter is widely used in municipal water treatment plants. However, it has several major disadvantages in domestic environments:

1. As the water flows downwards, the sandy layer traps the fine mud that comes with the water. After some time, the mud will block all the pores in the sandy layer, after which no more water will flow through it, thereby negating the very objective of rainwater harvesting. An additional factor is the difficulty of installing such a filter at a height in the case of diversion to tanks above ground.

2. In order to restore the effectiveness of the filter, the mud held in the sandy layer has to be removed In municipal water treatment plants, this is achieved by passing clean water through the filter in the reverse direction till the outflow water is clear and free of mud. As such a process is not feasible in

domestic environments, the sand has to be physically removed and washed with water to remove the fine mud and returned to the filter. Alternately, the clogged sand has to be discarded and replaced by fresh sand free of any mud. Neither route is convenient, particularly during periods of heavy rain, both in terms of effort and frequency, and therefore not user-friendly. The cleaning process becomes even more inconvenient if the water is being diverted to a tank above ground as the filter in such a case has to be compulsorily located at a level higher than that of the tank.

3. Besides, the filter has to be sized to handle the volume of rainwater expected to flow through it in an hour. This quantity can be approximately calculated by multiplying the total collection area (in sq.m.) by the maximum rainfall (in metres per hour) that may occur in the place concerned. The latter is termed the peak intensity of rainfall per hour and data on this for various towns are given below:

Table 7.1 Peak Intensity of Rainfall in Select Towns and Cities[1]
(Maximum rainfall recorded in 1 hr over a 10-year. period)

Sl. No.	Town/City	Peak Intensity	Sl. No.	Town/City	Peak Intensity
1	Agra	51 mm	14	Kolkata	66 mm
2	Agartala	76 mm	15	Kodaikanal	58 mm
3	Allahabad	50 mm	16	Lucknow	40 mm
4	Amritsar	63 mm	17	Mangalore	64 mm
5	Aurangabad	55 mm	18	New Delhi	48 mm
6	Bangalore	53 mm	19	Shillong	56 mm
7	Bhopal	75 mm	20	Guwahati	72 mm
8	Bhuj	48 mm	21	Hyderabad	47 mm
9	Chennai	65 mm	22	Indore	62 mm
10	Dehradun	93 mm	23	Jaipur	50 mm
11	Jabalpur	69 mm	24	Tiruchi	70 mm
12	Jodhpur	40 mm	25	Tiruvanandapuram	69 mm
13	Jamshedpur	66 mm	26	Vishakapatnam	65 mm

1. Watershed Management – Guidelines for Indian Conditions, E.M.Tideman, Omega Scientific Publishers, New Delhi, 1996.

The peak intensity of rainfall for Chennai, for instance, is 65 mm/hr over a period of ten years. This means that one can expect a maximum rainfall of 65 mm or 0.065 metres over an hour at least once in a ten-year period.

If the terrace collection area in a particular premises in Chennai is, say 100sq m., the volume of rainwater that has to be filtered is 100 x .065 cu.metres or 6.5 kL. This would require a filter area of at least 1 sq.m. Alternatively stated, every 100 sq.units of terrace area in Chennai would need 1 sq.unit of filter area. This is a pretty low ratio. Even for a 4-storey apartment complex of say 8 flats of 1125 sq ft each, the terrace area would be about 2250 sq ft, which would need a filter area of 22.5 sq.ft. (about 6 ft long and 4 ft wide. This kind of space may not be readily available in apartment complexes above ground and besides, as stated above, its maintenance will be very cumbersome, particularly during the rainy season when it will become particularly necessary.

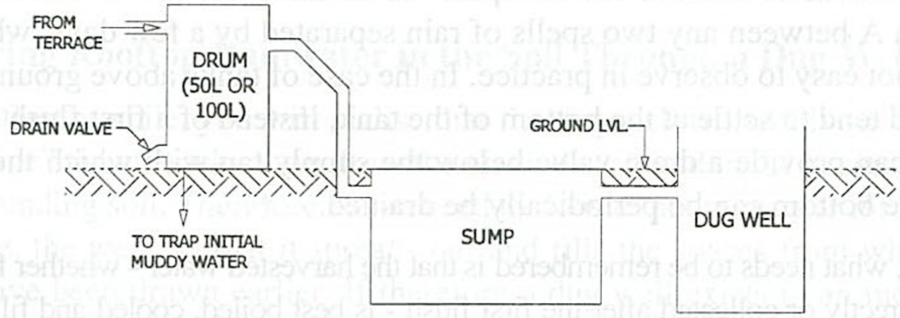
4) The other serious implication is that, if the filter is laid below the ground, the outlet line from this filter has to be laid at the bottom of the filter. This results in a sharp increase in the depth at which the subsequent stretch of concealed piping has to be laid. This in turn necessitates considerable increase in the excavation of the earth needed to lay the piping. The overall cost of installing the system thereby shoots up. *Worse still, if the piping terminates into a sump, the inlet into the sump* will be at only a small height from the bottom and therefore the quantity of water that can be *collected will be reduced steeply*[20].

A Simpler Alternative – The First Flush Arrangement

A simpler and much more user -friendly means of preventing the fine mud from getting into the tank or the sump is to install on line what is called a "First Flush Arrangement" (Figure below).

Type 1

Sketch 7.4 First Flush Arrangement : Type 1



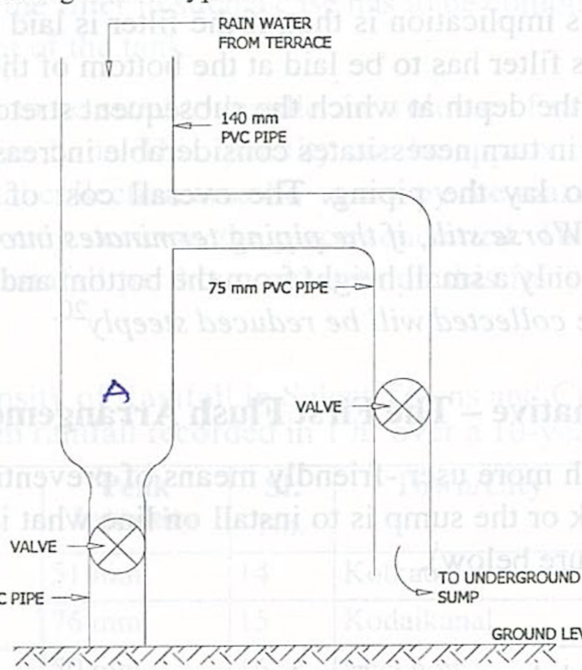
A small drum of, say 50 or 100 litres capacity, is kept in the pipeline between the terrace and the sump. The initial flow of water carrying the mud and leaves will fall into the drum. Only when the drum is full, the rainwater will flow into the sump. By the time the drum is full, all the mud and leaves would have been washed out from the terrace and so only clean water will flow into the sump. Although the leaves will also be prevented from going into the sump, it is better to sweep the terrace free of leaves before the rains so that the leaves do not come even into the drum. The drum can then be drained periodically to remove the mud that would have settled in it and the leaves removed.

20. The author will be happy to receive designs of any user friendly filters for inclusion in future editions of this book.

Type 2

In such an arrangement, the rainwater in the first few seconds of rain fills up the portion A and only thereafter flows via the branch into the sump. This water filling up the portion A would have carried most of the mud from the terrace. The water that thereafter flows into the tank or sump will be free of mud.

Sketch 7.5 First Flush Arrangement : Type 2



However, one must observe the discipline of draining off the water retained in the portion A between any two spells of rain separated by a few days, which discipline is not easy to observe in practice. In the case of tanks above ground, as the mud would tend to settle at the bottom of the tank, instead of a first flush arrangement one can provide a drain valve below the supply tap with which the muddy water at the bottom can be periodically be drained.

In any case, what needs to be remembered is that the harvested water - whether filtered or collected directly or collected after the first flush - is best boiled, cooled and filtered and then only drunk. Sterilising it using commercially available water filters or purifiers can also be done, provided these have been well maintained (~~see note on "In the front half of the garden in this longish plot, Canna plants clean up the grey water. In the rear half, other garden plants are flourishing. The level of the soil is about a foot below the driveway because the grey water flows from a distance of about 20ft across the driveway by gravity. Note how the treatment bed blends harmoniouly with the rest of the garden plants.." on page -110). Incidentally, some people prefer to fix grills at the~~ outlet points for the water on the terrace to prevent leaves and plastic carry bags from getting into the down take pipes. While this is well intended, if the terrace is not cleared of leaves and carry bags before the monsoon sets in, these leaves and particularly carry bags could block the grills causing stagnation of rainwater on the terrace. It is therefore important to sweep the terrace clean before the monsoon, irrespective of whether grills are provided or not.

2: Storing Rooftop Rainwater in the Sub-soil

We noted earlier that the simple principle in RWH is to catch rainwater wherever and whenever it falls and divert it into an appropriate storage. We can now look at the second simple principle of RWH that is derived from this first one: **Any water storage unit that supplies us with water is equally capable of receiving and storing water**. Thus a tank or a sump which when filled with rainwater supplies us with water can also receive and store rainwater when it is partly or fully empty. However, the disadvantage in using a tank or sump for storing rainwater is that when there is a good spell of rain, the tank or the sump will get filled very quickly. And once it is full, the rest of the rainwater will be lost. And when the tank or sump is empty again, rainfall may not occur. Building large storages above or below the ground is not practicable because the cost of constructing them is quite high and more critically, the space to accommodate them is not available in most cases. Therefore one has to look for a storage that is both inexpensive and has a huge capacity. Luckily in most places we do have such a storage. This is the soil below us. We had noted earlier (pages 25 and 29) that sub-soils that are reasonably sandy or composed of loose rock, or hard rock with large fissures could hold large quantities of water. All that we need to do therefore is divert the rainwater to these favourable layers. In the case of a sump or a tank, we draw the water through a pipe or a 'conduit' and fill them up also using a pipe. In the same manner, we have two types of 'conduits' that can take harvested rainwater to these layers and also enable the water to be drawn from these layers: (1) The dug well and (2) The bore well! The techniques for utilising these two "conduits" are described below:

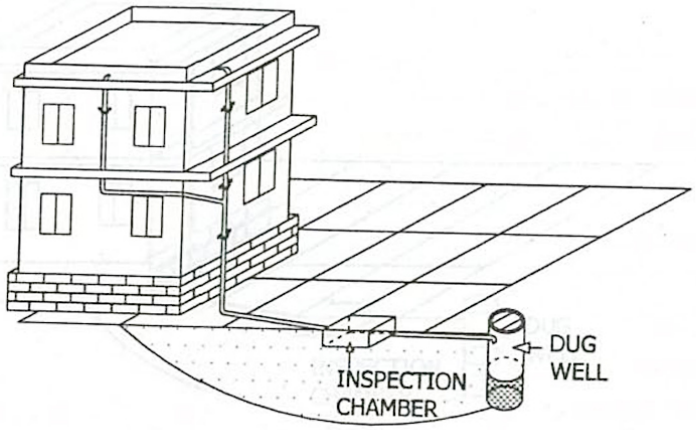
2A:Storing Rooftop Rainwater in the Soil Through a Dug Well

If you reflect a while, you will realise that the dug well is literally the "conduit" or the "pipe" through which we draw the water distributed in the porous spaces in the surrounding soil. Therefore all we need to do is to put rainwater into the same "pipe" i.e. the well, so that it spreads out and fills the spaces from which water would have been drawn earlier. If therefore a dug well exists in an independent house or an apartment complex, one simply connects all or as many of the terrace down take pipes as possible *directly* to the well.

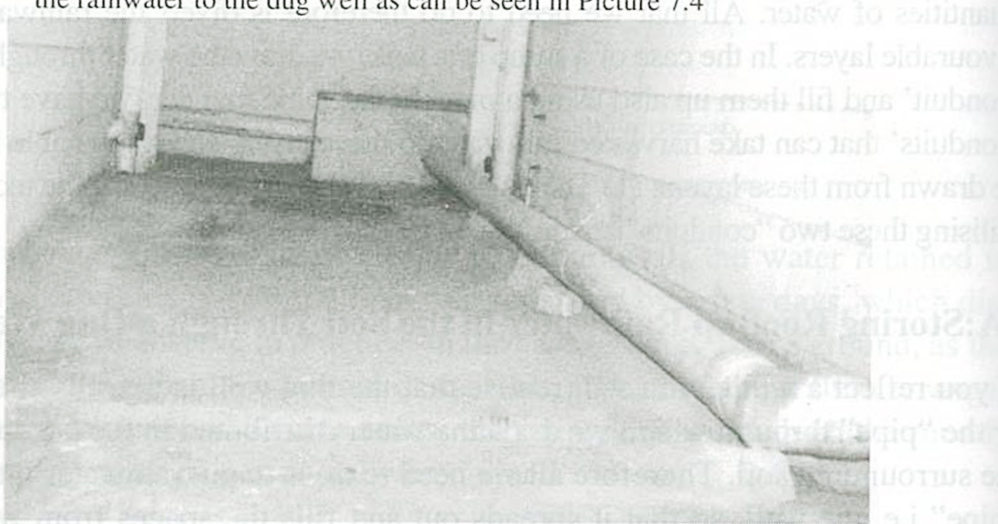
Such a connection can be made through PVC pipes either above ground or below ground or through stoneware piping below ground or through the mug and hose arrangement mentioned earlier. A cemented channel can also be provided for this purpose. If the distance between the building and the well is more than 40ft, an inspection chamber should be preferably introduced in this line as in Sketch 7.6.

If no dug well exists in the premises and the soil at shallow depths is reasonably favourable for storing water, it will be well worth providing a dug well specifically for the purpose of receiving rainwater. The cost incurred for this will be recovered in terms of the good quality water that will be obtained from it. In cases where it is feasible or advantageous, one can connect one or more terrace down take pipes to an above ground tank or a sump below ground and the overflow from this can be connected to the dug well.

Sketch 7.6



Picture 7.3 Two downtake pipes (hidden in the photograph) come from the two corners of the cut-out, join together in the small inspection pit. One single pipe from this pit takes the rainwater to the dug well as can be seen in Picture 7.4



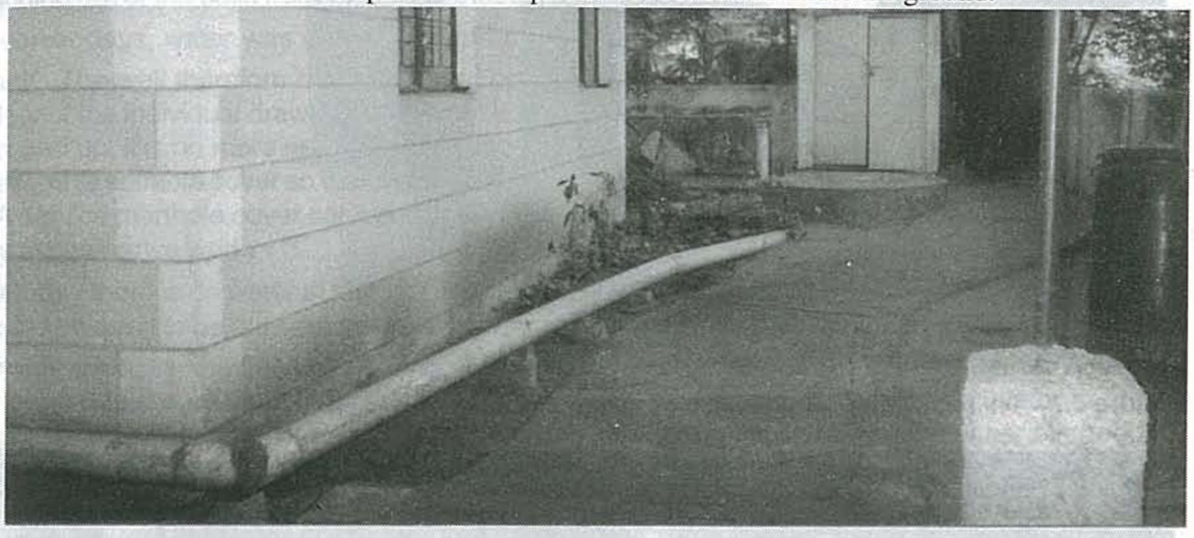
The advantages in utilising the dug well to charge rainwater in the subsoil are:-

1. As it has a greater area of the surrounding soil exposed for water infiltration both at the bottom and on the sides, the rate at which it can receive water is much higher than that in a bore well.
2. During heavy rain spells, the water level in the well will rise. The resultant hydraulic pressure of the water column will further increase the rate at which the water is pushed into the soil.
3. Water at shallow depths will generally be free of salts and so water charged into shallow depths will not pick up any salts from the soil and therefore the quality of the harvested water drawn from the dug well will be good.
4. Pumping water from shallow depths can be done using electrical motors of smaller horse power and so one's electricity bills will be less.

The sizing of a dug well's diameter would depend on the quantum of rainwater put into it as well as on the quantum of water drawn from it regularly. However there is no ready mathematical formula available for doing this.

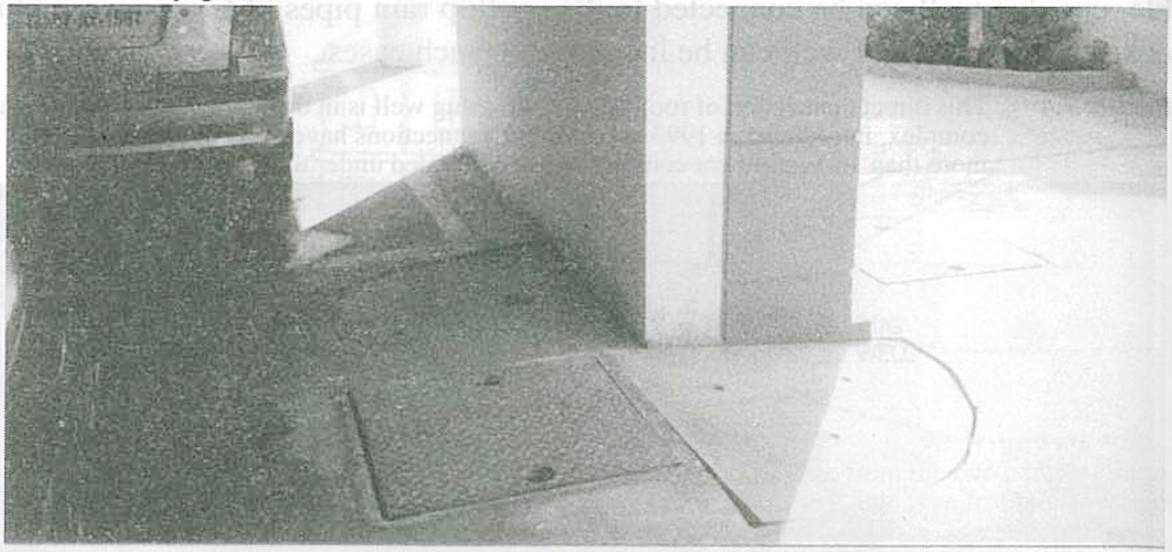
In apartment complexes where there are multiple blocks, if the strata are favourable, one dug well can be connected to the rooftop rain pipes of two or more blocoks. The diameter of well can be increased in such cases.

Picture 7.4 This direct connection of rooftop pipes to a dug well is in the author's own apartment complex, introduced in 1993. Such direct connections have thereafter been made in more than 150 apartment complexes but concealed under the ground.

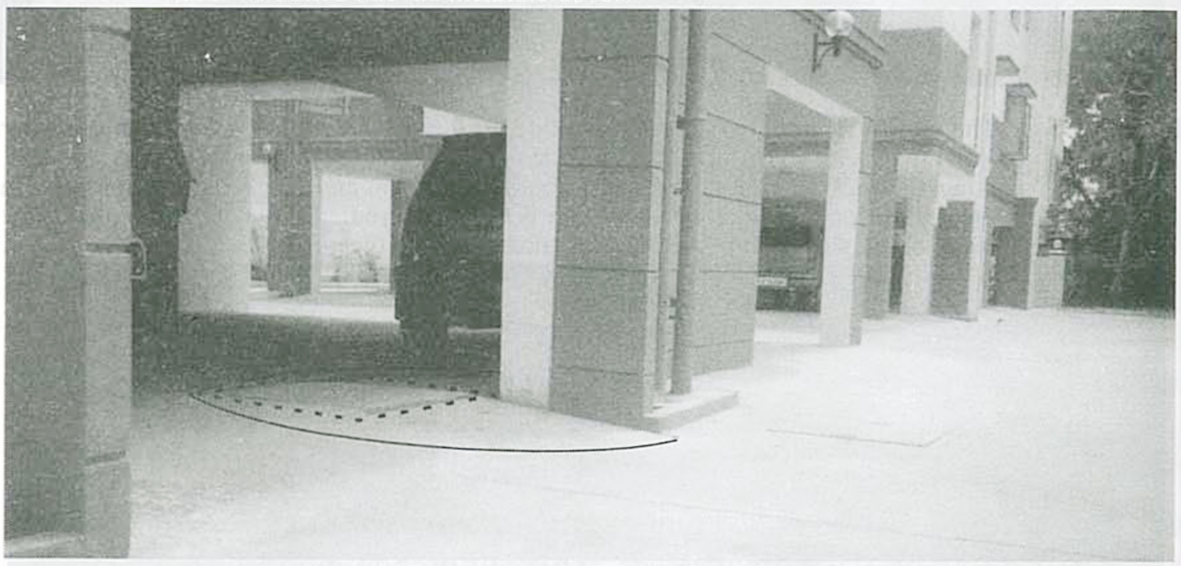


Picture 7.5 The rainwater pipe is given a bend inside the dug well (as seen) so that the rainwater flowing in with some force hits the side of the well, loses its momentum and flows down the wall, without disturbing the water column in the well. This acquires value in the dry season when the water column is less and turbulence may result in muddy water being pumped up. All these pictures are from the author's own colony.

Picture 7.6 Below the circular section with a manhole cover is a dug well. This well existed in the plot orginally but fell within the building line when an apartment complex was to be contructed on the plot. Since the ground floor area in the complex was exclusively for covered car parking, the well was retained by slightly modifying the sturctural design. All the roof-top rainwater pipes have been connected to it, The integrated water management system introduced in this complex is depicted in Sketch 12.5 on page -109



Picture 7.7 Another view of the dug well inside the building. The solid line demarcates the well and the dotted line the manhole cover.



THE DUG WELL: OUR INSURANCE FOR THE FUTURE:

When we tap water from depths of 200, 400 and 600 ft through bore wells, we are actually mining water – water which was formed and stored at those depths over centuries and millennia; a stock of water which like coal or petroleum is non-renewable and exhaustible. If we go on mining it, this stock will dry up one day, as the rain from the hydrological cycle does not percolate to these depths. Besides water from deeper levels is often much more brackish than that drawn from shallow depths. This is because the soil at deeper levels contains salts that come out with the water in the dissolved state. On the contrary, the water drawn from shallow depths is invariably of good quality. The reason for this is that the rain from the hydrological cycle percolates to these shallow depths and takes away salts from the soil when it is drawn for use. This cycle of rainwater percolating in and being drawn for use over long years, would have resulted in the leaching out of the salts from the soil at these depths.

When we tap water from depths of 200, 400 and 600 ft through bore wells, we are actually mining water – water which was formed and stored at those depths over centuries and millennia; a stock of water which like coal or petroleum is non-renewable and exhaustible. If we go on mining it, this stock will dry up one day, as the rain from the hydrological cycle does not percolate to these depths. Besides water from deeper levels is often much more brackish than that drawn from shallow depths. This is because the soil at deeper levels contains salts that come out with the water in the dissolved state. On the contrary, the water drawn from shallow depths is invariably of good quality. The reason for this is that the rain from the hydrological cycle percolates to these shallow depths and takes away salts from the soil when it is drawn for use. This cycle of rainwater percolating in and being drawn for use over long years, would have resulted in the leaching out of the salts from the soil at these depths.

In earlier days, water was drawn by hand from dug wells with a wheel and a pulley arrangement[1]. The well therefore had to be kept open. A parapet wall was provided around it for the safety of the individual drawing water from it. Since water in urban areas is nowadays invariably pumped up, it is no more necessary to keep the well open. It can be closed at the ground level itself with a suitable cover so that there can be smooth pedestrian and vehicular movement over it. A service manhole cover can be included in the RCC cover for inspection of the interior or for any maintenance work.

But today there is no water at shallow depths in most places. Nevertheless the shallow dug well should be seen to be our best insurance for water in the future for the following reasons:

1. In many places, the deeper soil layer from which the bore well is drawing the water will not be connected to the shallow level soil layer to which the dug well is connected i.e. water in the upper layer cannot go down and reach the lower (deeper) layer. In such cases, there is good scope for the harvested rainwater to fill up the shallow layer quickly and one would not have to wait for years for drawing water from the dug well. In the interim period, one can continue to draw water from the deeper layer through the bore well.

2. In case the upper and lower layers are connected, and the dug well and the bore well are both drawing their supplies from the same aquifer but the water table is below the bottom of the dug well, here also the large volumes of water harvested by the dug well during the rains would reach the water table which is feeding the bore well But, even after good rains, the well may still be dry. This is not a negative sign as the dug well has acted as a conduit and efficiently passed all the water it has received to the lower levels of the soil from which the bore well is drawing the water. In effect, the shallow well would be sustaining the bore well actively.

These thoughts may appear highly unrealistic in a situation where the traditional dug well has practically become extinct in our towns and cities. But in many apartment complexes in Chennai where the dug well had been made a key component of the RWH system, it has proved to be a substantial source of good quality water. It has proved particularly useful in coastal areas that are sandy and therefore can store water at shallow depths as also in areas that have weathered rock at low depths. In the latter case, large diameter wells were provided which filled up substantially during the rains and provided quality water for a good part of the year, if not for the entire year.

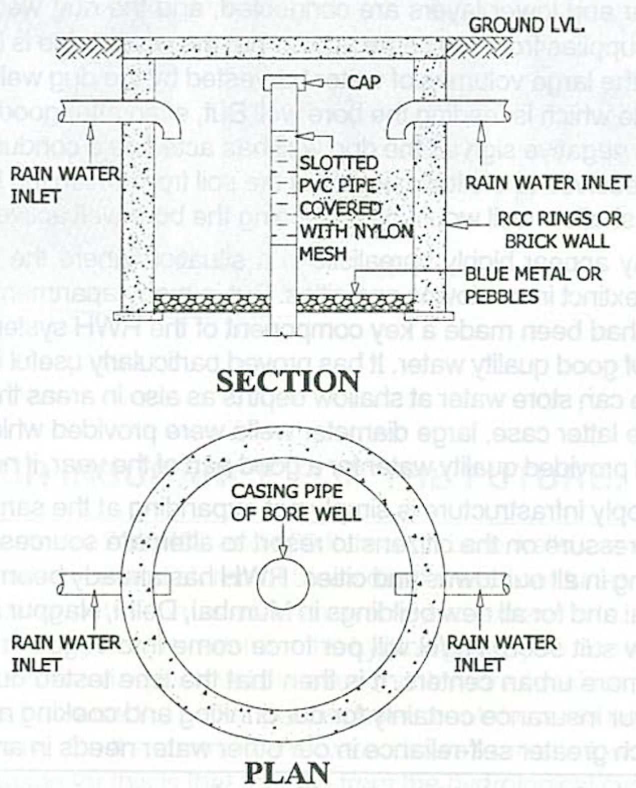
Municipal water supply infrastructure is simply not expanding at the same pace as the increase in population and pressure on the citizens to resort to alternate sources for their water needs is constantly increasing in all our towns and cities. RWH has already been made mandatory for all buildings in Chennai and for all new buildings in Mumbai, Delhi, Nagpur and Indore. More towns and cities will follow suit soon. RWH will per force come into vogue in entire neighbourhoods soon in more and more urban centers. It is then that the time tested dug well will come into its own and become our insurance certainly for our drinking and cooking needs in areas of scanty rain fall and for much greater self-reliance in our other water needs in areas of greater rainfall.

1. See "Water cycle in the good old days'" in Chapter I.

2B: Storing Roof-top Rainwater in the Soil Through a Bore Well:

The obvious method of charging the water table through a bore well may appear to be to extend the terrace down take pipe to reach the inside of the casing pipe of the bore well. This method can be adopted however only if the water is made free of mud and any other sediments in it i.e. only if there is an efficient filter in the pipeline from the terrace to the casing pipe (see section on filtration of rainwater on pages 49–50). Otherwise the mud and the sediments will accumulate at the bottom of the bore well and affect its yield. A technique that has worked quite satisfactorily and avoids this risk is to dig a circular pit around the bore well say 4 ft in diameter and about 6 ft in depth and line it with bricks or R.C.C. rings. Pebbles or blue metal is spread on the bottom for an inch or two. Horizontal slits are made in the PVC casing pipe[21] of the bore well with a hacksaw blade from 1 ft above the bottom of the pit to about 4 or 5 ft and this portion is covered with a nylon mesh cloth and tied with copper wire and polythene thread. Alternately this stretch of the plain pipe can be replaced by a machine-slotted pipe that is then covered by the nylon mesh. Machine slotted pipes usually have slots of 1mm width. They can be converted into slots of 2mm width using a double blades in a hacksaw or using a cutting saw used for cutting mosaic tiles. The pipe suppliers can also be asked to provide slots of 2mm width. Similarly 2mm wide slots can be provided on site on plain pipes by putting two blades in a hack saw. By doing this, the area available for water entry is increased.

Sketch 7.7 Charging a borewell with rain water: The casing pipe of the bore well should normally be in the centre of the pit as servicing it is simpler thereby. But if this is not possible for any reason, it can also be located off-centre without any loss of absorption efficiency.



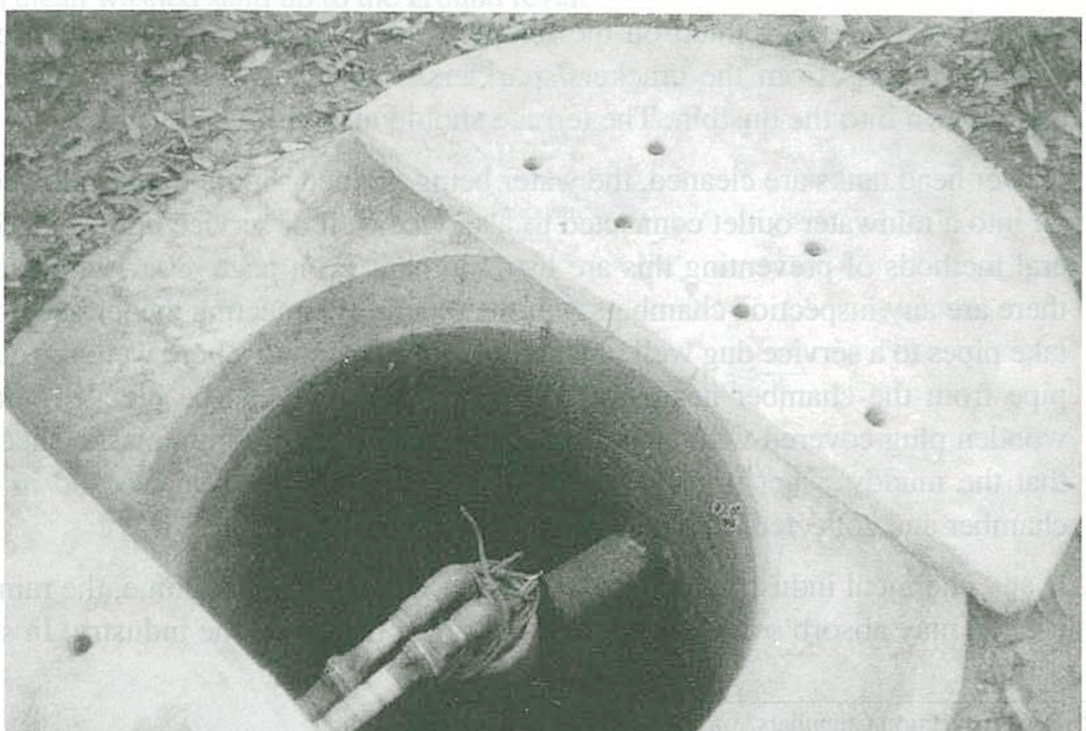
21. Old bore well pipes are often made of steel. In this case, holes will need to be drilled in the metal pipe

The pit is covered with a heavy duty R.C.C. slab with an inspection manhole cover to enable smooth vehicular traffic above ground. **The bore well casing pipe need not necessarily be at the centre of the pit.** The terrace down-take pipes are then connected to the pit (See Picture 7.9).

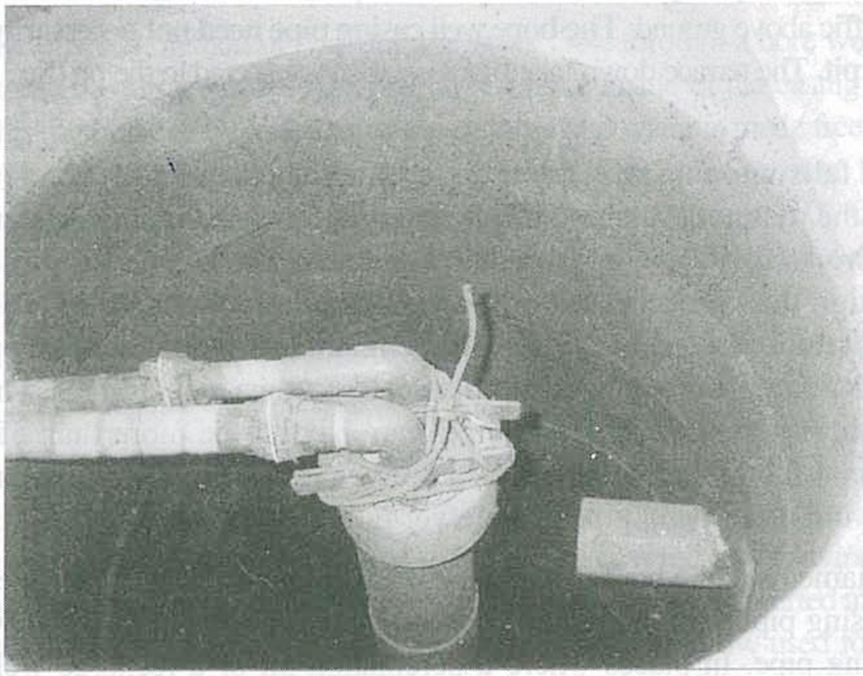
The rainwater that falls into this pit rises up in level, enters the casing pipe of the bore well through the nylon mesh and the slits, and goes to the bottom of the pipe from where the bore well is drawing its water. As the area available for infiltration of water through the slits of the bore pipe into the bore well is limited, the rate at which this system can receive water will be much less than that of an open well. Therefore, if a large terrace area is connected to this pit, in areas where heavy rainfall in short periods is likely, the pit may have to be more than 6ft.in depth or wider than 4 ft., so that it can act as a buffer tank that holds more water which can then go into the casing pipe at a slower rate.

Additionally, the diametre of the bore well can be made larger so that a larger area is available on the casing pipe for making the slits and increasing the rate of inflow of water into the casing pipe. In places where a percolation pit or a recharge well is located nearby, this can be connected to the pit around the bore well through an overflow line, so that what does not get charged into the bore well will go into the soil through them. The blue metal or brick-bats at the bottom of the pit absorb the momentum of the water falling from a height and prevent the mud at the bottom being disturbed and clogging the nylon mesh. Notwithstanding this, the nylon mesh may still get clogged with the mud coming along with the rainwater. The mesh may then have to be hosed down with water. If mud accumulates at the bottom of the pit over a period, this may have to be physically removed.

Picture 7.8 Figures 7.8 and 7.9 show a 4ft percolation pit around a service bore well.



Picture 7.9



SOME GENERAL PRECAUTIONS IN ROOFTOP RAINWATER HARVESTING

1. Sweep the terrace periodically free of leaves, paper, carry-bags etc., before the monsoon sets in.

2. If food is served on the terrace during any get together on the terrace, the food droppings on the terrace floor should be swept, collected and disposed of in the dustbin.

3. After fireworks are lighted on the terrace during Diwali or other such festivals, the debris from the crackers/sparklers/flower pots should be collected and thrown into the dustbin. The terrace should also be swept clean.

4. If over head tanks are cleaned, the water being drained should not be allowed to go into a rainwater outlet connected to a service well or service bore well. Several methods of preventing this are listed in para 7. on page -80. Alternately if there are any inspection chambers[22] in the pipeline connecting the terrace down take pipes to a service dug well or a percolation pit around a bore well, the outlet pipe from the chamber nearest to the down-take pipe can be blocked with a wooden plug covered with cloth or a cloth plug covered with a plastic sheet so that the muddy water drained from the overhead tank can be blocked in this chamber and collected. The plug can subsequently be removed.

5. If any chemical industries are located in the vicinity of your home, the rain, as it falls, may absorb some of the gases let off in the air by the industry. In such

22. See "Inspection Chambers" on page -68.

cases, before any RWH is done, the rainwater falling on the terrace should be collected and analysed thoroughly for its chemical constituents and acidity.

HARVESTING THE SURFACE RUN OFF

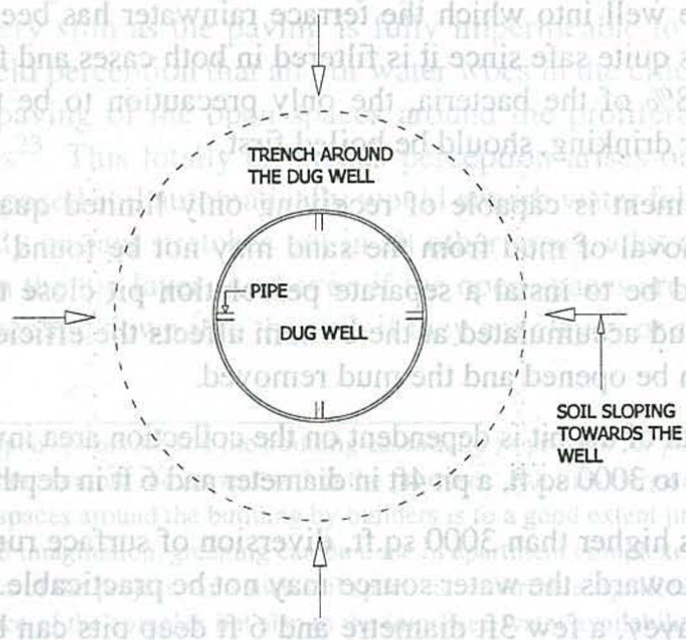
Harvesting the rainwater falling on the open spaces around the buildings is as important as roof top rainwater harvesting particularly in apartment complex in places like Chennai where the area of these open spaces is often double that of the terrace area. However, this water cannot be channelised directly into a service well as it might contain traces of grease or engine oil or cow dung or other extraneous matter. Therefore if this water is to be led into a service bore well or a service dug well, it needs to be filtered. The method of filtration would depend on the specific site conditions. Some typical situations are detailed below:-

1. An Independent House with space around it largely or fully unpaved

If the space around the building is largely or fully unpaved, and there is either a dug well or a bore well available, a gentle slope is provided in the soil so that water from all parts of the plot flows towards the dug well or the bore well.

If the water source is a dug well (dry or yielding), dig a trench around the retaining wall of the well to a width of 2 ft to 3 ft and a depth of 3 ft. At the bottom level of the trench, provide 3 or 4 holes in the retaining wall of the well. The holes should be distributed around the perimeter of the wall. Keep a jaali (grill) against each hole. Fill up a small stretch of the trench around the grill with pebbles or brick- bats or blue metal so that this layer covers the grill and is slightly higher than the hole. Fill up the trench with clean washed sand up to the ground level.

Sketch 7.8



When the rains come, the rainwater will flow to this trench, pass through the sand down to the bottom and flow into the well through the holes provided. The sand in the upper level will filter out any fine mud or oil or other sediments and only clean water will flow into the well. One can also keep the trench a few feet away from the wall of the well. In this case, one has to provide pipes from the bottom of the trench to the holes in the retaining wall. These pipes should project a few inches into the well through each hole. The ends of the pipes in the trench should be covered with pebbles or brickbats or blue metal.

In case the water source is a bore well, a circular percolation pit needs to be provided around the bore well with the exposed casing pipe being slotted (as described in the previous section). The size of the pit is dependent on the collection area. If the water flowing in to the pit is likely to carry significant quantities of mud, the pit is filled up with pebbles or blue metal up to the level where the slotted portion ends. Above this, a layer of 9" to 12" of clean washed sand is put. A gentle slope is provided towards this pit from all parts of the plot. The pit is covered with a light-weight slightly raised cover with grilled openings on the sides, adequate to take the load of people walking over it. In case the pit is located in a vehicular pathway, a heavy duty R.C.C. slab with holes on it is provided over the pit.

Over a period, the top most portion of the sand in the trench around the dug well or in the percolation pit which filters the water may get clogged by fine mud/grease/ waste oil and prevent rainwater from passing through. If this happens, this layer of sand has to be removed, washed clean and put back or replaced by a fresh layer of clean washed sand. The need for such replacement will be indicated either by a distinct change in the colour of the sand or by water- stagnation or both.

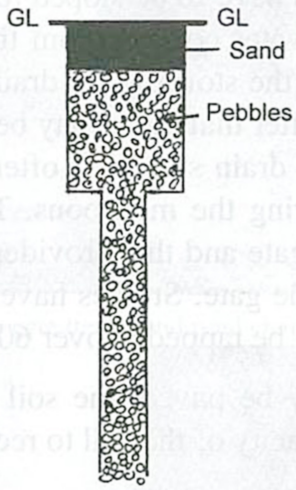
It may be doubted whether it is hygienic to divert surface run-off into the same dug well or bore well into which the terrace rainwater has been directly let in. Such diversion is quite safe since it is filtered in both cases and filtration through sand removes 98% of the bacteria, the only precaution to be taken is that the water, if used for drinking, should be boiled first.

Such an arrangement is capable of receiving only limited quantities of water. Besides, the removal of mud from the sand may not be found convenient. One alternative would be to instal a separate percolation pit close to the bore well. Whenever the mud accumulated at the bottom affects the efficient absorption of water, the pit can be opened and the mud removed.

The size and depth of the pit is dependent on the collection area involved. For a collection area of up to 3000 sq.ft, a pit 4ft in diameter and 6 ft in depth ought to suffice.

If the plot area is higher than 3000 sq.ft, diversion of surface run-off by giving a slope to the soil towards the water source may not be practicable. In such cases, if the soil is not clayey, a few 3ft diametre and 6 ft deep pits can be dug in places, away from the well/ bore well. These should be lined with rings and closed with covers having openings so that the rainwater around the pits gets absorbed in those pits. In clayey soils, one can have a few percolation holes reaching up to a reasonably sandy layer to absorb the rainwater. Open channels can also be provided wherever feasible to lead the rainwater to the trench around the well.

If any garbage dumps exist nearby or if there are chances of any sewage overflow in the area, such diversion of the surface run off into a pit around the service bore well is not advisable.



2. Houses and Apartment complexes where open spaces are largely paved

The Advantage of Paved Surfaces

Recently constructed houses as well as most apartment complexes tend to have a major part of the open spaces around the buildings paved to facilitate vehicular movement and parking. At first sight, it may appear that the scope for harvesting in these areas is very slim as the paving is fully impermeable to water. In fact, there is a widely held perception that all our water woes in the cities are the result of indiscriminate paving of the open spaces around the proliferating flat complexes in our cities[23]. This totally erroneous perception arises out of the naive assumption that exposed soil automatically would absorb water falling on it. This is true only in sandy coastal stretches but in all other areas, a lot depends on the nature of the soil in the top layer. And even if the open spaces are unpaved, very little water will percolate down into the soil, if they are clayey or silty.

23. Builders pave the open spaces around the building essentially to provide for parking of two and four wheelers and their smooth movement within the premises. But the charge of indiscriminate paving of the open spaces around the building by builders is to a good extent justified. With a little extra effort and imagination, greening can be done in apartment complexes without losing out on the economics of the project. And such soil space can contribute significantly to improving not only the ambience of the complex but also to the improved water availability through recycling of grey water. This aspect is dealt with in detail in Chapters 12 and 13.

In Chennai for instance, the top layer is clayey in most places and therefore highly unfavourable for water absorption. It is because of this that many areas of the city remain inundated for days on end after rains. On the other hand, paving of the open spaces around the buildings is actually very favourable for rainwater harvesting because:

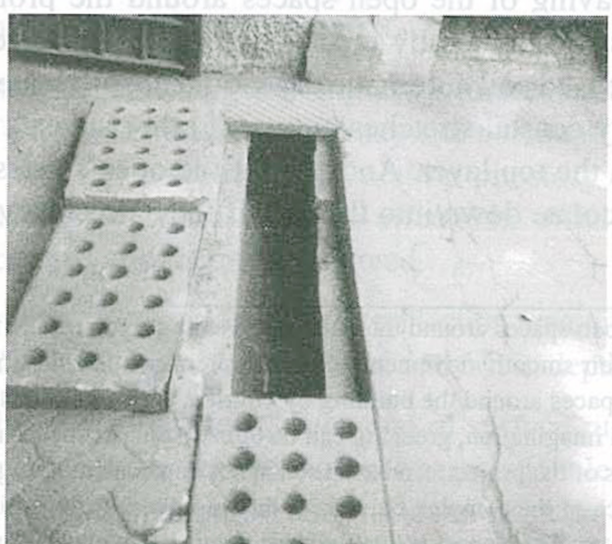
1. The National Building Code requires that the terrace rainwater pipes should not be connected to the internal sewage line but should terminate on the driveways. The driveways in turn have to be sloped towards the gate. The purpose behind this is that the rainwater coming from the terrace and falling on the open spaces will both reach the storm water drain on the road and be drained off thereby. It is another matter that there may be no storm water drain on the road or that the storm water drain system is often not in a sound state and so the roads get inundated during the monsoons. The fact remains that all the rainwater is brought to the gate and this provides excellent scope for tapping all the water efficiently at the gate. Studies have established that water flowing over a paved surface can be tapped at over 60-80% efficiencies.

2. While the top surfaces may be paved, the soil layers below remain undisturbed and therefore the capacity of the soil to receive and store large volumes of water remains intact.

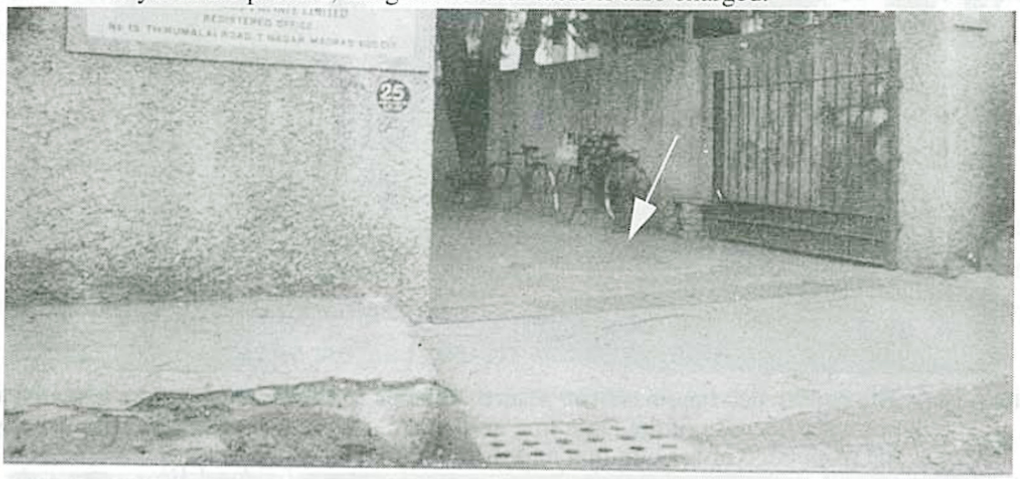
The Gate Trench

What is therefore required is an arrangement to tap all the rainwater flowing across the gate and put it into the soil. This arrangement is quite simple as can be seen from the Picture 7.9 (page -66) and the Picture 7.10 below: A shallow trench lined with bricks and cement of 1 ft width and 1ft depth finished dimensions is provided between the two gate columns. A gentle slope is provided at the bottom and from the lower end, a pipeline of stoneware or PVC is laid that connects it to a storage unit nearby.

Picture 7.10



Picture 7.11 The rainwater trapped by the gate trench shown in Picture 7.10 is put in the dug well seen just inside the gate (circular cover slab indicated by white arrow). The small chamber on the road edge is also connected to the same well. These pictures are from the author's colony. The chamber has been draining rainwater from the road during the monsoon and has eliminated the earlier inundation of the road that used to last for many days. In the process, the groundwater table is also charged.



Picture 7.12 Another view of the gate trench and road chamber

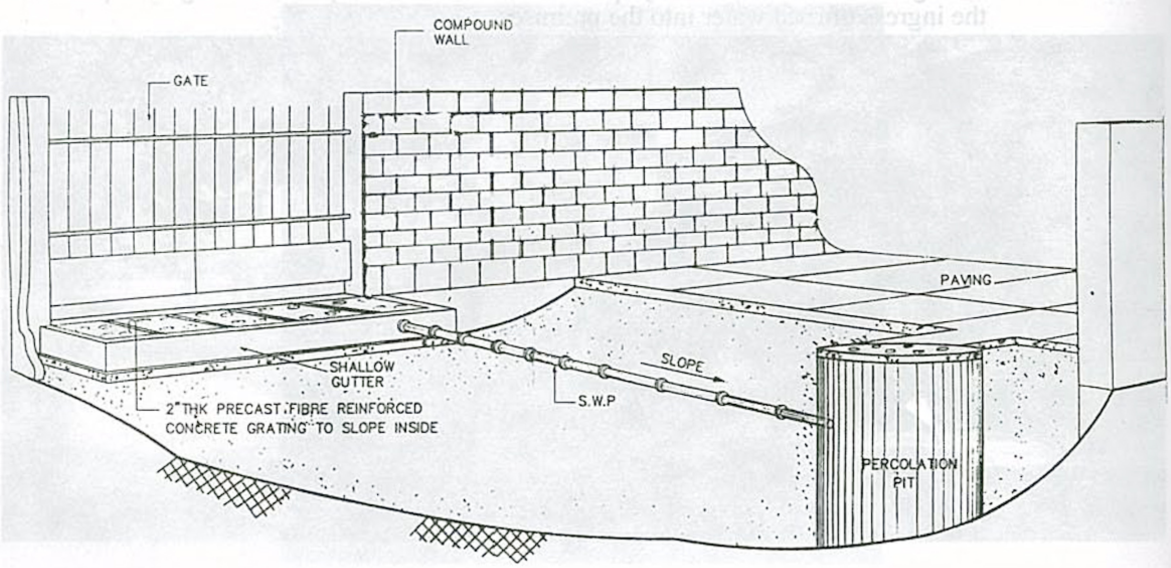
Picture 7.13 This is a complex of 48 flats in two blocks opposite each other. The trench has been located inside the premises, away from the gate and can be seen just behind the car. It spans the stretch between the two blocks. This has been done because the road level is slightly higher and road rainwater mixed with sewage tended to enter the premises during monsoon. Additionally speed breakers were also put near the gate to prevent the ingress of road water into the premises.

Picture 7.14 The arrow indicates position of the speed breaker

Picture 7.15 The gate trench here has been placed at about 15ft distance from the gate inside the premises because of the large tree at the gate. The trench spans the stretch between the front edge of the building and the compund wall.

The storage can be (a) an old abandoned dug well (b) a newly dug dug-well (c) a percolation pit around an existing bore well or (d) a percolation pit that reaches down to a favourable sandy layer of the soil.

Sketch 7.9



In very clayey areas one may not reach a sandy layer at shallow depths. In such areas in order to ensure efficient absorption of water, one may have to put a bore pipe in the pit to reach a reasonably sandy or gravelly layer. The bore pipe should extend 4 to 5 ft above the bottom, slits made on the pipe and covered with nylon mesh. A layer of brick bats or blue metal is to be laid on the bottom of the pit to absorb the momentum of the water falling into it and thereby prevent the soil at the bottom being disturbed. *The top of the casing pipe of the bore needs to be covered by a tight fitting cap.*

A typical design for harvesting both the roof-top rainwater and the surface run-off is illustrated in Sketch 7.10 on the next page. In this both the gate trenches are connected to one dug well/percolation pit. In large apartment complexes with multiple blocks, the volume of the surface run-off would be substantial. Therefore, it maybe advisable to connect each gate trench to a separate dug well or percolation pit. Alternately, a dug well of large diameter or greater depth whose ability to recieve and absorb water will be higher can be provided. A second trench can also be provided saome distance away from the gate and connected to the well.

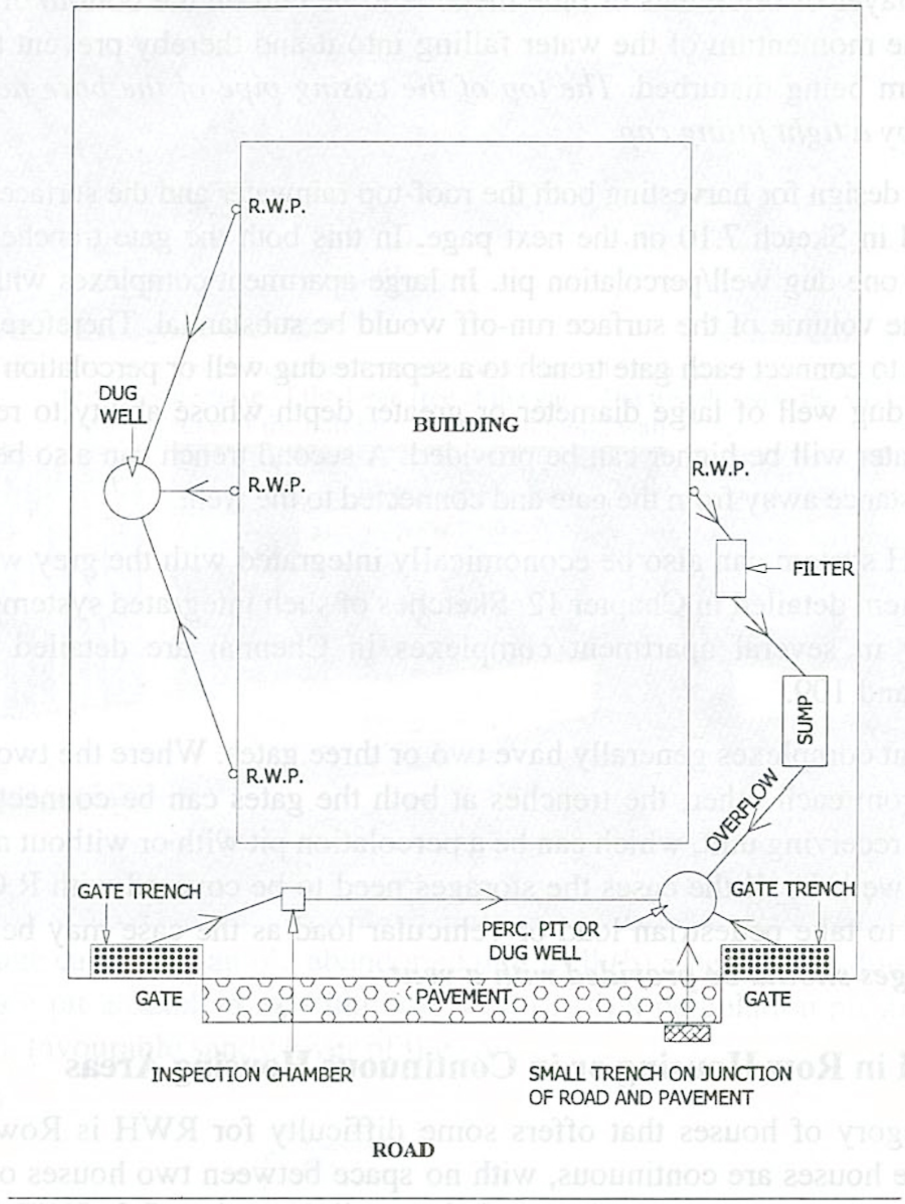
The RWH system can also be economically integrated with the grey water recycling system detailed in Chapter 12. Sketches of such integrated systems working smoothly in several apartment complexes in Chennai are detailed on pages 106,108 and 109.

Apartment complexes generally have two or three gates. Where the two gates are not far from each other, the trenches at both the gates can be connected to one common receiving unit, which can be a percolation pit with or without a bore in it or a dug well. In all the cases the storages need to be covered with R.C.C. slabs adequate to take pedestrian load or vehicular load as the case may be. ***None of the storages should be provided with a vent.***

3: RWH in Row Housing or in Continuous Housing Areas

One category of houses that offers some difficulty for RWH is Row Housing where the houses are continuous, with no space between two houses or with the open space between any two houses being as little as 4 or 5 ft. In such housing areas if there are open courtyards as depicted in Picture 6.1 on page -37 then a small percolation pit or 3 ft dia dug well can be provided or a percolation pit with a bore inside it as described ~~on Page 60~~ above can be provided. If between two houses, at least 5 ft space is available, a series of shallow bores can be dug and at the top, small pits 2 ft square and 3 ft deep, can be provided around each bore and the pits filled up with sand. Often, very old dug wells exist in such houses and efforts can be made to connect roof top pipes to this well so that the water can be absorbed at a rapid rate and drawn for use directly later. A first flush arrangement will have to be necessarily provided where the roofs are tiled with semi-circular tiles placed one over the other, as insects tend to be present in such tiled roofs. If there is a well in the open courtyard of one house but not in the neighbouring houses, one can connect the roof top pipes from the neighbouring houses to this well wherever feasible, as the water charged into the well will benefit both houses.

Sketch 7.10



Inspection Chambers

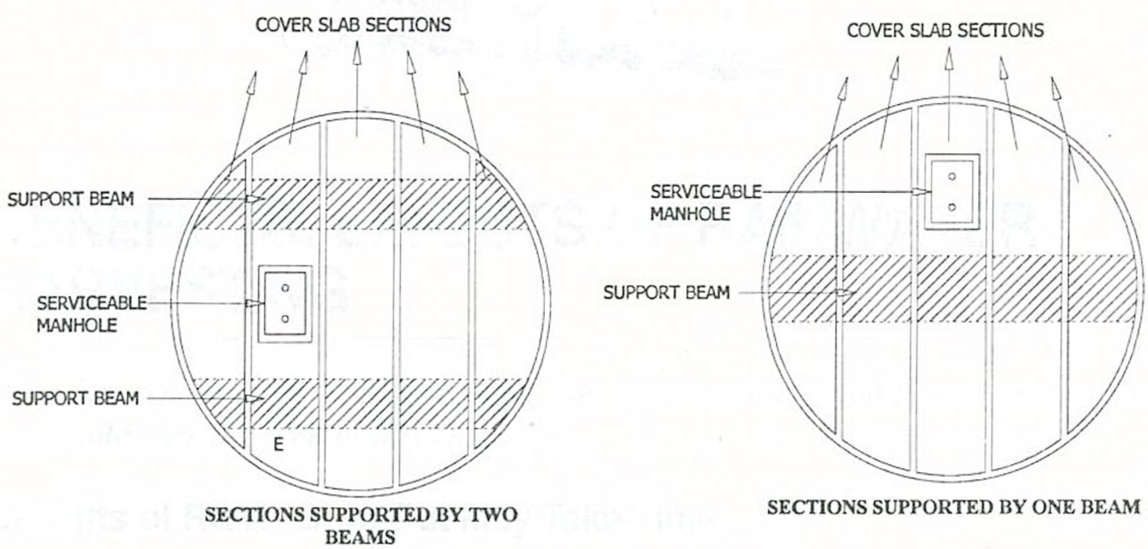
In connecting a series of terrace down take pipes or in connecting the gate trenches from two or more gates, the direction of water flow will change. Wherever such change of direction takes place in concealed pipelines it is advisable to provide inspection chambers (2 ft wide and 2 to 3ft long) made of bricks and cement plaster, to avoid resistance to smooth flow of water in the desired direction. Even, where the pipeline is straight but is an extended one, it would be advisable to provide such inspection chambers at intervals of 40 ft. These can be covered with light duty or heavy duty RCC. covers depending on the nature of the load it will be taking. Apart from facilitating smooth flow of water such chambers also enable clearing of any blockage in the concealed pipes. The depths of these chambers would depend on the depth at which the concealed pipeline is at that point.

Pipe Sizes

Pipe sizes to be used have not been specified as this would depend on both the intensity of rainfall and the catchment area feeding the pipeline. In connecting a series of water outlets, it is advisable to use either stoneware piping of 4" or 6" diameter or 110mm piping. For single pipe or two pipe connections, 75 mm PVC piping ought to suffice generally.

Covers for Dug Wells and Percolation Pits

Sketch 7.11 Plans of HeavyDuty Cover Slab of a Percolation pit or Dug well with Multiple Sections



The cover of a percolation pit or a dug well has to be designed according to the load it is likely to take. If only pedestrian movement is going to take place above it, a light-weight ferro-cement or RCC cover is enough. If two wheelers are likely to move over it, it has to be strengthened accordingly. If four wheelers are going to move over it, then a heavy-duty RCC cover has to be provided. When heavy-duty covers are provided, they can be of two types: cast in single piece or cast in multiple sections. It is necessary that the cover be made up of multiple sections for pits of diametre more than 4ft, so that they are easily removed for any maintenance work such as desilting. When the cover is in multiple sections, it has to be supported below by either one single beam at the centre or two beams placed at equal distances from the centre. If two beams are provided, we can deepen the pit or the well in the future, if necessary, by introducing rings of smaller diametre. A single beam will not allow the rings to be inserted into the pit for such deepening. In either case, an inspection or service manhole cover has to be necessarily provided for inspection and servicing purposes, like replacing a broken suction pipe or to take the water level in a dug well.

Vents

No vents should be provided for any of the dug wells or percolation pits as these will only contribute to the breeding of mosquitoes.

CHAPTER 8

BENEFICIAL EFFECTS OF RAINWATER HARVESTING

(The concrete benefits accruing from the introduction of RWH systems in our households are detailed in this chapter)

Benefits of RWH –Sure But May Take Time

If you sow some coriander seeds, you will get coriander leaves for your cooking needs within a few weeks. But the leaves get exhausted soon and you will have to sow seeds afresh periodically to maintain continuity of supply. If you sow chilli seeds, you will have to wait for a few months before you can harvest the first crop of chillies. Unlike in the case of coriander, you will get several crops of chillies before the plant dries up. For the next season, you will have to sow the seeds again. But if you sow mango kernels, you will have to wait for a number of years before you can harvest the first crop of mangoes. (If you had planted a grafted seedling, you can of course reap the first harvest earlier.) But once you start getting the fruit, you will, in both cases, continue to get them again and again for years

The situation in respect of RWH is similar in many respects.

Let us say you have connected the terrace rainwater down-take pipes to a tank above ground or a sump below ground, just before the onset of the monsoon. You will get the harvested rainwater in your tank or sump after the very first rains!

But the quantity available will be limited by the capacity of the tank or sump. Once it is empty, you will have to wait for the next spell of rain for getting a fresh supply of water. Let us say you have not merely connected the terrace pipes to the sump or tank but also connected the overflow to a dug well or a pit around a bore well. Then you will be collecting much more water into the soil. And if you have taken the initiative to harvest the surface run-off also, the water put into the soil will be even more.

But how soon you will be able to draw this water from the soil will depend on the water table in your locality and the nature of your water source. The water table in different parts of the same town could be at different depths. Let us consider the case of four individuals A, B, C and D., of whom A, B and C all have a dug well of 25 ft depth in their premises whereas D has a tube well of 40 ft depth.. The water table in A's locality is at 20 ft, in B's locality at 27 ft and in C's and D's locality at 30 ft. Assume that the same amount of rainfall occurred over all parts of the town. The dug well in A's premises which already had a water column will show a rise in the water level and A can pump out this water immediately. D too will be able to get the benefit as his tube well is at 40ft depth. B and C will have to wait till more rains come and the water table rises above 25 ft. Between B and C again, C may have to wait longer than B as the water table in his locality was lower. The fact remains that all of them will enjoy the benefits of their efforts sooner or later and these benefits will be accruing on a continuing basis.

Another aspect influencing the time factor is the pattern of rainfall in your town after you have installed your RWH system. The annual rainfall in any place is not the same every year. It may rain less in a particular year and more in the next. The harvestable quantity is calculated on the basis of the average annual rainfall in that place over a long period (25 or 50 or more years).

The annual rainfall in Chennai, for example, over the last 100 years shows variations but the statistical average works out to 125 cm. In some years, it is less than 100cm. This means that if in one or two years, the rainfall is less than this average then it will be made up by more than average rain in the subsequent years. Therefore, the positive impact of the RWH measures installed in Chennai will become evident quickly if the rain in the period immediately following the installation is bountiful. If not, the impact will take one or two more years to show up. The same reasoning will hold also for improvement in the quality of the ground water after introduction of rainwater harvesting systems.

Thus there is no doubt that properly designed RWH systems will yield results sooner or later. The author has been involved in the installation of RWH systems in over 200 apartment complexes of various sizes comprising over 4000 flats during their construction stage itself. Besides, in over 50 complexes that did not have any, such RWH systems were retrofitted in the last three years. These complexes range in size from 8 flats to 200 flats and the soil conditions vary from very sandy in coastal areas to varying mixtures of sand, silt and clay at shallow depths and rocky at deeper levels (70 ft and over). In several complexes, the soil was weathered rock or fractured hard rock even at shallow depths. The concrete benefits experienced by these complexes are summarised below. These prove beyond all doubt that RWH can and does indeed take us forward in becoming self-reliant in our water needs. The benefits have been strikingly noticeable in complexes where the harvesting measures were retrofitted while in the case of complexes where systems were in place from the day of occupation, the residents have been able to withstand the dry seasons much better than others around.

QUANTITATIVE BENEFITS

In complexes where rainwater harvesting systems were retrofitted, the following distinct quantitative benefits have been experienced:-

1. Bore well pumps which earlier pumped water only when the neighbour's bore well pump was not switched on, were able after installation of rain harvesting measures, to pump water even when the neighbour's pump was on.
2. Bore wells and dug wells that used to yield water only for a limited period at a time yielded for a much longer period in one stretch.
3. Bore wells and dug wells that either yielded less or dried up in the dry season, became year round sources of water.

QUALITATIVE BENEFITS

1. Ground water that used to be brackish or hard earlier improved remarkably in quality after rainwater harvesting. Initially this impact may be experienced only during the monsoon and for some time thereafter. In course of time, the quality improvement will be sustained over the entire year. And one day one could even get potable water from the same source.
2. In certain areas, the ground water contains iron salts that remain in the dissolved condition. But as soon as the water is pumped out and gets exposed to air, these salts change into insoluble salts that separate out from the water. These salts are present generally in very minute amounts, i.e. 5 to 15 parts of the salt in a million parts of the water. Nevertheless they are a major irritant in the use of that water because: (a) The salts fully separate out very slowly, taking a few hours to almost a day. In the process the water becomes coloured. (b) Clothes washed in that water get stained, and (c) The iron salts that separate stain the ceramic or mosaic flooring, the walls of the bathroom, the buckets and the mugs used. Removal of these minute quantities of iron salts requires the installation of special equipment[24].

24. See Chapter 21 for details of iron removal methods

In such areas where the water tends to have iron salts, rainwater harvesting dilutes the iron salts substantially and one may get colorless water during the monsoon for use. Besides, with every successive monsoon, the iron salts from the soil get progressively leached out and over a period, the water can become totally iron free.

OTHER BENEFITS

1. With water levels rising, water yields will improve, the quantity pumpable in an hour will increase and thereby electrical energy consumed by the pumps will decrease. The power saving will be even more if a shallow well replaces a bore well as the water source.

2. When rainwater is ingested into the soil, the soil remains moist and in clayey areas, the building walls will be free from cracks that can develop if the soil around becomes dry. Cracks, which may have already appeared due to the dry soil, close up again in many cases.

3. By collecting rainwater into a drum or tank above the ground or in a sump below the ground, you can get enough water to meet your drinking and cooking needs. This has tremendous advantage in areas where the ground water has harmful contamination like arsenic salts or fluorides in high concentrations or the ground water is very brackish or has iron salts in it.

It needs to be emphasised once again that the efficacy of the RWH system will be concretely experienced only after the system becomes optimised over a couple of years. One also needs to recognize that the full potential of any RWH system will be realised only when more and more people go in for it. The common stock of water will thereby get augmented and ground water can then be drawn by habitats with various population densities as per their needs.

CHAPTER 9

MISCONCEPTIONS ABOUT RAINWATER HARVESTING

(Some widely held misconceptions about RWH are dispelled in this chapter)

We have in earlier pages, advocated the direct diversion of rainwater from terraces (roof-tops) into shallow dug wells and into water sumps because of the high efficiency of tapping. However there are several widespread fears and misgivings on such direct usage of rainwater for our daily needs. There are also some fears about RWH in general. If we examine these fears and misgivings in some detail, we will find that these are mostly unfounded. In fact in the case of buildings with more than four storeys, all of them will be found baseless on a simple inspection of the terrace.

Misconceptions about Rooftop RWH

1. *Leaves from the trees near the terrace will go into the wells or storage sumps*:

   In the present urban scenario, the presence of tree branches close to the terrace is likely only in single or double storeyed hóuses, as trees tall enough to shed leaves on terraces of four storeyed apartment complexes will be a rarity. Even if there be such trees close to the terraces, *leaves are shed either before or after the rains and never during the rains.* If there are only a few branches near the terrace, these can be cut off so that the problem is eliminated. Otherwise two simple precautions will completely take care of this aspect:

   a. Sweep the terrace before the onset of the monsoon and/or

b. Provide grills (Jaalis) at the water outlet point that will block the leaves from going into the pipe. Even if some leaves get through, these won't pose any risk to the usage of the well water for bulk uses. The water may be slightly yellowish but clear; the colour that is derived from some harmless organic materials derived from the leaves poses no risk for all general uses. For drinking, if the water is boiled, cooled and filtered through cloth (before or after boiling), there is no risk whatsoever of contracting any waterborne disease. However, where grills are provided, if the terrace is not swept, the grill may be blocked by leaves abd water may stagnate on the terrace.

2. *Dust from the terrace will go into the well along with the rainwater*:

The fine dust that often settles on the terrace floor is exposed to the relentless heat of the sun and is thereby rendered sterile in no time. If such dust goes into the well it just mixes with the fine mud which exists already at the bottom of the dug well and does not in any way affect the water in the well and poses no risk whatsoever to our health. The simple precaution of sweeping the terrace a little before the onset of the monsoon will remove most of the dust. If desired, a first flush arrangement (described on page -51) can be installed to fully prevent the dust from going into the well.

3. *People may urinate on the terrace and this will mix with the rainwater going to the well or sump:*

This is a totally unfounded fear for the following reasons:

a. The urine of a normal healthy human is totally sterile and does not pose any health risk whatsoever, even if it gets into the sump or the well accidentally.

b. The total output of urine of a normal human in **an entire day** of 24 hours amounts to a mere 80 g dry weight! Even if such an amount were to exist on the terrace, it will be diluted enormously by rain and will have no impact whatsoever. Just a bucketful of rainwater would result in a dilution of this 80 grams with 15,000 grams of water (15 litres)! The dilution in the course of actual rainfall will be hundreds and thousands of times more than a bucketful. The fear thus is more in the mind than warranted by reality.

4. *Bird droppings will contaminate the rainwater:*

Birds are most unlikely to be on terraces during rain, as they would prefer the more comfortable shelter of trees where they will be protected from the rain. And so fresh bird droppings are most unlikely to fall on the terrace and get mixed with rainwater. Even if theoretically one presumes some bird droppings do get mixed, the quantity will be so miniscule and microscopic in comparison with the volume of rainwater with which it will get mixed up, that nothing will happen. If there were any residues of bird droppings left on the terrace from sunny days, these would have been rendered sterile in no time by the relentless heat of the sun. In some areas, there could be faecal matter of cats. These also would be rendered sterile in no time. However, if dogs tend to be taken by their owners to the terrace even during the rainy season, either the harvesting has to be stopped or the movement of the dogs stopped. In areas infested with monkeys, only if monkeys are known to frequent the terraces even during the rains, the direct diversion may have to be reconsidered.

5. *The rainwater may carry with it dead rats or dead lizards:*

   Lizards usually will not haunt terraces as there is no food there for them. Therefore chances of dead lizards falling on the terrace are extremely remote. Dead rats, if at all, will only be dropped by crows and crows are rather uncommon in today's urban environment. Even if there are some crows, these are unlikely to visit the terrace during rains. In the remote event of such a thing happening, the jaali or the grill at the outlet point will prevent them from going into the sump or the well. In short the simple precaution of sweeping the terrace clean periodically and particularly just before the break of monsoon will render safe the collection of rainwater directly into a storage unit for subsequent use for general non-potable needs. If the water is of potable quality, it can be boiled, cooled, filtered through cloth and drunk without any worry whatsoever.

6. *What if fire crackers are lighted on the terrace on occasions like Diwali?*

   The simple precaution of removing the remnants of fire crackers, sparklers and the like from the terrace by hand picking or sweeping after the activity is over will be a good practice. Even if this is missed, the consequent risk is negligible because the residual quantities of the chemicals left on the terrace are by themselves very little and the dilution by rainwater will be enormous and so no consequential risk is involved.

Other Misconceptions about RWH in General

1. *If rainwater is allowed to flow directly into the well, the springs supplying the well will be choked leading to the well going dry:*

   The author has channeled rainwater directly into the dug well (from the top) in his own colony since 1995[25], and in over 150 other apartment complexes in the last 7 years. The results have been only beneficial and no negative impact whatsoever has been experienced in any of these complexes. Those who have been citing this as a risk have not to date offered any rational explanations as to why or how this choking of the springs can occur or has occurred.[26]

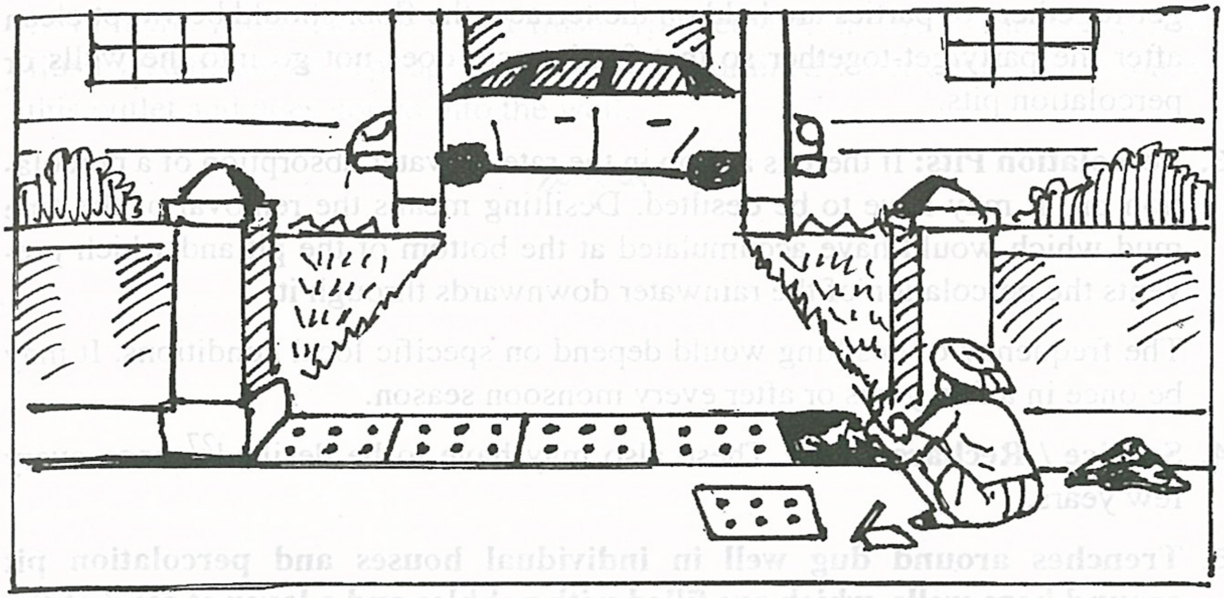
25. In fact, the pictures showing direct connection of roof-top down-take pipes above ground to the dug well were taken in the author's own colony.

2. *Harmful chemical pollutants may be present in the rainwater harvested*

Gases like sulphur dioxide and oxides of nitrogen dissolve in water and form acids that pose a risk to human health. However, these gases are not present in the air at terrace levels in residential areas normally. Only if there are chemical industries in the vicinity of the terrace, is there the possibility of such gases being picked up by the rain as it falls.

26. Strangely, some reputed authorities who hold this view have, at the same time, recommended channeling rainwater directly into the casing pipe of bore wells. Given the narrow bore of the pipe (compared to a dug well) and the height from which the rainwater falls on the water in the bore well, the risk of the pores in the soil around the slots of the casing pipe getting blocked due to air bubbles is quite high.

CHAPTER 10



MAINTENANCE OF THE RAINWATER HARVESTING SYSTEM

(To reap the full benefits of any RWH system, it has to be maintained in a good condition. This chapter details what has to be done.)

Regular maintenance of the RWH system that one has installed is very important not only because this contributes to its efficient functioning but also because it extends its longevity as well. As will be seen below such maintenance is not complicated, and can be done at a small cost and effort, compared to the benefits it will bring.

1. **Shallow Gate Trenches:** These tend to get filled with mud/debris/dry leaves during the dry months. These need to be removed before each monsoon. Thus in Chennai, the task has to be done twice a year - once in April- May before the onset of the South West Monsoon and again in September - October before the onset of the North East Monsoon. This is a simple task. It will also be a good idea to block the outlet from the trench to the percolation pit in the dry seasons with a cloth plug covered by a polythene sheet and open it after pre-monsoon cleaning of the gutter. Special care must be taken if any mud is put on the road due to any digging work done on the road or if any construction work is going on in the vicinity. If too much mud goes into the percolation pit or recharge well, its permeability will be lost and water won't get absorbed into the soil.

2. **Terrace:** The terrace should be swept clean prior to the monsoon in the place concerned - either the North East or the South West Monsoon or both. If any get-togethers or parties are held on the terrace, the floor should be swept clean after the party/get-together so that food waste does not go into the wells or percolation pits.
3. **Percolation Pits:** If there is a drop in the rate of water absorption of a percolation pit, it may have to be desilted. Desilting means the removal of the fine mud which would have accumulated at the bottom of the pit and which prevents the percolation of the rainwater downwards through it.

   The frequency of desilting would depend on specific local conditions. It may be once in a few years or after every monsoon season.
4. **Service / Recharge well:** These also may have to be desilted[27] once every few years.
5. **Trenches around dug well in individual houses and percolation pit around bore wells, which are filled with pebbles and a layer of sand at the top:** The sandy layer on top may become clogged with fine mud resulting in low rate of rainwater flow through it. Often this is indicated by the sandy layer turning brownish. The sandy layer would have to be taken out and either replaced with fresh sand or returned after being washed with water to remove the mud trapped in it. This process is not very convenient.
6. **Inspection Chambers:** If inspection chambers are provided between the rainwater trapping point and the receiving percolation pit/dug well, then it is advisable to check the pits prior to the monsoon and remove any material deposited in them
7. **Cleaning of the Overhead Tanks:** If water is regularly pumped up into the overhead tank from a shallow dug well or bore well, then mud from the bottom of either tends to come along with the water and accumulate at the bottom of the overhead tank compartments. When the tank is cleaned and the water is drained, the muddy water from the tanks will end up in the well or the percolation pit to which the tank is connected via the terrace rainwater pipe. This can be avoided by one of several methods: I) The drain- pipe of the overhead tank compartments can be connected to the nearest waste water line (sullage line). ii) The drained water can be collected in a drum and disposed off into the drainage gulley. iii) If an inspection chamber has been put in the line connecting the terrace rainwater down take pipe to the well, this can be opened and

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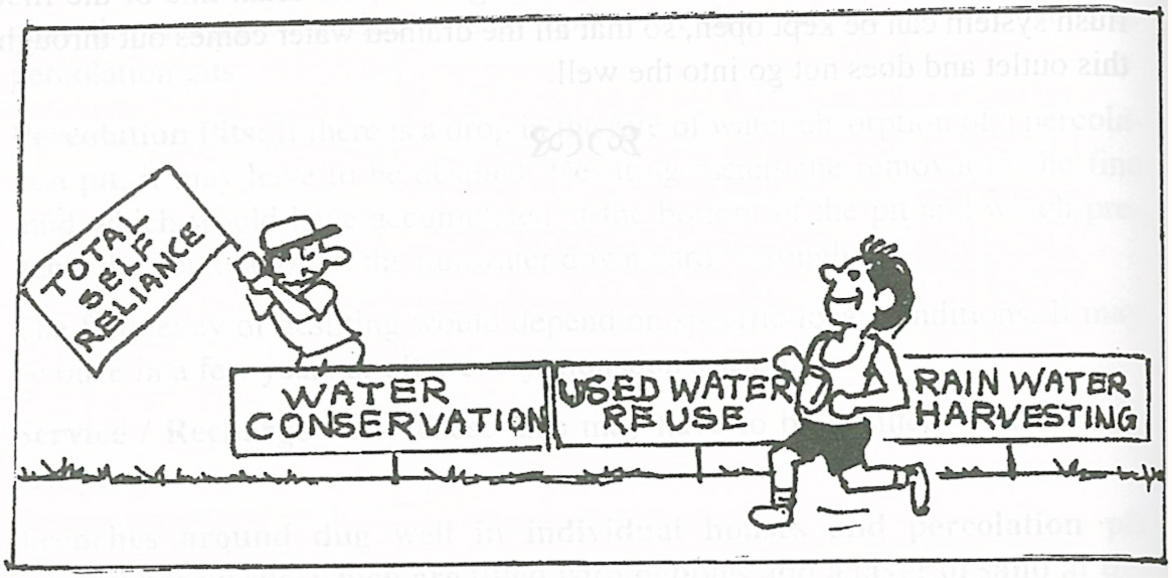
27. *Cautionary Note:* Before doing any maintenance work that involves entry into any pit or well that has been kept closed for long periods, open the manhole cover or the lid and cautiously check whether any unpleasant or foul odour emanates from it. A stale odour of stagnant water may not be worrisome but any unpleasant or fetid or foul odour has to be handled with caution. In such cases, keep the cover or the lid open till the odour subsides and then only allow entry.

the outlet pipe plugged with cloth covered by a plastic sheet. The drained water will thereby accumulate in the inspection chamber and can be removed from there. iv) If there is a first flush arrangement, the drain line of the first flush system can be kept open, so that all the drained water comes out through this outlet and does not go into the well.

CHAPTER 11



THE SECOND STEP IN SELF RELIANCE– USED WATER REUSE

(The water used for bathing and washing of clothes constitutes as much as 50–65% of our total water usage. This chapter details how this stream of used water is good water which, if purified, can be used again and how such use takes us substantially towards self-reliance in our water needs.)

The Value of Used Water

Do we throw away our vessels after they are used for cooking, because they have become oily? We don't. We clean them and use them again. Do we throw away our shirts and sarees after wearing them once or twice because they have become soiled or stained? No, we don't. We wash and iron them and wear them again. We do so because we are aware that clothes and vessels are items of value and we cannot afford to throw them away after a single use. But what do we do with the water after we use it for bathing or washing our hands or for cleaning our vessels and clothes and vehicles? All of it disappears from our sight when it goes into the drain. And we do not give even a second's thought as to what happens to this water, where it goes and whether this is how it should be dealt with - except, of course, when the pipeline gets choked. We then try to get a plumber and if one is not readily available, we take a stick or a metal rod and try to poke into the drain.

Because water happens to flow at the turn of a tap or a shower valve, we take it for granted. While increasing difficulties in its ready availability in recent years may have made us more careful in our water usage, we tend to consider this more as a passing problem and never give water the kind of value we give to our clothes and vessels or other possessions.

In primary school, one used to be told that to an Arab in the midst of a desert, water is much more precious than diamonds. This may not be true today with changed modes of travel for the Arab. But the time has come when, on our part, we have to value water as dearly as we value our other possessions, if not even more, for the availability of usable water for each individual will reduce with increasing population density. Those of us enjoying the privilege of receiving piped treated water need to realise that this supply is considerably subsidised presently by the water authorities and they will reduce these progressively out of sheer financial constraints. Those who have deep bore wells in their premises which are yielding copiously need to remember that drawing water from deep levels is no different from drawing cash from our bank accounts without putting any money into the account. Just as the account will dry up, our water source also will dry up one day. Therefore, we must devote our thoughts to use the available water more efficiently than we are doing at present. To this end, we must perforce enlighten ourselves as to what is the course taken by the used water we put in the drain and see whether that course can be altered and how it can be altered to our advantage. The first thing we have to do is to give up calling used water as "waste" water and start calling it only as "used" water. The next thing we have to recognise is that a good part of the water we have used can be cleaned up and rendered fit for use again, if only we are ready to do it. For this, we first need to know more about what happens to the water after we have used it.

Varieties of Used Water

Used water can be classified into three varieties:

Sewage or Black Water: This is water flowing out from the closets and constitutes 30-40% of the total water used by us.

Kitchen out flow: Water used for washing of vessels generally flows out from the kitchen sink or the utility. This constitutes about 10-15% of our total usage.

Bath Water or Grey Water: Water used for bathing, washing of clothes and mopping of floors. This constitutes about 50 - 60% of the total usage, depending on whether washing machines are used or not.

Good building practice requires that these three streams of water be taken out of our homes through three different pipelines. It will be a good learning experience for residents of houses and flats to go out, stand facing their kitchens and their bathrooms and trace the course of the pipes that come out therefrom. The two pipes that come out from the kitchen sink and the bath area will be seen to terminate above the ground. The water coming through them falls into a gully that is connected to the nearest manhole chamber of the internal sewage line. Sometimes these two pipes are connected and brought down together as a single pipe. However one pipe will be seen to go directly into the ground . This pipe is the one that carries the outflow from the closet and it goes straight into the nearest manhole chamber, so that human contact with this stream of used water is totally avoided from the point where it leaves the closet till it reaches the internal sewage line(The outermost two pipes in Picture 7.2 on page -47).

Thus all the water that we use ends up in the internal sewage line and from there it flows into the road sewer. However, there are significant differences in the characteristics of these three streams of used water:

1. Sewage has very little organic content but contains harmful pathogens – bacteria and viruses – that are discharged from our intestines along with faecal matter. These pathogens cause water borne diseases like jaundice, cholera and typhoid. It is for this reason that this stream is taken directly to the internal sewage line.

2. The kitchen outflow i.e. water used for washing vessels contains considerably more organic matter – mostly made up of dissolved food products, onion pieces, curry leaves, chillies (red and green) vegetable pieces, rice and dal crumbs etc and other left-overs from the preparation and consumption of food. Importantly however, this water does not contain any harmful pathogens.

3. Bath water and water from washing of clothes contain very little organic matter made up of some sweat, some urine and exhausted and un-exhausted toilet soap and detergents. This stream too is totally sterile i.e. it has no pathogens whatsoever.

The Make Up of Sewage and Its Wasteful Disposal

Sewage is nowadays referred to as "Black Water" because of the presence in it of pathogens and the other two are referred to as "Grey Water." We noted above how both black water and grey water both go into the internal sewage line, get mixed and go into the road sewerage. In unsewered areas, the mixed stream ends up in the septic tanks. It will be on eye-opener for most of us if we examine the consequence of such mixing of the two streams.

A fact little known to most of us is that the total dry weight of the faecal matter expelled from the body per day by an individual is only around 70 grams and the total dry weight of urine in only 80 grams.

In unsewered areas, with increasing population, the soil around the septic tanks is inadequate to treat the outflow from them and consequently, good quality water in the shallow aquifer gets contaminated and poses serious health risks to those who consume it.

In places having sewerage, when this small quantity of 70g of faecal matter is flushed from the closet, 70g of harmful matter gets mixed up with the entire 135 litres water used by that individual in a day and all of it goes into the sewerage. This results in a mere 70g of harmful matter poisoning the entire 135litres or 1,35,000 g of water and rendering it unfit for any use except after it has been subjected to involved treatment at considerable expense!

And having spoilt 135000 g of water with 70g of faecal matter, how do we have to go about cleaning it? We build an expensive underground pipeline system to carry all this water by gravity flow to sewage pumping stations first. From here it is pumped to sewage treatment plants that are usually located in areas away from the city. In the sewage treatment plants, it is subjected to a 3-stage treatment to eliminate the 70g of faecal matter and 80 g of urine and the rest of the marginal organic matter from soaps, detergents and food products present in it. Even after all this effort, involving considerable energy, cost and effort, there still remains a major problem i.e. disposal of the treated water. Because, this water is still not fully free from spores of the pathogens and so is unsafe for direct human use, although it is safely usable for growing crops.

Excreta and Urine: Smelly Waste Products? No, Useful and Valuable Products!

We tend to casually and commonly apply the adjective "waste' to many materials we handle or come across in our daily life. But, pause for a minute, reflect for a while, and answer the question, "Is there any entity at all in the myriad ramifications of nature that can be truly called a 'waste product'? The answer has to be a categorical '**No**'! Mother Nature recognises only two categories in all her processes: Usable Products and Used Products. When products cannot be used anymore for the purpose for which they are intended, they can be reconditioned or cleaned so that they can once again be used for the same purpose. In cases where such reconditioning or cleaning is not feasible, the worn-out used product can be converted into another usable product.

Consider the example of a cotton tree: Cotton is woven into cloth. We stitch our dresses from that cloth. Worn out cloth can be used as floor wipes. Enterprising ladies use the waste cuttings of the tailor for making rag dolls and patch-work quilts. They also can serve as fuel. When the wipes turn to tatters, they can be converted into paper or burnt to produce heat. The resultant ash is manure that can contribute to the growth of a new cotton tree. From the cotton- seed, valuable cotton- seed oil can be extracted. The sludge i.e. cotton seed cake is a good fertiliser. The matured cotton tree is an excellent bio-mass that can provide heat energy.

This fascinating cycle can be traced for every material known nature. The only true waste products in this world are products not known to Mother Nature and sadly, they are man-made i.e. synthetic polymeric materials (plastics of various types) and the by-products of nuclear fission, the disposal of both of which is a looming and alarming problem in our country.

If therefore we apply the adjective 'waste' to any material, we in effect imply that we do not know how it can be used. And more often than not, *we also do not want to know or bother to know!* The most glaring example of this is seen in the manner we view the two by-products we generate in our bodies from our digestive system: urine and faecal matter. The minute these products are out of our bodies, we view them with distaste, as dirty, smelly products that need to be got rid of quickly. And once we flush them both out of the closet, we forget about them. We also associate both with the highly unpleasant smells that we experience while passing street corners where even educated men conveniently and shamelessly would have urinated or the less privileged, for want of better hygienic facilities would have defecated. Are these two apparently unpleasant products from our own digestive system really a problem and a nuisance?

No, they are not. On the contrary, if handled properly, they are valuable materials. If they smell, it is only because they have been deprived of air. When spread out and exposed to air, the smell will go off quickly. Alternately, if they are covered with some soil, the smell will be gone. Anaerobic bacteria in the soil act and take care of them. 'But how are they useful?' you may ask. Remember that they both are derived from food. Not surprisingly therefore, both *can be converted back into food!* Urine is an excellent fertiliser, which contains 18% by weight of urea. The urine output of one individual in a day is a mere 80g as solid but the total output over a year has enough nitrogen content in it to meet the needs of an acre and a quarter of farmland. And it can be mixed with ten times its volume of water and used to fertilise garden plants as well[28].

We may have heard of gobar gas being generated from cow-dung (the end product of bovine digestion) and used for cooking and for street lighting, with the sludge being used as fertiliser. Human faecal matter too can be put through a similar fermentation process to generate biogas and a sludge usable as a fertiliser. In Gandhian centres like Gandhigram in the Dindigul District of Tamil Nadu or Dandi in South Gujarat and in Anna Hazare's model village, Ralegan Siddhi in Ahmednagar District of Maharashtra, the biogas so generated is used as fuel for cooking needs and for street lighting. The sewerage authorities of Delhi (the Delhi Jal Board) had pioneered the generation of bio-gas from their sewerage treatment plants in Okhla, Rithala and Nilothi and offered it at very attractive rates to more than a dozen colonies around these plants. Sadly the response was very poor. People were reluctant to use it for cooking on the baseless premise that

28. See: The Miracle Called Compost, Vasant Bombatkar, The Other India Press, Above Mapusa Clinic, Mapusa, Goa 403 507, 1990,.pp.21-22.

it is very unhygienic and smelly. Consequently, the Delhi Jal Board has been forced to use the biogas for power generation.

While these are recent developments, what is little known is that human faecal matter has long been used just like cow dung directly as a fertiliser to grow the very rice, wheat and vegetables from which themselves it had originated in many parts of the world in yesteryears particularly in China, Japan, Korea and India. It was also widely used for farming even in the latter half of the nineteenth century in London, Antwerp, Berlin, Brussels, Paris and Milan. This resulted in the faecal matter being used up by the crops for their growth and any left over was treated by the soil. Sewage was thereby rendered free of all organic matter and the water that came with it became fit for use again. It may be of interest to know that even in the United States, substantial quantities of human faecal matter were directly used for farming till as late as 1912! In several places in our country, sewage is used for growing vegetables e.g. on the sides of the railway lines in the suburbs of Mumbai. Consumption of the vegetables or greens grown thus does not pose a risk to our health as long as they are consumed after being heated (as in cooking). If consumed raw, they do pose a risk.

The following extract from Victor Hugo's famous 19th century novel, "Les Miserables" will be of interest in this context: *"Science knows now that the most fertilising and effective manure is the human manure.... Do you know what these piles of ordure are, those carts of mud carried off at night from the streets, the frightful barrels of the nightman, and the fetid streams of sub-terranean mud that the pavement conceals from you? All this is a flowering field, it is green grass, it is the satisfied lowing of heavy kine, it is perfumed hay, it is gilded wheat, it is bread on your table, it is warm blood in your veins"*. In effect, Victor Hugo was marvelling at the amazing ability of Mother Nature to convert the apparently smelly products of our digestion into life-supporting food products again!

Can We Improve the Situation?

In a pioneering effort, the Chennai Metropolitan Water Supply and Sewerage Board has been supplying secondary treated sewage to certain industries in the outskirts of the city who treat it further by subjecting it to reverse osmosis and use the water for their air-conditioning and cooling water needs. This is however a costly process. More recently, in Chennai and Mumbai, the Development Authorities have made it a condition that hotels and large commercial establishments that have central air-conditioning must treat their waste water *in situ* and then only discharge it into the town sewerage or use it for their air-conditioning units.

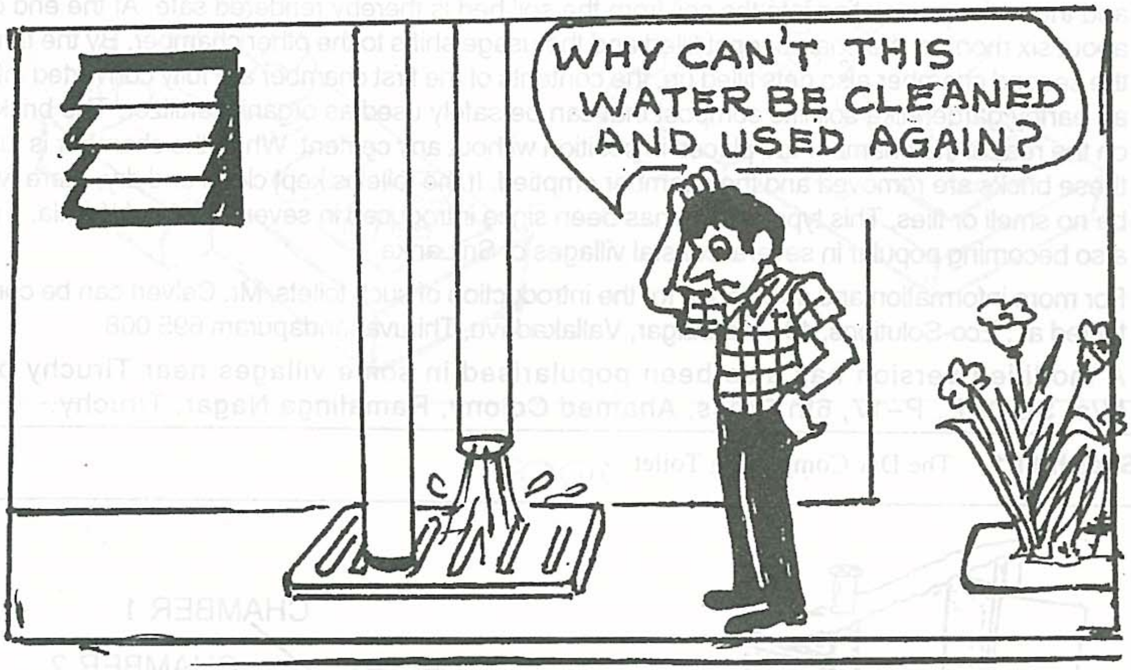
But most towns and cities in India have been unable to increase the capacity of their pumping stations and sewage treatment plants to keep pace with the continuous increase in the population of their towns and cities. Whenever the pumping stations are unable to meet the load, the sewerage lines on the roads overflow. And if the treatment plants are unable to handle the load, they dump it into the nearest water body that is generally a river or a lake or a tank. Such dumping takes place often for the simple reason that treatment plants in most cities are old or inefficient and therefore not capable of handling their load. In many towns, treatment plants exist only as edifices, and the sewage goes into the waterways directly without any treatment whatsoever.

Not surprisingly, the sacred Ganga water today has 50,000 times the permitted amount of sewage contamination. And this, after crores and crores has been spent over a decade in implementation of the Ganga Action Plan designed mainly to treat the sewage that was flowing into it. The Yamuna in Delhi is no better. Chennai's Adayar River is a reasonably clean river till it enters the city after which it becomes a sewage channel - 82% of its pollution being caused by discharge from this city's sewage treatment plants. These are only glaring examples. The stark reality is that most of our waterways have already been polluted or are being heavily polluted by untreated raw sewage apart from industrial effluents. This situation is not going to improve because the growth of our towns and cities is much faster than the ability of our municipal authorities to match this growth with improvements in the infra-structural facilities.

The other serious consequence of this water- borne disposal of faecal mater is that it takes all the water used by us miles and miles away from our homes, with the inevitable depletion of our ground water table. In addition, the disposal of the water after treatment itself becomes a problem. The need to treat sewage in such a manner in a centralised place arises because of the harmful pathogens present it. What most people are unaware of is that water is the wrong carrier for disposal of faecal matter because it is a mere carrier and does not operate in any way to decompose faecal matter.The best treatment unit for faecal matter in fact is soil and if the raw faecal matter is not diluted with water, it requires very little soil area for its safe conversion into manure. In unsewered areas, not being in water, the faecal matter does not move across the soil and therefore will not contaminate the shallow water table Traditionally in our country, defecation was done only on soil. Change over to the water borne sewerage system came after its earlier introduction in England.

In fact, dry toilets i.e. toilets which avoid usage of water as a carrier and treat the faecal matter hygienically within the premises using soil are widely prevalent in small communities in Australia, which cannot afford a water-borne sewerage system. While these dry toilets fit into individual households excellently even in cities, they cannot be fitted into flat complexes having several floors. Such toilets have been introduced in Norway in flat-complexes also but these are high-tech installations and not suitable for our environment. An interesting innovation well suited for rural areas is the toilet introduced by Mr.Paul Calvert, an Englishman, in a fishing village in Kerala recently (see page -90 for details). This unfortunately does not readily lend itself to adaptation to flats in the urban context but can certainly be utilised in independent houses. Ironically, in rural areas, the Government is introducing wet toilets in the name of development when, what is really needed is provision of hygienic facilities through construction of the toilets introduced by Mr. Calvert.

Thus at the moment, we have no choice but to live with the existing system in our cities and towns. This does not however prevent us from exploring ways and means of reducing the quantum of water wastefully going into the internal sewage line and then into the town sewerage. If, for example, we collect the first and second rinses of the washing machine, we will realise how clear and clean the water is. Similarly, if we stand in a shallow basin or tray and pour water over our soaped bodies, we will see how clear and clean the water collected in the basin or tray is. Should all this water go into the internal sewage line, mix with sewage and end up miles away from our homes? After all, it contains only small amounts of exhausted and unexhausted soap, some sweat, urine and dirt and poses no threat to our health as such.



"What do we do with this water", one may ask. The answer is "Clean it and put it for reuse within your own premises". By doing so, we not only get this huge quantity of water for our use again but we also reduce the volume load on the sewage treatment plants and prevent discharge of raw sewage by them into our water bodies. Thus, with concerted effort at the micro-level, we not only benefit ourselves but we will also be contributing to a vastly healthier environment at the macro-level. The vital key to all this is no doubt the 'How" of it i.e. the technique by which we can clean this grey water and retain it in our own premises. In the next chapter, we will see how simple the **"How"** of it is.

THE DRY COMPOSTING TOILET

The fisher-folk in a coastal village of Kerala called Pulluvila did not have a proper community toilet. Defecation was therefore only in the open. Being a coastal village, the water table was quite shallow. Consequently this got contaminated by the faecal matter. Consumption of this water resulted in water- borne diseases. Sadly, such situations are not isolated. In this village, however, Mr. Paul Calvert, an English engineer, representing M/s Intermediate Technology Development Ltd., London, in collaboration with some NGOs resolved the problem by introducing an innovative toilet that was economic to construct, hygienic, easy to maintain and requiring only very limited water.

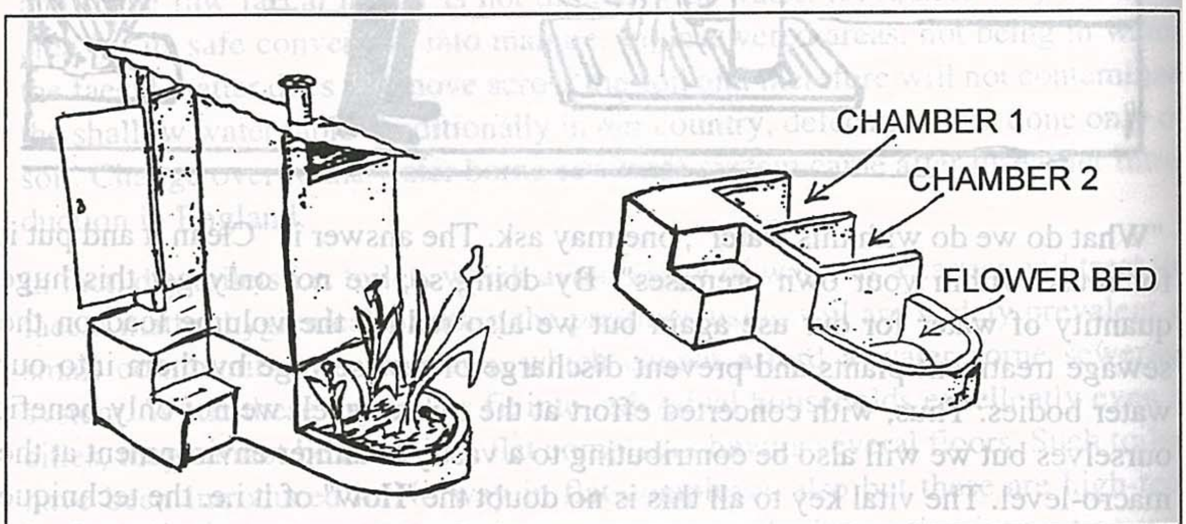
This consists of two rectangular chambers (about 2ft x 2ft and 2ft ft high) constructed side by side with bricks and cement, as seen in the sketch below. The chambers are covered with a cemented floor accessed by two or three steps. On this floor, above each chamber, a defecation hole is provided. In front of this hole, another hole is provided for urination. Between the two defecation holes, a wash hole is provided.

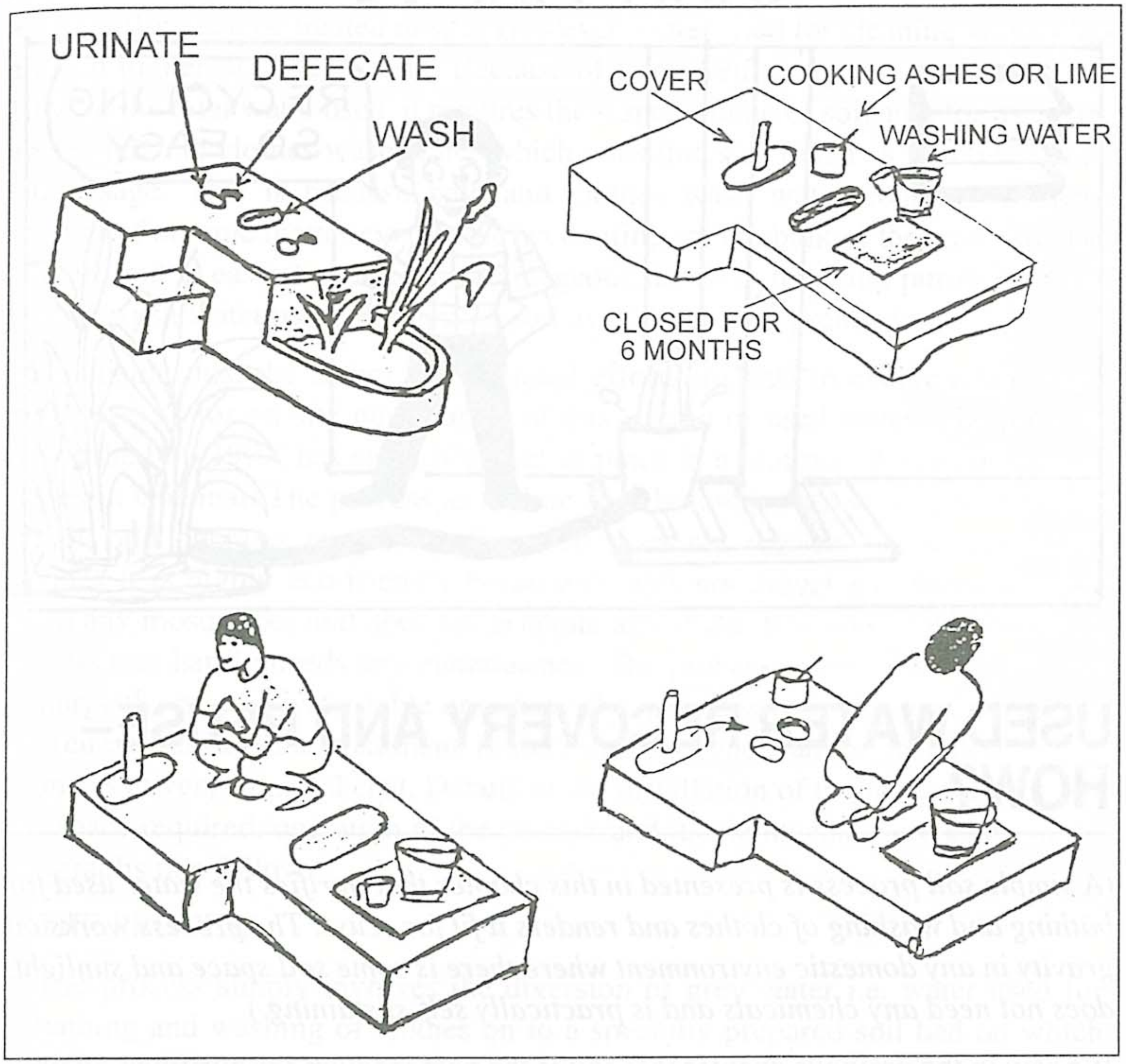
Each chamber has, at its bottom, a bed of straw on which the faecal matter falls. Each of these chambers is used for about six months by turn. After defecation, the individual turns 90^{o}, washes himself/herself over the wash hole and instead of flushing, sprinkles a little lime or cooking ash over the faecal matter. The defecation hole is then closed. Both the urine and the wash water pass through a pipe to a soil bed on which a water-loving plant like Canna indica is planted. The urine and any residual faecal matter in the wash water are dealt with by the soil and the water percolating into the soil from the soil bed is thereby rendered safe. At the end of about six months, the chamber get filled and the usage shifts to the other chamber. By the time the second chamber also gets filled up, the contents of the first chamber are fully converted into an earthy garden-like soil like compost that can be safely used as organic fertilizer. The bricks on the rear of the chamber are placed in position without any cement. When the chamber is full, these bricks are removed and the chamber emptied. If the toilet is kept clean and dry, there will be no smell or flies. This type of toilet has been since introduced in several parts of Kerala. It is also becoming popular in several coastal villages of Sri Lanka.

For more information and assistance for the introduction of such toilets, Mr. Calvert can be contacted at : Eco-Solutions, 49, Asannagar, Vallakadavu, Thiruvanandapuram 695 008.

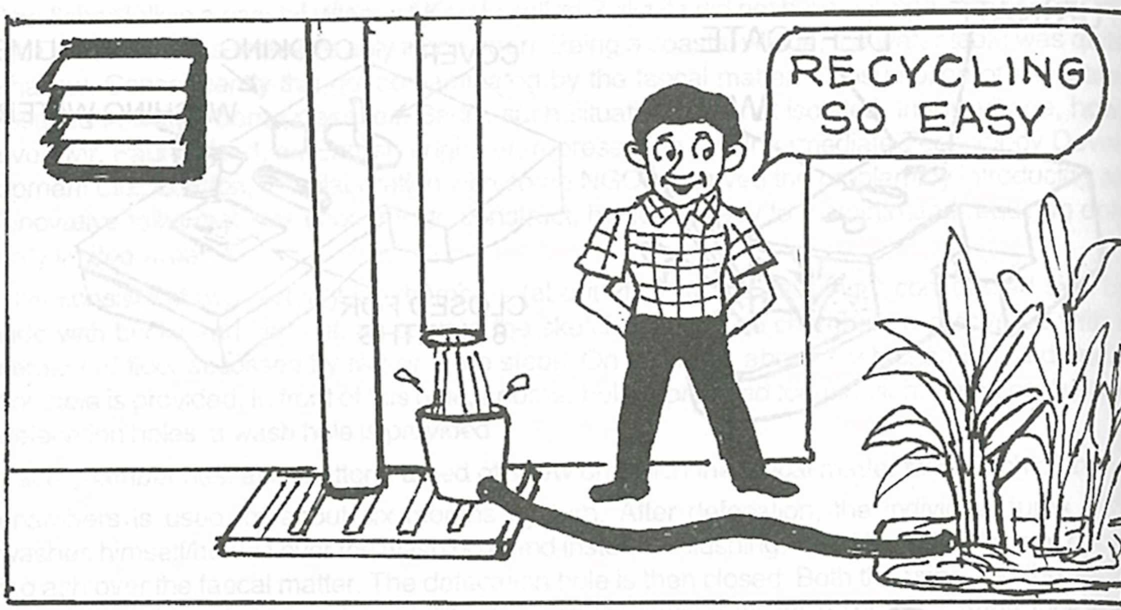
A modified version has also been popularised in some villages near Tiruchy by M/s. SCOPE, P–17, 6th Cross, Ahamed Colony, Ramalinga Nagar, Tiruchy.

Sketch 11.1 The Dry Composting Toilet




URINATE
DEFECATE
WASH
COVER
COOKING ASHES OR LIME
WASHING WATER
CLOSED FOR
6 MONTHS

CHAPTER 12



USED WATER RECOVERY AND REUSE–HOW?

(A simple soil process is presented in this chapter that purifies the water used for bathing and washing of clothes and renders it fit for reuse. The process works on gravity in any domestic environment where there is some soil space and sunlight, does not need any chemicals and is practically self-sustaining.)

We saw in the previous chapter that soil is the best medium for purifying all used water including sewage. However, given the high population density in our towns and cities, the soil area available around the flat complexes is inadequate to treat and purify all the used water flowing out of the complexes. Nonetheless, this doesn't prevent us from exploring how to utilise the available area beneficially.

We saw earlier that water used for bathing and clothes- washing makes up for the bulk (50-60%) of the total water we use daily. Water for flushing of closets accounts for about 30-40% and the balance 10-15% is used for cleaning of vessels and for sundry uses like floor swabbing. All of these when passed through soil are purified and rendered fit for reuse. The purification essentially involves the removal of all organic matter from the water by soil bacteria.

Attempting to treat diluted faecal matter with the limited soil area available in apartment complexes is not advisable for several reasons, the most important of which is that this stream contains pathogens that can cause water borne diseases like typhoid, cholera and dysentery. If they are not removed totally, they may contaminate the ground water. The other two streams are free from pathogens and therefore can be treated in situ. However, water used for cleaning vessels has a much higher organic content. Because of this, even though it constitutes only 10 % of the total water used, it requires the same volume of soil area for its clean-up as bath and clothes wash water which constitutes as much as 50-60 % of the total usage. This is because bath and clothes wash water contains the least amount of organic matter even while accounting for the bulk of the water we use. Therefore it is easiest and most advantageous for us to treat and purify bath and clothes wash water using the limited soil available in our premises.

Recognising this, the author had initiated efforts in 1995 to evolve a soil treatment process for on site purification of this stream of used water. The process, established by 1997, has since been put in place in a number of apartment complexes in Chennai. The process, as will be seen below, is simple, needs very little outlay, and operates on gravity flow and does not require any energy input. Besides it is highly eco-friendly because it does not attract any flies, does not breed any mosquitoes and does not generate any smell. It is also a self-sustaining process that hardly needs any maintenance. The process can be tailored either to recharge the ground water table or to have the treated water recovered physically for reuse. Further, the treatment is decentralised and can be installed in any premises at very minimal cost. Details of the installation of the infrastructure, the soil space required, operation of the process and its maintenance are given in the paragraphs that follow:

1. THE PROCESS

The process simply involves the diversion of grey water i.e. water used for bathing and washing of clothes on to a specially prepared soil bed on which some plants that can withstand heavy watering are planted. These can be flowering plants like Canna Indica and Hedichium Coronarium (Ginger Lily), fruiting plants like banana or vegetation like Colocasia esculenta (Hindi:Arvi; Tamil: Seppan) or Cyperus alternifolius(Umbrella plant). These plants supply oxygen to the soil in their root zones. The soil bacteria break down the organic compounds in the grey water with the help of the oxygen and render the water clean. Earthworms present in the soil enhance the efficacy of this cleaning process. While several plants can be used for the process, Canna Indica has been preferred because its lush foliage with attractive red or yellow flowers adds a beauty to the garden that other plants do not do. Cyperus also has its own charm and can be utilized, but it does not bear flowers.

2. SOIL AREA REQUIRED

An individual can be assumed to use about 20-30 litre of water for bathing. The water needed for washing of clothes can be taken to be 30 litres per person if a washing machine is used and less if hand washing is done. The water used for wiping the floors is comparatively very low and can be ignored. Thus, the used water generated by an individual can be assumed to be about 50 to 60 litre per day from bathing and washing of clothes. The soil area required for treating this quantity will be 2.5 sq.ft[29].

Picture 12.1 The pilot plant in a 12 flat complex where the process was first established.

Picture 12.2 The purified water from the treatment bed shown in Picture 12.1 above was drained into a 8ft deep percolation pit (with the three part cover), from which the water percolated through the soil into the dug well (with the two part cover) nearby.

Thus if the user population is 4, 10 sq.ft of soil space is needed. If the user population is 12, 30 sq.ft of soil space is needed and so on. This soil space can be provided in any shape – in the form of a rectangle, a square, a circle, a triangle, a segment or any irregular shape as well, depending on local site

29. The areas given are for treatment using Canna plants. Areas required with other plants have not been established.

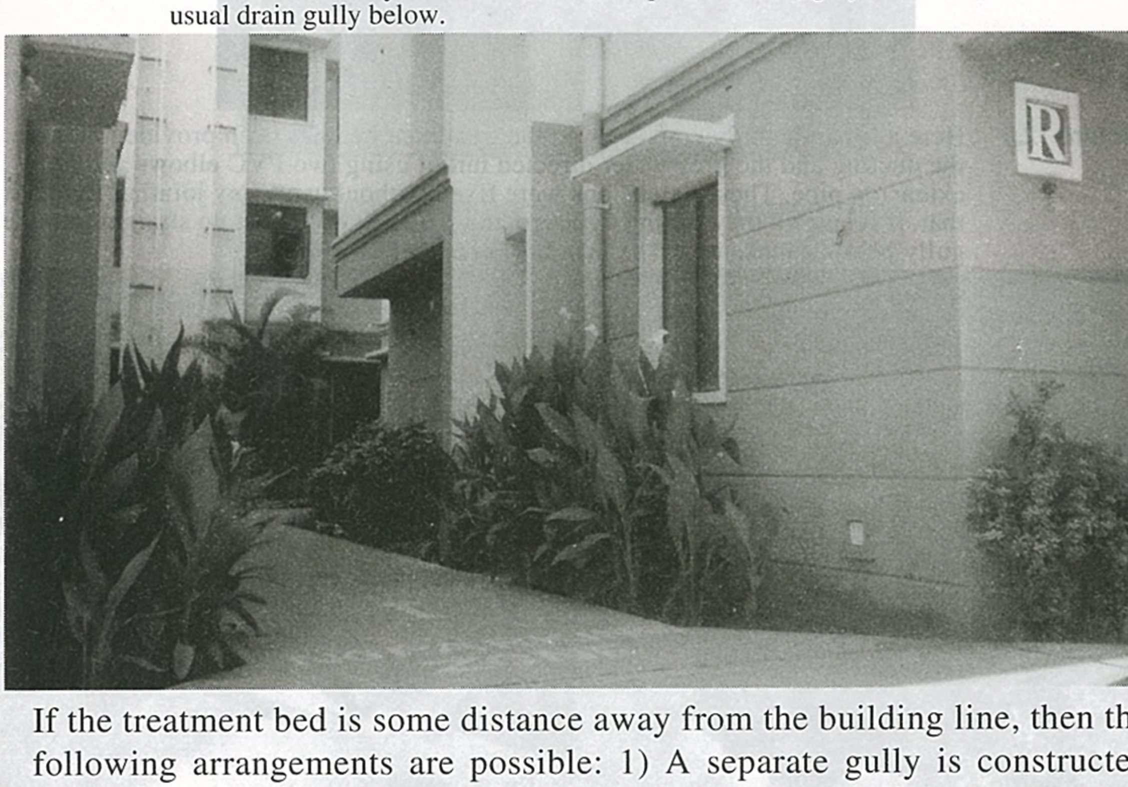
conditions. The only requirement is that it has to be at a slightly lower level (6" to 9") than the bottom most point of the used water outlet pipe from the bathrooms, so that the used water can flow over it by gravity ~~through a horizontal pipe~~.

However, in dwelling units having more than one bathroom, the volume outflow from each bathroom has to be calculated from the number of people using it and the outflow from clothes washing, if any from that bathroom. If the available soil area is limited, then the indicators listed in para 5 below can be used arrive at the minimum area required for each bathroom.

3. DIVERSION OF THE USED WATER TO THE TREATMENT BED

To start with, one has to examine how to connect the outlet of the vertical pipe from the bathroom to the treatment bed. If the particular treatment bed is abutting the peripheral wall of the building, then the diversion of the grey water to the bed is simple and easy – an elbow or a bend with an extension pipe will suffice. Picture 12.3 shows such a treatment bed and Picture 12.4 shows the diversion through the elbow.

Picture 12.3 The diversion of the grey water onto the treatment bed here is done by just attaching a PVC elbow to the bottom of the grey water drain pipe. This can be seen below the circular inspection cover in Picture 12.4. This is attached without any jointing fluid and so can be easily removed whenver required and the grey water drained into its usual drain gully below.

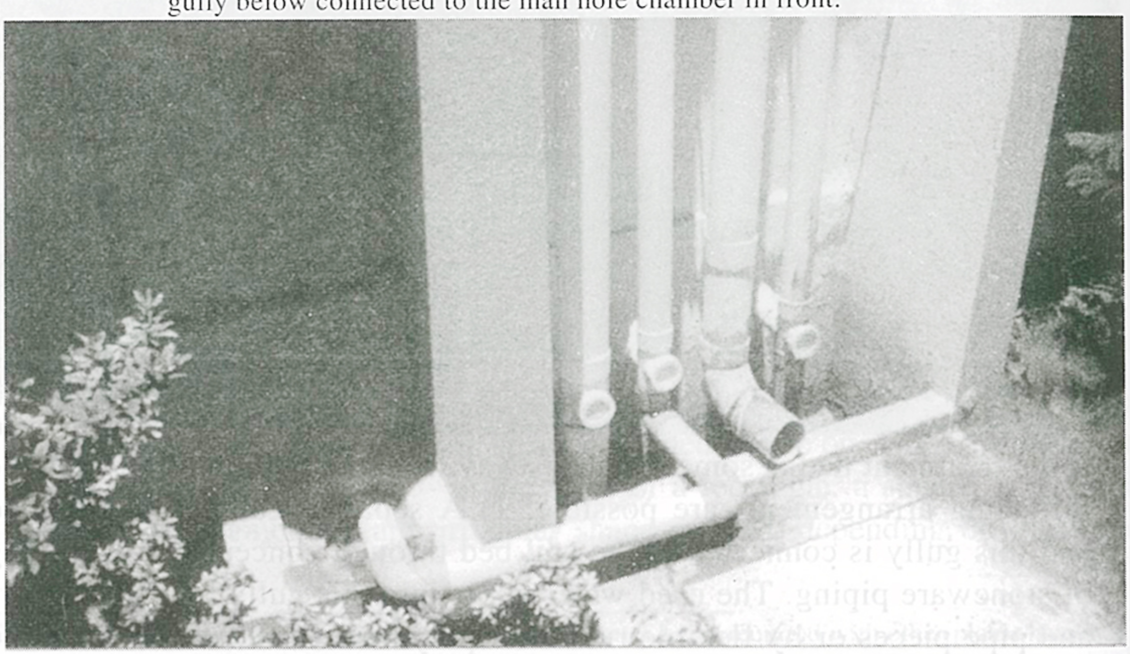


If the treatment bed is some distance away from the building line, then the following arrangements are possible: 1) A separate gully is constructed and this gully is connected to the soil bed through concealed PVC piping or stoneware piping. The used water is put into this gully by PVC elbows and pipe pieces or by flexible rubber or polythene hose (see Picture 12.6

and 12.7 on page -97) or by cemented channels, which can be open or covered as per the situation involved

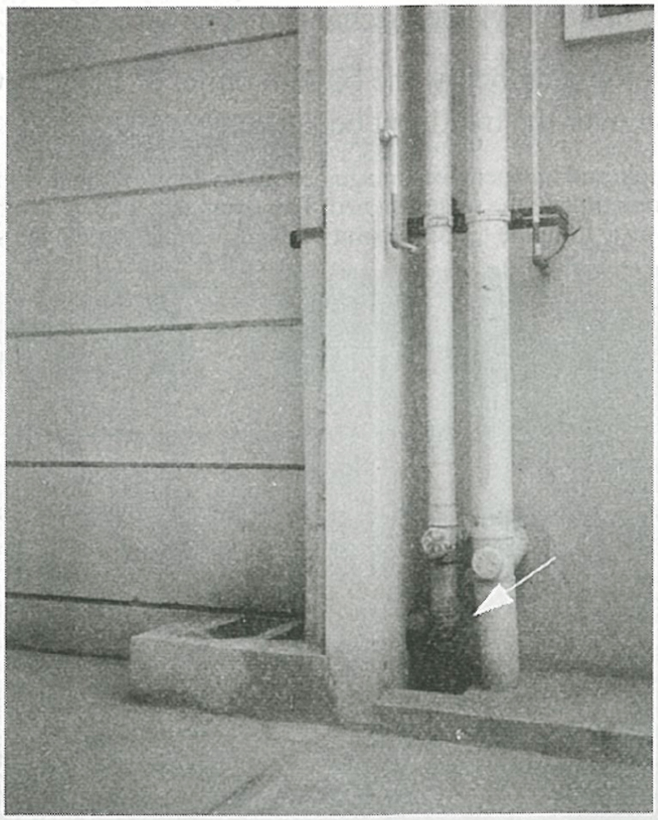
Picture 12.4

Picture 12.5 Here a separate gully connected to the treatment bed has been provided outside the ducting and the grey water directed into it using two PVC elbows and an extension pipe. These extensions were fixed without using any jointing fluid, so that, if required, they can be removed and the grey water can go straight into the gully below connected to the man hole chamber in front.

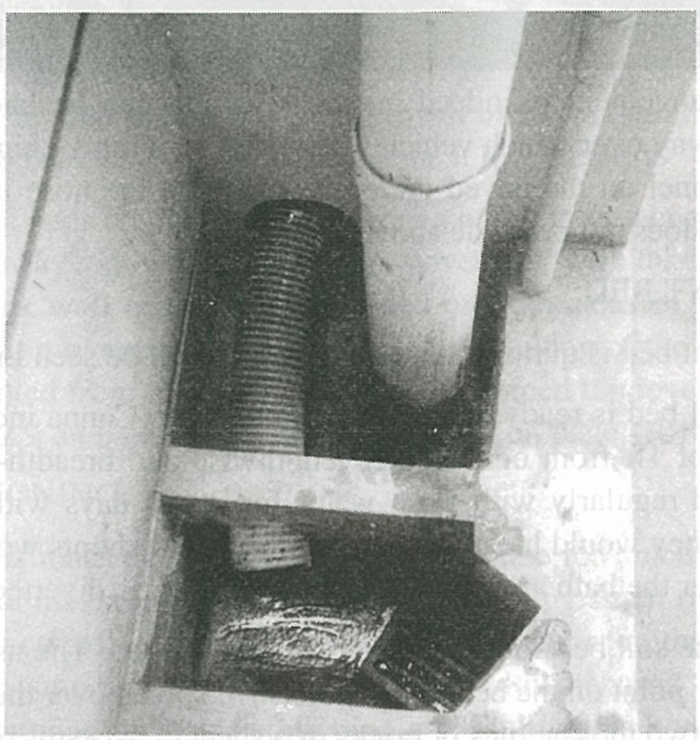


.A simple inexpensive arrangement to divert the grey water to the treatment bed would be to rig up a portable piping system shown in Picture 12.8, made from a plastic mug and a PVC or polythene garden hose.

Picture 12.6 Here, a hole was made in the wall of the ducting and the grey water diverted into another gully on the other side connected to the treatment bed. The connection was made using a PVC elbow and a flexible hose (marked with an arrow), both of which can be removed whenever needed. The diversion is seen more clearly in Picture 12.7.



Picture 12.7



With a divider from a schoolboy's geometry set, a circle is etched on the side of the mug about midway, identical in diametre to the outer diametre of the garden hose. Holes are then made along the etched circle with a poker or a screwdriver heated on a gas burner flame. Care should be taken to avoid the holes going beyond the etched circle. After the holes are made, using a small knife, the circular disc is removed and the hose inserted with some pressure into the hole. Our conveyance mechanism is now ready.

One just keeps the mug below the bottom outlet of the greywater pipe and the end of the hose over the treatment bed.

Picture 12.8 A simple and inexpensive arrangement to divert grey water from the terminal point of the drain pipe to the treatment bed. This arrangement can also be used to divert rainwater from the terminal point of the downtake pipe to the sump

Such an arrangement is indeed inexpensive and can be laid even across a paved driveway over which vehicles may pass by simply chipping off a semi-circular channel on the paved driveway such that the hose just fits in to the channel and does not protrude above ground.

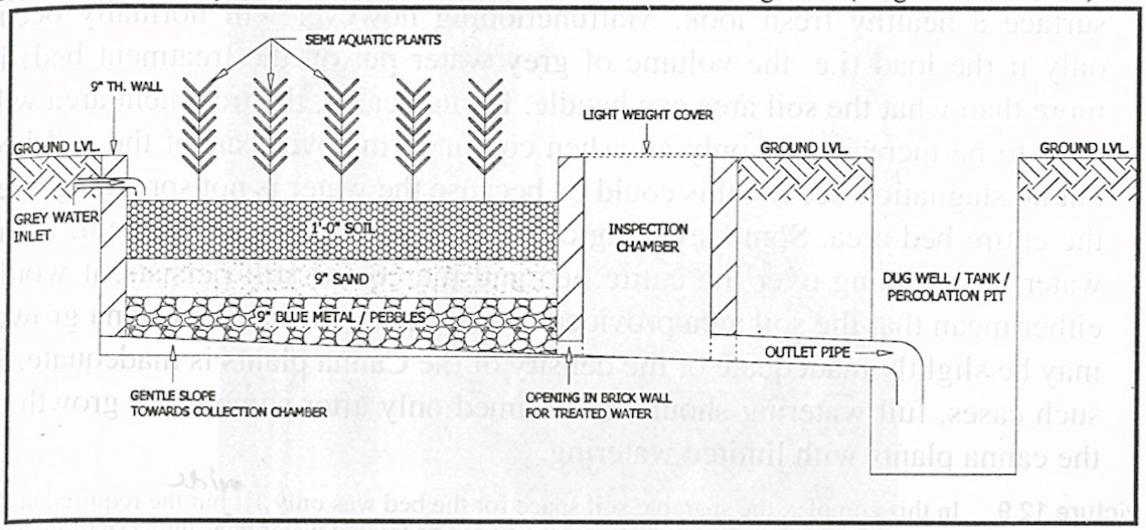
4. TREATMENT BED:

The treatment bed is quite simple to prepare as will be seen in Sketch 12.1

Once the soil bed is ready, tubers of Canna plants (Canna indica) are planted at intervals of 1ft from one another lengthwise and breadth-wise. These are then watered regularly with fresh water for 20-30 days with fresh water in which time they would have become stabilised and shoots would have sprung up. Thereafter the bath and clothes wash water can be diverted on to the bed.

The top of the soil bed should be level and not sloped. The used water can be loaded at any point on the bed as the water will spread over the bed on its own. Keep one or two mosaic tiles or bricks or a sheet of asbestos or hard plastic on the soil below the feeding point so that a depression is not formed in the soil by the water falling on it at peak hours. If a depression forms, water will tend to stagnate in it.

Sketch 12.1 Grey Water Treatment Bed and connection to storage unit (longitudinal section)



The bed can be in any shape, as long as the total area required is available. When peak loading occurs, the water may stagnate to a height of several inches on the bed. This however will subside within 30-45 minutes.

Once the used water is loaded on the bed, the purification process is self-sustaining. As the water stagnation on the bed does not last more than about 45 minutes, there is no scope whatsoever for any mosquitoes to breed. Neither will any flies be attracted to the bed. The purification of the water is effected in the vicinity of the roots of the plants by soil bacteria, utilising the oxygen supplied by the roots of the Canna plants. This process is further enhanced by the presence of earthworms in the soil. On prolonged operation, the soil may turn black but this has no impact whatsoever on the process. In fact, the soil may not even be seen due to the thick growth of the plants. If desired, some fresh soil can be strewn over the bed to make it look healthy.

If the treatment beds are located away from a building or a compound wall or a paved driveway on which vehicular movement will take place, then a supporting brick wall needs to be provided on both sides of the bed so that a) any vehicular movement will not result in the sinking of the road and b) the water is prevented from moving laterally and is forced to move only vertically (See Picture 12.9 on page -100 and Picture 12.10 on page -101).

5. MALFUNCTIONING:

If the process is malfunctioning, water will stagnate for much longer periods than the normal maximum of 45 minutes and a strong smell of stale stagnant water will be noticed. Algae or a slimy dark formation on the bed may also result. In such situations loading of the bed with the used water must be stopped by removing the connecting piping or the flexible hose and diverting the water into the regular gully. The bed is then allowed to dry over a week or 10 days, and the slimy layer that would have caked up is removed. The soil is then lightly stirred and the loading resumed. A light sprinkling of sand or garden soil over the bed before resumption of loading will give the soil surface a healthy fresh look. Malfunctioning however will normally occur only if the load (i.e. the volume of grey water put on the treatment bed) is more than what the soil area can handle. In such cases, the treatment area will need to be increased. If only an ashen colour forms over part of the soil bed but no stagnation occurs, this could be because the water is not spreading over the entire bed area. Some levelling of the bed may solve the problem. If the water is spreading over the entire bed and the colour still persists, it would either mean that the soil area provided is inadequate or that the Canna growth may be slightly inadequate or the density of the Canna plants is inadequate. In such cases, full watering should be resumed only after some more growth of the canna plants with limited watering.

Picture 12.9 In this complex the sparable soil space for the bed was only 1ft wide but the required area was got by having a long stretch of the bed. The treated water goes into a shallow well from which water required for flushing of closets is taken. The balance percolates into the soil.The overall water management in this complex is very similar to that shown in Sketch 12.4 on page -108

Picture 12.10 The 1ft bed was close to a compound wall on one side and at the edge of a paved driveway on the other. Therefore walls were put on both sides You can see the dried parts of the plants fallen on the ground. If these are not removed, free flow of grey water over the bed is hindered. Note that the ;evel of the treatment bed is lower than the level of the driveway..

6. PRUNING OF THE BED:

Once in six or eight weeks, the matured Cannas must be pruned to facilitate fresh shoots coming up. Matured plants are those that bear some rounded seeds after having put out flowers earlier. These will not flower again. Pruning can be done either (i) by cutting off the stem just above the ground with a knife or (ii) more easily by holding the stem of the plant at the middle or slightly above and giving it a jerk with the hand slightly downwards (Not upwards or laterally). This jerk will result in the stem getting neatly cut just above the ground. A little practice will show how easily this can be done[30]. However, while doing so, care should be taken not to damage other adjoining plants. Pruning will result in fresh stalks of the plant coming up which will

30. Some of the plants may not break at the desired point but may come off with the tuber. One need not worry on this account

maintain the efficiency of the cleaning process. It also results in continuous blooming of the flowers, which adds to the greenery of the garden. Pruning should be done when there is no loading of the bed. Sometimes the free dispersion of the used water over the entire bed is hindered by too dense a growth of the plants in some pockets of the soil bed. In such a case, some of the plants may have to be removed *with the tubers* to facilitate free spread of the water. Free movement of the water may be hindered because of the dried leaves and stems of the plants falling on the soil bed and acting as barriers to the smooth movement of the feed water over the bed, if pruning is not done.

7. SOIL BED LEVELS:

a) If any depressions are formed on the soil bed, the feed water tends to stagnate in them. These should be filled up with some soil (b) At peak loading, the feed water should be seen to have spread on the entire bed so that the treatment load does not fall on any particular part of the bed. For this, the bed should have an even level all over.

8. IMPACT OF RAIN:

Rainfall does not normally interfere with the functioning of the bed even if it is heavy as the bed is actually handling the equivalent of several inches of rainfall during the peak loading of the used water on it in the mornings when all the inmates may have their baths and clothes also get washed. If however, the ground water table in the area rises to within 2 or 3 ft from ground level during the monsoon, the treatment may have to be temporarily stopped to avoid stagnation of the used water on the bed.

9. CHARGING THE TREATED WATER INTO THE SOIL:

If the objective is only to charge the treated water into the soil, then the process can become decentralized i.e. There could be several bathrooms separated from one another by fair distances. The outflow from each of the bathrooms can be treated on separate soil beds close to each particular bathroom and the treated water allowed to percolate downwards into the soil. Downward percolation would however take place only if the soil below the treatment bed is reasonably permeable. If the soil is highly clayey, the treated water may tend to travel laterally. In such cases, the treated water may have to be taken to a central collection unit.

10. .PHYSICAL COLLECTION OF THE TREATED WATER FOR REUSE:

Physical collection of the treated water for reuse would require the channeling of that water to shallow wells or sumps. To channelise the water, the bottom of the bed (or beds) has to be slightly sloped towards the collection unit. It also has to be made impermeable to water so that the water does not move downwards. This can be achieved either by having a layer of clay that is tamped well or by laying two layers of empty polythene cement bags or polythene sheets. If the soil at the bottom of the bed is already highly clayey, then these measures are unnecessary. At the end of each bed a small 2ft wide inspection chamber can be provided. From this chamber, the water can be taken to a sump. In case the water table is at a shallow depth, the water can be led into a shallow well. The water from the sump or the well can then be pumped into the cistern compartment of the overhead tank for flushing the closets (See Chapter 14). The advantage in diversion to a well is that it can continue to receive the treated water even if this water is not used for any purpose temporarily. Besides if the water used for flushing the closets is less than the water recovered, the excess water becomes part of the water table and can be used for other purposes via other water sources in the premises. If the rainwater trapped at the gates is being diverted into a shallow well or percolation pit, then the treated water can also be diverted into the same well or pit (See Sketches 12.3, 12.4 on page -108 and Sketch 12.5 on page -109).

11. TREATING WATER USED FOR CLEANING VESSELS:

The author's experience in this has been limited. Because of the higher organic content in this stream the area required is much more: While the area required has not been rigorously established, approximately 6-8 sq.ft seems to be needed per individual. In treating kitchen water outflow, it would be advisable to filter out the suspended matter in it (Chillies, vegetable pieces, onion pieces, curry leaves, rice crumbs etc.) before loading the treatment bed. This can be done using a plastic tray or waste paper basket that has perforated sides or bottoms. This will reduce the cleaning load on the soil. However, the suspended materials will soon clog the pores of the tray. So the tray will have to be cleaned once in two or three days.

Because of the large area required for treating this stream of water, attempts to purify this stream should be made only if liberal soil space is available. Otherwise, it is prudent to ignore this stream and treat only the grey water coming from bathing and washing of clothes.

12. QUALITY OF THE TREATED WATER:

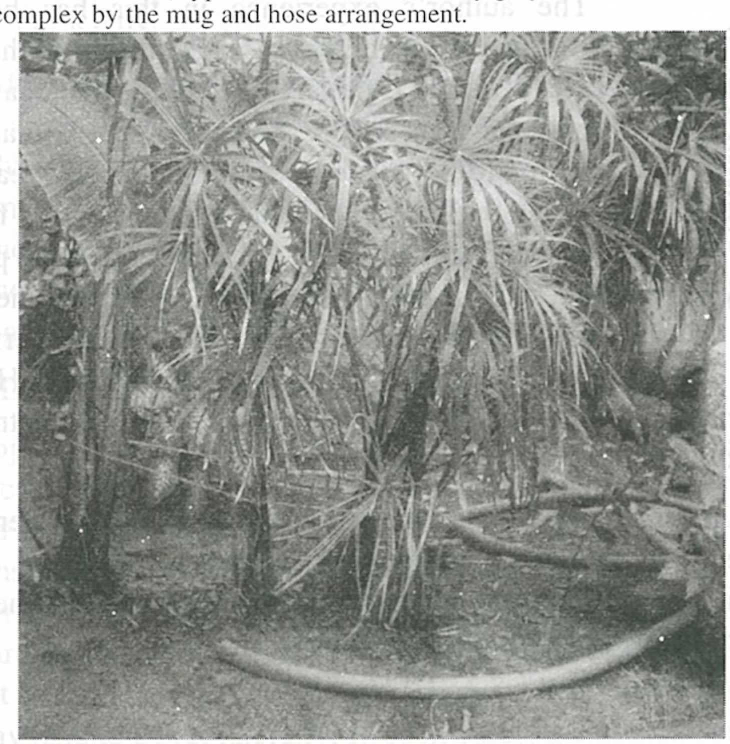
The outflow grey water consists of very small quantities of exhausted and unexhausted soap, unexhausted and exhausted detergents, some sweat, dirt, some urine and small quantities of inorganic salts like washing soda. The bacteria in the soil only consume the organic components in the grey water. The major organic compound present is Linear Alkyl Benzene Sulphonate (LABS for short), the main component of detergents All the organic compounds are biodegradable including LABS[31]. The small quantity of urine incidentally acts as a fertiliser and is used up by the plants. As soil does not consume the inorganic salts, the salt content of the water after treatment will marginally increase. Detergents contain a fair percentage of an inorganic compound called STPP or Sodium Tri Poly Phosphate. The phosphate in STPP acts as a nutrient for the plants and is mostly consumed under aerobic conditions. The residual phosphate, if any, poses no health risk in any use of the water. The treated water has been tested by the Chennai Metropolitan Water Supply and Sewerage Board and found satisfactory.

13. SUNLIGHT NEEDED

The efficiency of the entire process depends on the healthy growth of the plants used for the purpose. Therefore, the soil area on which they are planted should receive reasonable sunlight on normal dry days. If sunlight is inadequate, the plants may grow but may not put out flowers. Or else they may grow at a much slower rate. Even in such situations, the process would operate but would require more soil area. There may also be a faint smell of stale water, detectable only at close quarters.

14. TREATMENT USING PLANTS OTHER THAN CANNAS

Picture 12.11 Umbrella Plant (Cyperus alternifolius) fed by grey water in the author's apartment complex by the mug and hose arrangement.



It will be seen that the technique is not original but only a modification of the natural process that had been operating for long in our gardens in earlier days (See Chapter 3). The modification has been in introducing a semi aquatic plant like Canna in order to withstand heavy watering over a limited soil area. While the area requirements in using Cannas for the treatment have been

31. *See Industrial Applications of Surfactants III, Ed. by Dr.R.Karsa, (Proceedings of a symposium* organised by the Royal Society of Chemistry ,Northwest Region. Industrial Division at University of Salford), Harcross Chemicals (U.K) Ltd, Manchester, 199 , PP 63-81.

established, those interested can easily experiment with other water-loving plants like bananas, Hidechium coronarium(Ginger Lily), Colocasia and Cyperus alternifolius(Umbrella plant) and establish the required areas by trial and error. The procedure has to be similar i.e. after planting the particular variety, they should be watered normally till they are stabilised in the soil and start putting out shoots, after which the used water loading can be started. To arrive at the optimum areas, the key monitors are: (1) Formation of a slimy layer on top of the soil resulting in stagnation of the water for extended periods, and 2) Formation of an ash colour on the soil layer but no stagnation. If the first symptom is observed, rectification can be done as explained in para (3) above and either the water load on the soil bed can be reduced or the soil area increased. The second symptom could be due to any of the following three reasons:- (a) the plants have not grown sufficiently to take the load therefore loading should be reduced till the plant growth becomes denser; or (b) the soil area needs to be slightly increased; or (c) .the water is not spreading over the entire bed area and so the soil layer has to be levelled.

Picture 12.12 Banana Plant in the author's apartment complex fed by grey water. Notice the height of the plant and the abundance of fruits.

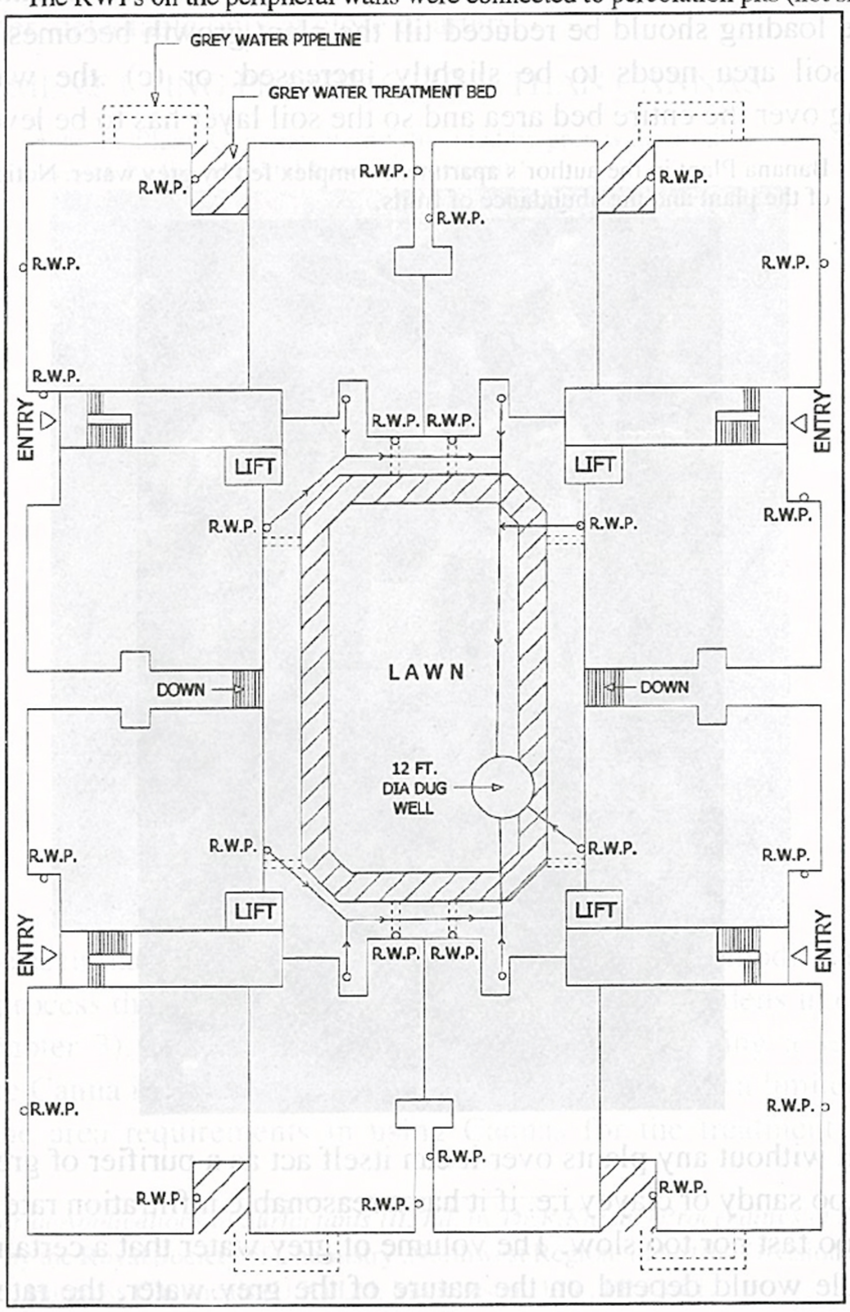
Plain soil without any plants over it can itself act as a purifier of grey water if it is not too sandy or clayey i.e. if it has a reasonable infiltration rate for water, neither too fast nor too slow. The volume of grey water that a certain soil area can handle would depend on the nature of the grey water, the rate at which water seeps through the soil and the amount of sunlight that the soil receives during the day. By using the two key monitors mentioned above, the volume of grey water that bare soil area can handle can be ascertained.

Apart from this, the grey water can be used directly to water normal garden plants also which are reasonably hardy and not too sensitive. The extent of loading will depend on the area of the garden and the type of plants. The optimum loading can be decided by careful monitoring.

15. INTEGRATING GREY WATER RECOVERY AND RWH SYSTEMS

If during construction of any building, planning for RWH and Grey Water are also considered, then both systems can be integrated with saving on financial outlay.

Sketch 12.2 Intergrated Water Management in a Block of 48 Apartments in a 124 Apartment Complex The RWPs on the peripheral walls were connected to percolation pits (not shown here).



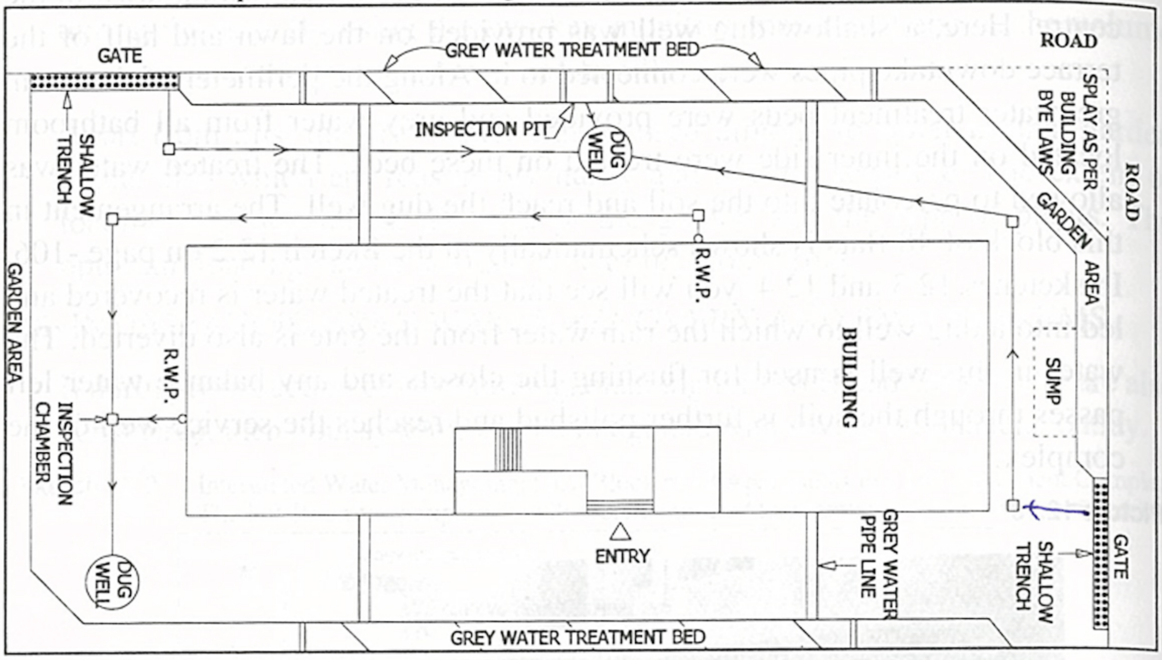
In Picture 12.13 you can see a four sided block of 48 flats with a lawn in the centre. Here, a shallow dug well was provided on the lawn and half of the terrace downtake pipes were connected to it. Along the perimeter of the lawn, greywater treatment beds were provided and grey water from all bathroom located on the inner side were treated on these beds. The treated water was allowed to percolate into the soil and reach the dug well. The arrangement in this block of 48 flats is shown schematically in the Sketch 12.2 on page -106. In sketches 12.3 and 12.4, you will see that the treated water is recovered and led into a dug well to which the rain water from the gate is also diverted. The water in this well is used for flushing the closets and any balance water left passes through the soil, is further polished and reaches the service well of the complex.

Picture 12.13

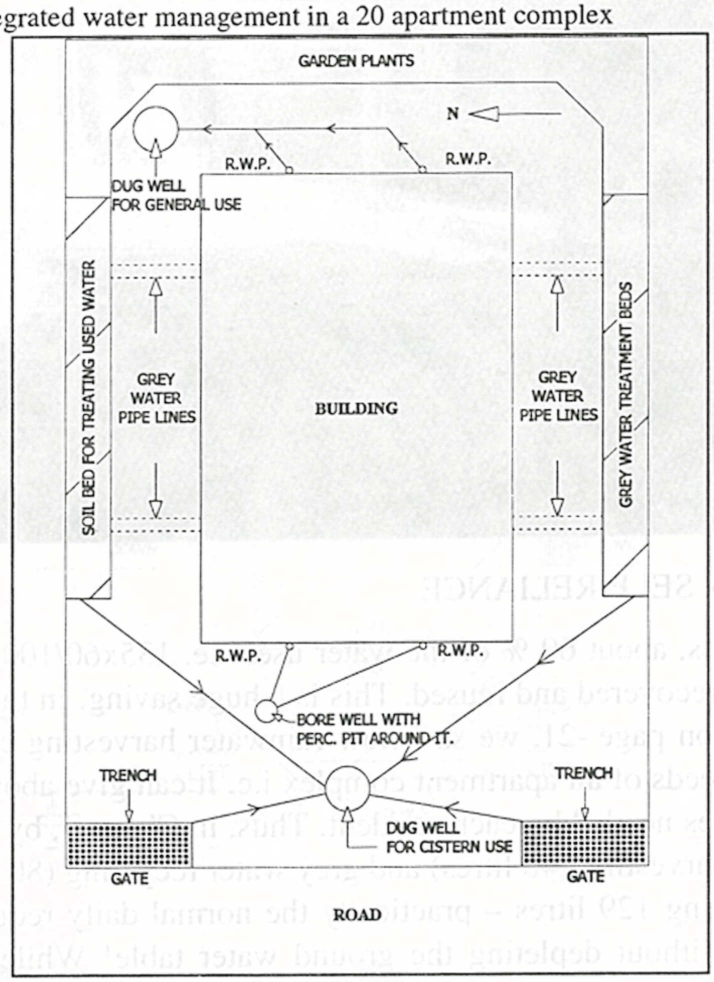
16. IMPACT ON SELF-RELIANCE

By this process, about 60 % of the water used i.e. 135x60/100 or 80 litres of water can be recovered and reused. This is a huge saving. In the workings for Chennai city on page -21, we saw how rainwater harvesting can meet about 35 % of the needs of an apartment complex i.e. It can give about 48 litres out of the 135 litres needed by each resident. Thus, in Chennai, by a combination of rainwater harvesting (48 litres) and grey water recycling (80 litres), there is scope for getting 129 litres – practically the normal daily requirement of an individual - without depleting the ground water table! While this dramatic situation can be attributed to the substantial average annual rainfall of 125 cm in Chennai, the recovery and reuse of the bath and cloth wash water that constitutes 50-60% of our total water usage is independent of the rainfall pattern. And this in itself is a huge jump towards self-reliance in any place, irrespective of the rainfall in that place.[32]

Sketch 12.3 Comprehensive water management system in an 8 apartment complex

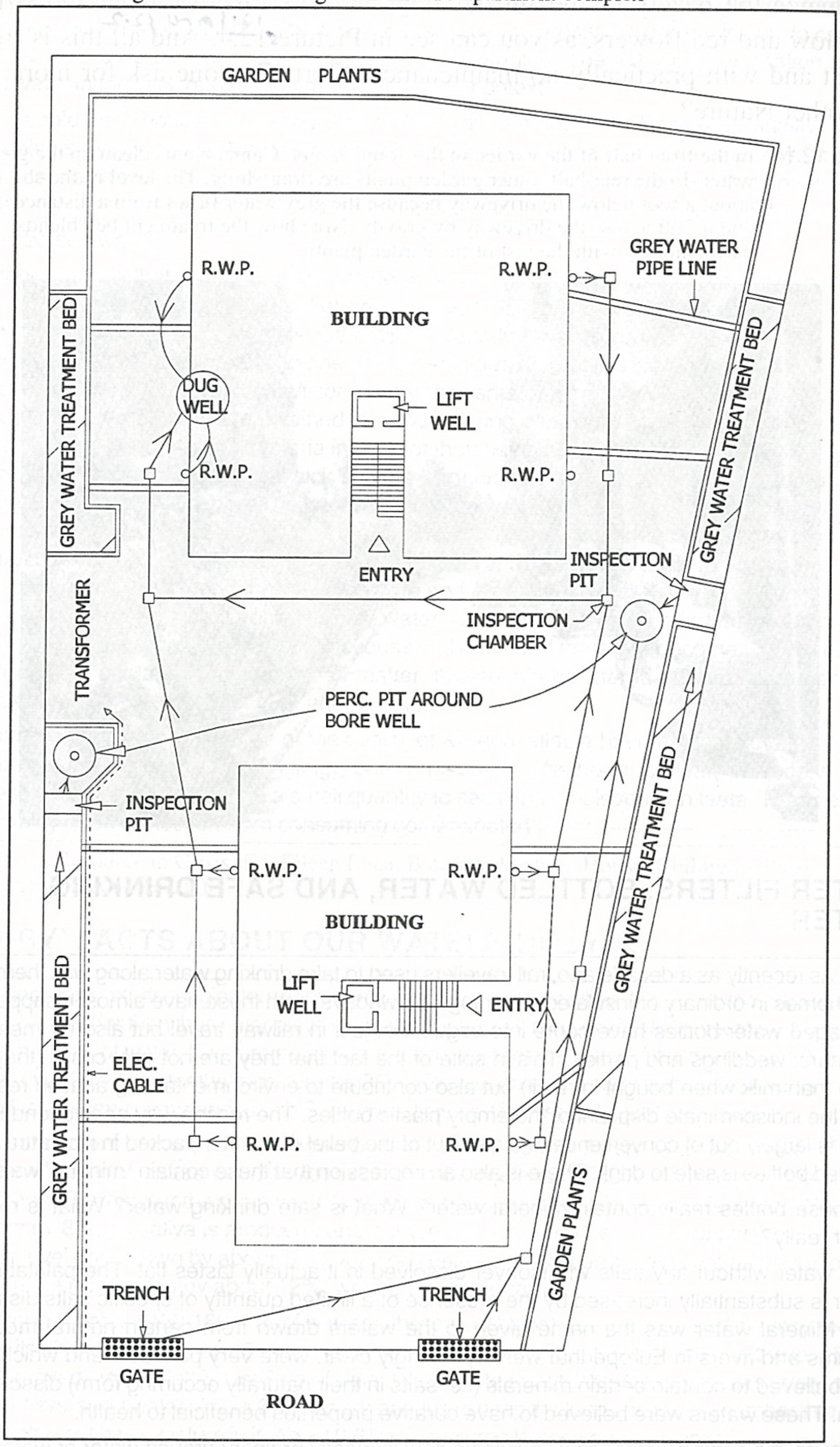


Sketch 12.4 Integrated water management in a 20 apartment complex



32. Although the emphasis in this chapter has been on domestic environments, the treatment process can be equally well utilised in hotels and hostels. If at the design stage itself, the internal plumbing is kept separate from the peripheral wall to the cisterns and the other service points, the treated water can be used safely for flushing the closets.

Sketch 12.5 Integrated Water Management in a 16 apartment complex



And if Cannas are the plants used, a well maintained Canna bed will not only purify 50% or more of the water we use and return it to the soil but it will also enhance the beauty of the surroundings with its lovely foliage and striking yellow and red flowers, as you can see in Picture 12.4. And all this is free of cost and with practically no maintenance effort. Can one ask for more from Mother Nature?

Picture 12.14 In the front half of the garden in this longish plot, Canna plants clean up the grey water. In the rear half, other garden plants are flourishing. The level of the soil is about a foot below the driveway because the grey water flows from a distance of about 20ft across the driveway by gravity. Note how the treatment bed blends harmonioulsy with the rest of the garden plants..

WATER FILTERS, BOTTLED WATER, AND SAFE DRINKING WATER

Even as recently as a decade ago, rail travellers used to take drinking water along with them from their homes in ordinary or insulated water jugs. Nowadays, both these have almost disappeared. Packaged water bottles have come into vogue, not just in railway travel but also for meetings, seminars, weddings and parties. This in spite of the fact that they are not only costly (they cost more than milk when bought in retail) but also contribute to environmental degradation resulting from the indiscriminate disposal of the empty plastic bottles. The reason why people tend to buy them is largely out of convenience and also out of the belief that water packed in nice attractively labelled bottles is safe to drink. There is also an impression that these contain "mineral" water.

Do these bottles really contain mineral water? What is safe drinking water? What is mineral water really?

Pure water without any salts whatsoever dissolved in it actually tastes flat. The palatability of water is substantially increased by the presence of a limited quantity of specific salts dissolved in it. Mineral water was the name given to the waters drawn from certain natural mountain streams and rivers in Europe that were sparklingly clear, were very palatable and which were also believed to contain certain minerals (i.e. salts in their naturally occurring form) dissolved in them. These waters were believed to have curative properties beneficial to health.

However, the bottled water widely available now is mostly ordinary ground water or water from a waterway, which naturally contains limited quantity of salts in it (100 to 150 ppm) or water whose salt content has been artificially reduced to this level.

Mere bottling of clear water with low salt content does not guarantee freedom from microorganisms. This is not to imply that all varieties of bottled water are unsafe to drink. It is only to caution the consumer not to be misled by mere cosmetic packaging. The following information about bottled water in the U.S. ought to be of interest in this context:

"Many people drink bottled water because of their concern about drinking water quality. Many water bottlers belong to the American Water Bottlers' Association that has established regulations for its members. But these regulations are no stricter than the regulations that govern public water supplies. And many of the contaminants found in municipal drinking water are also found in bottled water" [1].

The other practice that has come into vogue in recent years is the use of water filters in the house. Some water filters in the market are claimed to kill micro -organisms using ultra violet rays or iodine or silver iodide crystals. Other filters claim to have micro-filters that filter the micro -organisms. While ultraviolet rays, iodine and silver iodide do sterilise water and good micro filters can indeed destroy/inactivate/filter microorganisms, the efficacy of these appliances depends a lot on their being maintained in good working condition. In fact, non-maintenance can even lead to generation of bacteria instead of their being destroyed. This is particularly true of micro filters. If one does not fall sick in spite of drinking water that has passed through ill-maintained appliances, it can well be because the water would have been safe for drinking even before passage through the filter or that the individual has enough immunity not to be affected. The surest way to ensure that the water we drink is safe is to boil it vigorously for a minute or two (called "rolling boil"), cool, and then drink it. If we add ice cubes to chill it, we must be sure that the cubes had been prepared from sterilized water. Otherwise the entire effort is wasted as the water may have become contaminated because of the ice and therefore become unfit for drinking. If the water contains any suspended matter, this should be filtered off through a piece of clean, closely- woven cloth prior to or after boiling.

In situations where one is not sure of the quality of water available but may have to drink it, (as for example, in the course of travelling), one must check whether it is clear, colourless and odourless. One must also sample a small quantity to see if it is wholesome in taste. These criteria offer fairly good protection from consuming contaminated water.

1. Water –A Resource in Crisis, Ed. Eileen Luca, B & B Publishing House, Children's Press, Chicago, U.S.A., 1991, p,84.

'WATERY' FACTS ABOUT OUR WATERY BODY.....

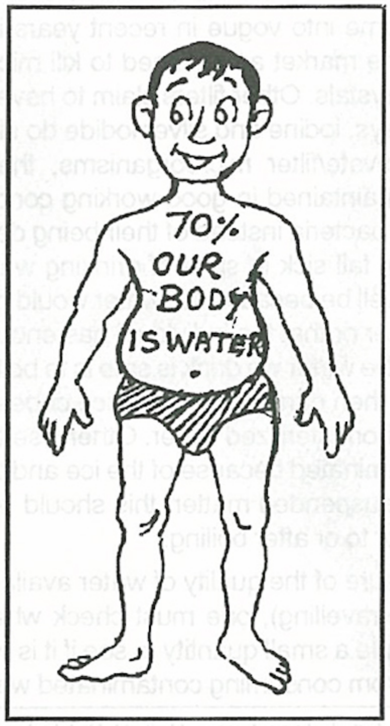
The earliest form of life originated from water. Subsequent evolution led to Homo Sapiens or humans. No wonder then that water plays such an important part in our life. Just look at our body: 70 % of it is made up of water. If we are talking of the brain, 90 % of it is water. If it is the blood or the kidneys, it is over 80 % and for the muscles, it is 75 %. Bones are less watery with 20 %. And all this is as true of tough army commandos and Sumo wrestlers as it is of spindly gents and ladies!

If the water content of the body falls down by even 0.5%, we feel thirsty. A 2 % drop can affect short - term memory, cause trouble with basic calculations and difficulty focussing on the computer screen: Remember the brain is 90 % water! If it falls down by 5% we feel feverish. When it falls down by 8%, no saliva is produced and our tongue and throat feel dry and parched. When the water level goes down by about 10%, we won't be able to walk and may have hallucinations. And when the level drops by about 12%, we are close to death.

Our kidneys filter about 150-160 litres of water (in the form of blood) a day, but most of it is recycled in the body itself, with only about 1.5 - 2 litres being excreted as urine. If all the water in these 1.5 -2 litres is removed, what is left is just 80 g of solid. We excrete about 300 -450g of faeces every day, but 75 % of this is just water. About 0.4 litres are needed to keep the lungs moist. Remember that the air we breathe out has moisture in it. About 0.6 litre is required to keep our skin moist.

Every day, we have to drink about 1.5 to 2 litres of water in order to make up for the water lost in urine. We however have to drink more in summer to regulate our body temperature: Surplus warmth produced by physical activity is neutralised by the loss of water through perspiration. A person working for eight hours in an environment of 18° C (64° F) can lose 4 litres of water in perspiration and at 30° C (86° F) as much as eight litres.

If we want to live a long, healthy and active life, we can't take out good health for granted. Nor can we therefore take water for granted. Let us recognise the vital role played by water for our continued good health and give it the respect and value that it deserves!

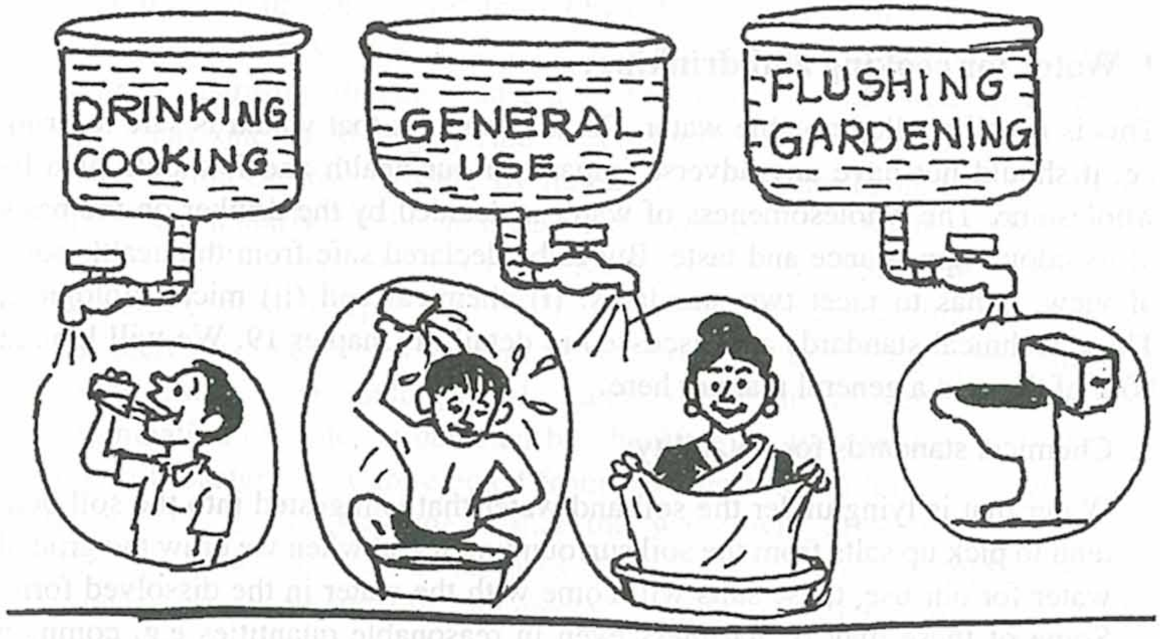


.......AND THE FANTASTIC WATERWAY IN IT!

If 70% of our body is made up of water, how is this water distributed in it? An average adult human body has about 40 litres of water in it. Of this, about 25 litres are inside the cells and 12 litres in tissue fluid. Blood plasma contains about 3 litres. These 3 litres are spread over a fantastic waterway - the blood stream - which is an intricate extensive waterway that stretches over 1,12,000 kilometres! A distance equal to a train going up and down between Kanyakumari and Delhi eighteen times! And like the train, the blood which is constantly on the move over this 1,12,000 kilometres, keeps continuously carrying items to various parts of the body waste products like urea in the venal blood and energy giving items in the arterial blood like oxygen for the lungs and nutrients for all the tissues, vital to our very survival.

Incidentally, this fantastic waterway is a very salty one. Blood is almost as salty as seawater itself!!

CHAPTER 13



USING WATER OF DIFFERENT QUALITIES ADVANTAGEOUSLY

(Good quality water is not needed for all of our daily needs but we often end up using it for a purpose that does not require that quality. This chapter details the qualities of water needed for our various daily needs and how we can advantageously use available water for these different needs.)

We use water in our daily life for many purposes. Chief amongst these are for:

1. Cooking and drinking
2. Cleansing of teeth and the mouth
3. Bathing and washing of clothes
4. Washing of vessels and vehicles
5. Watering of plants in the garden
6. Cleaning of floors, windows and paved areas around the building
7. Flushing of closets (after urination and defecation).

The quality of water required for these seven major areas is not the same. The highest quality required is for cooking and drinking and the lowest is for flushing of closets. Water suitable for one particular usage in this list is suitable for all other uses that follow it. In order to utilize available qualities of water advantageously and at the same time ensure that our health and hygiene are not affected, we need to know more about the quality of water required for these various uses.

1. Water for cooking and drinking:

This is usually called potable water. Potable water is that which is safe to drink i.e. it should not have any adverse impact on our health and it should also be wholesome. The wholesomeness of water is decided by the drinker on the basis of its odour, appearance and taste. But to be declared safe from the health point of view, it has to meet two standards: (i) chemical and (ii) micro-biological. These technical standards are discussed in detail in Chapter 19. We will look at both of these in a general manner here:

1. Chemical standards for potability:

   Water that is lying under the soil and water that is ingested into the soil both tend to pick up salts from the soil surrounding it and when we draw the ground water for our use, these salts will come with the water in the dissolved form. Some of these may be harmless even in reasonable quantities e.g. common salt (sodium chloride), washing soda (sodium carbonate); some up to certain limits e.g. magnesium sulphate or epsom salt (used as a purgative); and some are harmful even in very minute quantities (e.g. lead salts, mercury salts, cyanide).

   Fortunately ground water does not generally contain the salts in such a quantity as to have any acute effects on consumption and salts that are dangerous are not normally present in water. Also our instinctive rejection of water on grounds of unacceptable taste, odour and appearance itself is an in-built safety factor. Besides, when we talk of the salt content in water, the unit used is generally "**ppm**" i.e. **p**arts of the particular salt (or salts) present **p**er **m**illion parts of water! The situation alters drastically in areas where the wastewater (effluents) from dyestuff and other chemical industries and tanneries is discharged on to the ground or into waterways without any prior treatment. In some parts of our country, particularly West Bengal, ground water contains Arsenic salts that cause many life-long disabilities to those drinking it. In several other parts, the fluoride content is high which impacts on the teeth and the bones. In some areas, the ground water is highly brackish and therefore undrinkable. In all such areas rainwater harvesting is a tremendous boon - For, it is free of all salts and so can be collected in suitable storages and used safely for drinking.

   In this context it is worth noting that rainwater is water of very high purity with negligible dissolved salts in it. Therefore if rainwater is harvested and ingested into the soil, it will mix with the ground water and thereby dilute the salt content.

2. Microbiological standards for potability:

The much bigger risk to our health arises from our intake of water contaminated with human and animal faecal matter. Human and animal waste matter contains a variety of bacterial, viral and protozoan pathogens and helminthes parasites that can cause intestinal and other infectious diseases. In urban areas, one could largely rule out contamination with animal wastes but contamination of ground water by human faecal matter cannot be ruled out. This is particularly likely in areas that have poor or inadequate sanitary facilities, or in areas that do not have sewerage facilities, and sewage is disposed of through septic tanks. The scope for such contamination in these areas increases in the rainy season, particularly in coastal areas where the soil is very sandy and underground water movement is very fast. Faecal contamination of water is detected by checking for the presence in water of the E coli bacteria that are ejected from our intestines in huge numbers. The presence of E coli will mean that the water will also contain harmful pathogens that can cause diseases like typhoid, cholera and amoebic dysentery, as these pathogens are ejected from the intestines along with the E coli. Substantial contamination of the water will be indicated by its unpleasant or foul odour, appearance and taste. Low levels of contamination however, may not be easily detectable but if used in cooking where it is heated to boiling, it gets automatically sterilised. But such water should be used for drinking only after specifically sterilising it.

The simplest and surest way to destroy any possible harmful pathogens that may be present is to boil the water vigorously at least for 2 minutes and cool it prior to drinking.[33] Many urbanities use water purifiers that claim to destroy bacteria by exposure to U.V., Iodine or by micro-filtration. While these purifiers may free us from the need to regularly boil and cool water, the efficacy of these purifiers depends on their being maintained properly.

2. Water used for cleansing of teeth:

Ideally the water used for cleansing of the teeth should be free of all faecal pathogens i.e. the water either should have been treated adequately or should be from a source known to be free of such contamination. Since such water may not be as readily available as desired, one has to consider the risk in using untreated water for cleansing the teeth. Since the water used for this purpose is spit out fairly completely, the scope for any possible infection is very low, unless the individual swallows the water – which is extremely rare. Moreover, the acceptable quality of water for this purpose is invariably influenced by its appearance, smell and

33. As per WHO, one or two minutes' of vigorous boiling will kill or inactivate cells of bacteria and viruses as well as the cysts of Giardia. See Guidelines for Drinking Water Quality, Vol.I, II Edition, WHO Office, New Delhi, 1993.

taste. This is a strong in built safety factor. So, the risk factor in using untreated water for this purpose can be considered to be low.

3. Water for bathing and washing of clothes

Soap lathers easily in some waters and not at all in others. If rainwater be used with soap, the lathering takes place with great ease, while brackish water gives a lather only with difficulty; and with sea water there is no lathering at all. Water that gives a good lather with soap is called soft water. Water that gives a poor lather with soap is called hard water. Therefore, for bathing and washing of clothes, the water should be soft.

Hard water gives poor lather with soap because it contains more than desired quantities of calcium / magnesium bicarbonate or calcium/magnesium sulphates, all of which react with soap forming an insoluble product which separates out and thereby stifles the lathering effect of soap. Once all these salts have reacted thus with soap, the water becomes soft and starts lathering with soap. In the process, considerable wastage of soap occurs while bathing as well as while washing clothes. While the WHO has laid down standards for drinking and cooking purposes, it has not laid down any standards as to which water is unfit for bathing or washing of clothes. This therefore indicates that suitability of water for bathing is decided mostly by appearance, ease of lathering with soap and the sense of freshness experienced by the skin after a bath.

4. Washing of vessels and vehicles

Where soaps are used for washing vessels, hard water will be found unsatisfactory for this purpose. If scouring powders are used, hard water may prove adequate. However, hard water or brackish water, if used, may leave a film of fine deposits on the vessels when they are dried - these being the salts dissolved in the hard or brackish water which are left behind when the water evaporates. This effect can be reduced substantially, if not fully, by dipping the washed vessels in a tray containing soft or potable water.

A similar procedure can also be applied for washing vehicles. Wash them first with the hard or brackish water and then give a rinse with soft water or wipe with a cloth dipped in soft water.

5. Water for garden plants and shrubs

The quality of water needed for a garden would depend on the type of plants involved. Some plants, particularly those grown indoors need water with minimal dissolved salts but others like the coconut palm can stand brackish water. Young plants in the garden may not thrive on brackish water but once matured (say after 3 to 4 years) they would stand brackish water to a much greater extent.

6. Cleaning of floors, windows and paved areas around the building:

These activities do not require much quantity and the quality is not critical.

7. Water for flushing closets

As the purpose of this is essentially to flush out urine and faecal matter from the closets into the sewage line, the quality is not critical, where hand flushing is involved. Where the flushing is from a cistern, the concealed pipe line bringing the water from the peripheral wall of the building to the cistern is generally made of G.I. Very brackish water, therefore, particularly water containing chlorides and sulphates is likely to corrode the G.I piping. Nowadays, special PVC piping is available for replacing the G-I piping and this is not affected by brackish water. However, there could be a slow deposition of salts on the walls of the PVC piping which may eventually lead to clogging.

8. Overview

From what has been detailed above, we see that, if in a particular plot of land, several qualities of water are available from ground water and treated water supply, we can use these different qualities appropriately without mixing the good quality water with water of lesser quality. Such advantageous usage however becomes practicable only if we have an appropriate overhead tank system that can store water of different qualities and supply them within our homes separately. In the next chapter, we can learn about such a system which is easy to install and versatile in serving the needs of apartment complexes

CHAPTER 14

DISTRIBUTION OF WATER IN HOUSING COMPLEXES

(Where a house or an apartment complex has access to more than one quality of water, the different qualities of water can be advantageously used if an overhead tank with three compartments is installed. Such a tank is capable of storing water of one, two or three different qualities as per their availability and supplying them for appropriate uses. Details of this versatile storage system and the manner in which it can be exploited are detailed in this chapter.)

The Three-Compartment Overhead Tank

The most fortunate among urbanites are those who get ground water of potable quality from their own premises and so can be totally self- reliant in their water needs. There are also the lucky or more favoured urbanites who get all or most of their water needs from the treated water supply of the water authorities. Thereby this water which is of the highest (potable) quality gets used for needs where a lower quality of water would have sufficed. This is a highly wasteful use of a precious commodity i.e. drinking water. It is particularly wasteful to use potable quality water for flushing of toilets and cleaning driveways or vehicles. In many places, groundwater of lower quality will be available but is not put to use because the overhead tank has only one compartment and so can store and supply only the potable quality of water. Consequently there will be inertia to alter the status quo. In many other cases, particularly in apartment complexes the overhead tank is provided with two compartments - one for storing and supplying the limited quality of treated (potable) water and the other for storing and supplying water of lower quality for all other bulk uses. While this is no doubt a better arrangement, there are many premises where the ground water is tapped from more than one source but the qualities differ. In such situations, both qualities have to be mixed out of necessity because only one compartment is available for storing water for non-potable needs. Thereby the residents lose the opportunity to use the better quality ground water for bathing and washing and the inferior quality for flushing the cistern.

Therefore, in order to use available water of different qualities appropriately, what is needed is a system that can store waters of different qualities and distribute them to the different usage points within the home or flat. Such a system is the three compartment overhead tank that has been operating excellently in over 200 apartment complexes in Chennai in whose contruction the author was involved. The design, utilisation and versatility of this system are detailed below.

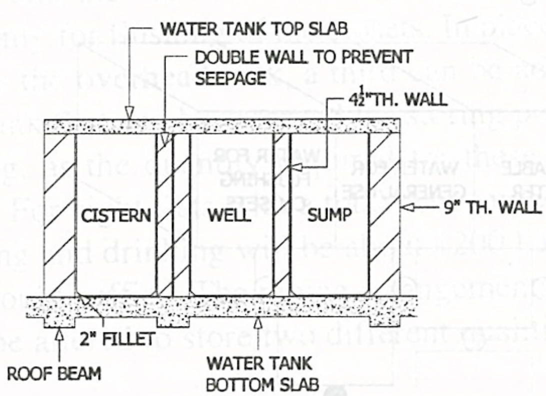
The Versatility of the Three Compartment Overhead Tank

If we look carefully at the seven major uses of water we had listed in the previous chapter, we will notice that they can be broadly grouped into three categories.

1. For cooking, drinking
2. For bathing, washing of clothes and vessels, and wiping/washing of floors and windows
3. For flushing of toilets

With an overhead tank with three compartments, we can store water of three different qualities, appropriate for these three uses. The lines from each compartment can then go to the respective usage points.

Sketch 14.1

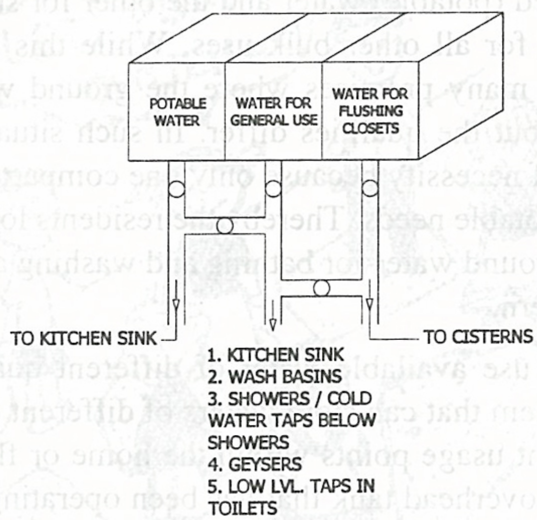


The system has the flexibility to adjust to a variety of situations by mere adjustments one or more of the five valves involved. This is illustrated below:

Situation 1 : When potable water availability is abundant

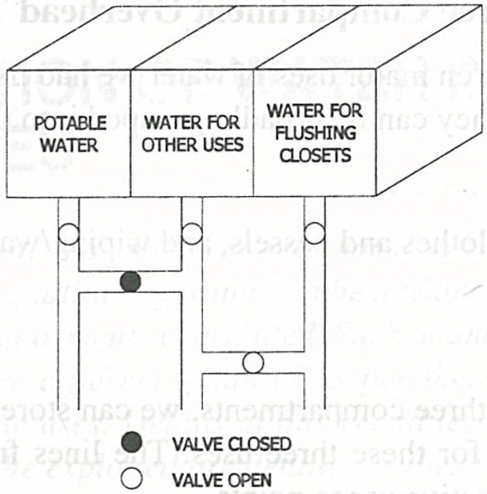
This is a very happy situation and can be taken advantage of as below:

Sketch 14.2



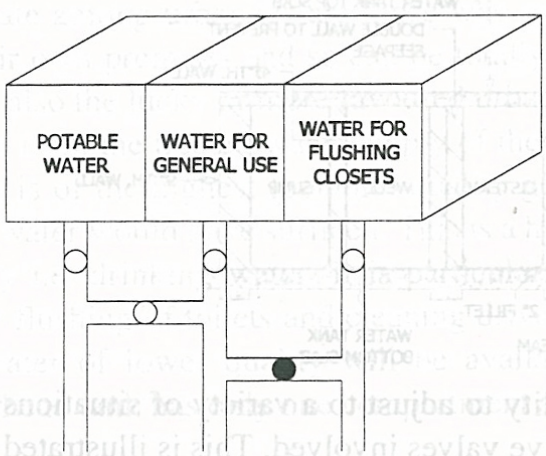
Situation 2 : Fair amount of potable water available and also ground water satisfactory for bathing.

Sketch 14.3 14.4



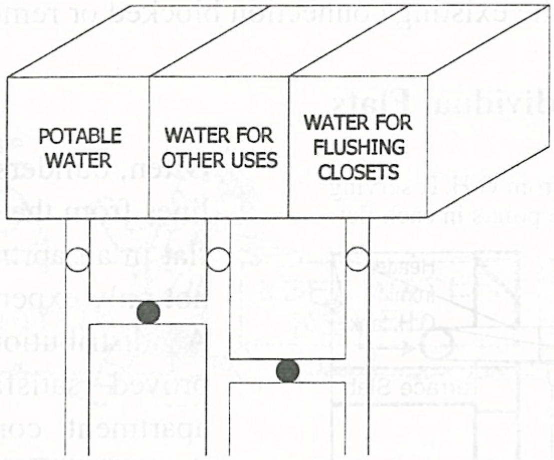
Situation 3 : Limited potable water available. Abundant availability of water, satisfactory for bathing.

Sketch 14.4 14.3



Situation 4 : Potable water availability limited but water satisfactory for bathing available in moderate quantity as also very brackish water.

Sketch 14.5



Situation 5: Potable water available in extremely limited quantity.

In such a situation, then capacity of one compartment is wasted. The potable water can more advantageously be stored outside somewhere and only non-potable ground water is stored in the overhead tank. If only one quality of ground water is available, this is filled up in all the compartments. If two qualities are available, then the worse quality is filled up in the flushing compartment and the better quality water in the other two compartments.

One other advantage offered by the three-compartment overhead tank is that each individual compartment can be cleaned without suspending supply to any service point, by appropriate setting of the valves.

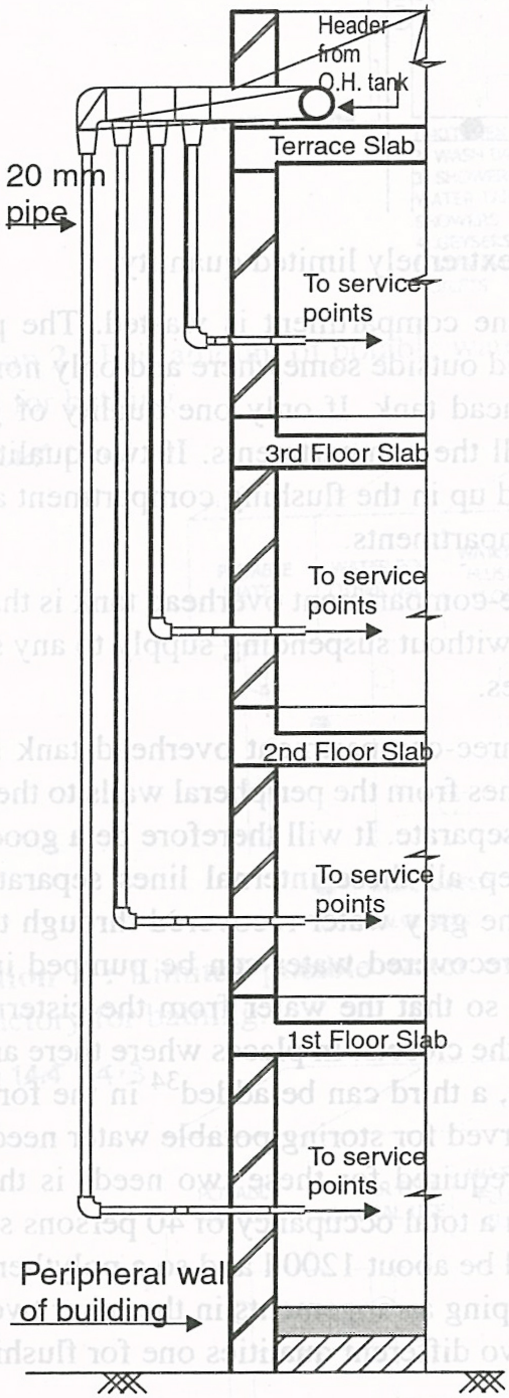
The great flexibility available in the three-compartment overhead tank system can be utilised only if the internal pipelines from the peripheral walls to the kitchens, bathroom taps and the cisterns are separate. It will therefore be a good practice for architects and designers to keep all these internal lines separate This overhead tank also enables the use of the grey water recovered through the soil treatment detailed in Chapter 12. This recovered water can be pumped into the cistern compartment and the valves set so that the water from the cistern compartment is utilised only for flushing of the closets. In places where there are only two compartments in the overhead tank, a third can be added[34] in the form of a separate polythene tank that can be reserved for storing potable water needed for cooking and drinking, as the quantity required for these two needs is the least among all the needs. For eight flats with a total occupancy of 40 persons say, the daily need for cooking and drinking will be about 1200 l and so a polythene tank of 1000 or 1500 l should suffice. The piping arrangements in the other two compartments can then be altered to store two different qualities one for flushing the

34. This may not be possible in all cases

cistern and the second for other general uses. Such an arrangement tantamounts to having a three-compartment tank but with slightly reduced versatility. In such a conversion, separate internal lines need to be provided to the cisterns from the peripheral wall and the existing connection blocked or removed.

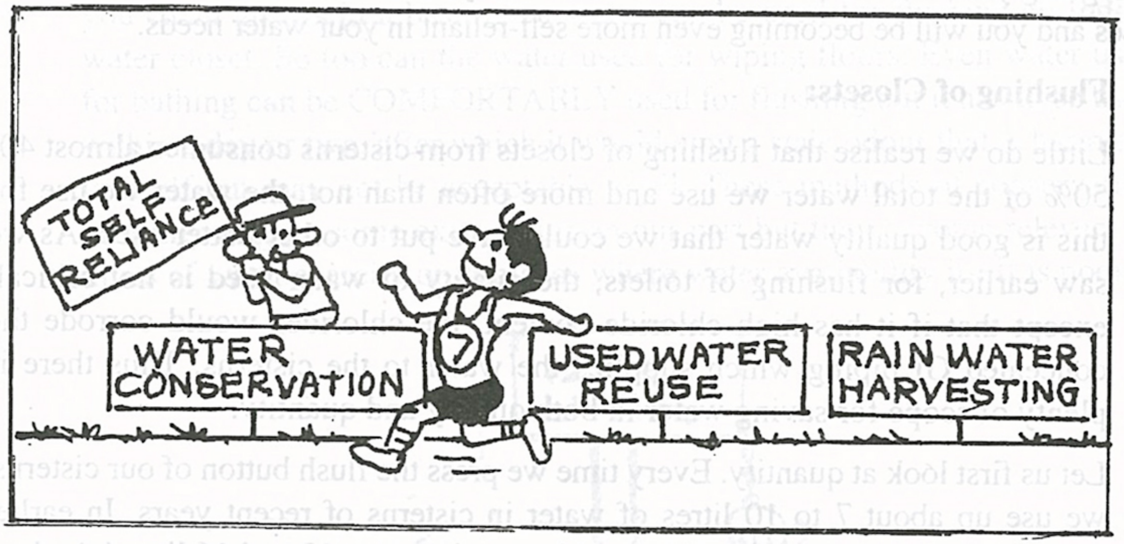
Distribution to Individual Flats

Sketch 14.6 Piping from O.H.T. serving multiple points in each flat.



Often, builders give individual pipelines from the overhead tank to each flat in an aprtment complex. This is not only expensive but unnecessary. A distribution system that has proved satisfactory in numerous apartment complexex with which the author was involved is illustrated in Sketch 14.6.

CHAPTER 15



THE LAST STEP IN TOTAL SELF-RELIANCE: WATER CONSERVATION

(Whatever the quantity of water we have access to, it will last us longer, if only we use it economically and effectively. Various methods of doing this are described in this chapter.)

'A penny saved is a penny earned' goes the old saying. So too a litre of water saved is a valuable litre of water made available for future use. We usually think of conserving water only in times of shortage. But even in normal times, there are many ways in which water can be saved with very little effort on a daily basis which will add up to substantial volumes. Some of these involve only a one-time effort. Others require implementation on a daily basis that too becomes simple if only we keep reminding ourselves that water is a precious commodity and we cannot afford to waste it.

One of the most common forms of wastage arises from the belief that water on storing gets spoilt and should not be used. So, we tend to throw away water stored by us yesterday and in its place store water afresh today. Nothing can be further from the truth than the belief that water deteriorates on storage. **Water which does not contain any dissolved or suspended organic compounds is a very stable entity and can be kept covered, in a clean container for days, weeks and even months without any change in quality, provided it is kept in a closed container and not exposed to sun light.** It is only used water, particularly water used for washing vessels employed for cooking and dining, that will start smelling (because of its high organic content) in a matter of days or even hours, if stored without exposure to sunlight and air.

foregoing your comfort. In the process the water you save will be available for other uses and you will be becoming even more self-reliant in your water needs.

1. **Flushing of Closets:**

Little do we realise that flushing of closets from cisterns consumes almost 40-50% of the total water we use and more often than not, the water we use for this is good quality water that we could have put to other better uses. As we saw earlier, for flushing of toilets, the quality of water used is not critical, except that if it has high chloride content, the chlorides would corrode the concealed GI piping which supplies the water to the cisterns. Thus there is plenty of scope for saving water in both quality and quantity.

Let us first look at quantity. Every time we press the flush button of our cisterns, we use up about 7 to 10 litres of water in cisterns of recent years. In earlier models of cisterns, this quantity would range between 12 and 16 litres! And we are likely to use the flush 5 to 6 times in 24 hours! What a waste of water!

There are several simple means of reducing this quantity:

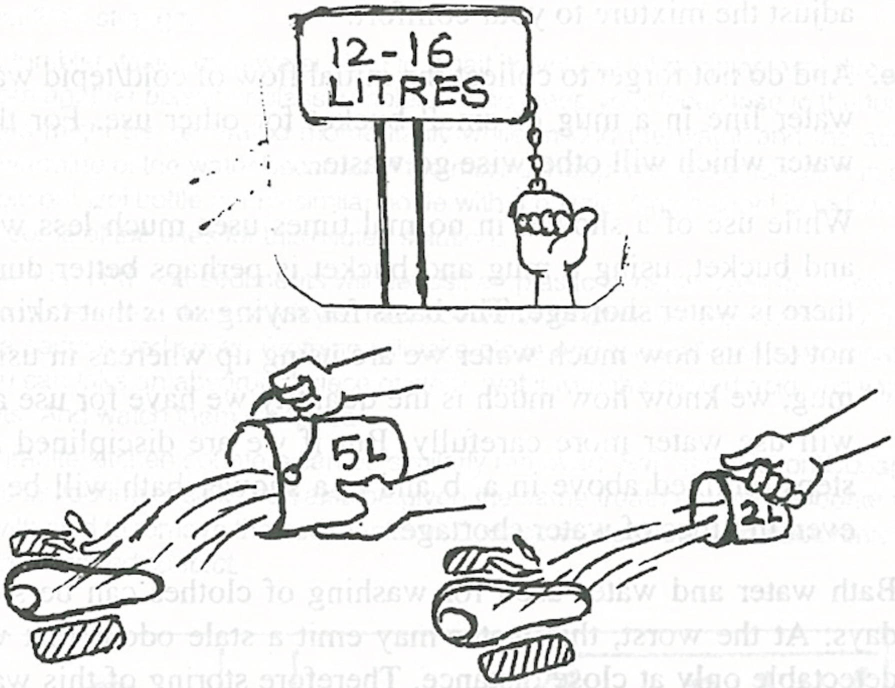
a. Every cistern today has a float arrangement inside which can be set at various levels from a minimum volume to a maximum volume to be flushed. By setting the float at its minimum level, in 99% of the cases, the water will be adequate for satisfactory flushing off faecal matter from the closet. In the 1% of the cases where it is not, all we need to do is to wait for the cistern to fill up and flush it again.

b. If you have an earlier model of cistern that flushes 12 to 16 litres, often the internal flushing system can be replaced by the current plastic version that will reduce the quantity flushed.

c. If this is not possible, you can keep a brick or two vertically (i.e. with its longer side being vertical). Each brick will reduce the quantity flushed by about a litre. The brick however may become soft at the edges over the years and the water may become coloured. At this stage, you can replace the bricks. Alternately, you can keep one or two plastic mineral water bottles inside the cistern, after filling them with water and tightly stoppering them.

d. If you have an Indian style water closet (i.e. the squatting type), hand flushing with a small 5 litre bucket will be adequate for flushing out the faecal matter. Even 3 to 4 l is often adequate. The author has found that effective flushing is also possible with two or three mugfuls of water thrown from a foot above the closet with some force.In an Indian style water closet, there is no need to flush after urination. You can fill a plastic mug of 1litre capacity with water and pour it into the closet slowly to wash off the urine with no compromise on hygiene. This simple practice can result in your saving at least 30 to 60 litres of water per person on each day.

e. As we saw in chapter 13, the quality of water for flushing is not critical. If you clean greens in a basin, that water can be used for flushing an Indian water closet. So too can the water used for wiping floors. Even water used for bathing can be COMFORTABLY used for flushing but it has to be used within a day or two, after which it would emit a stale odour that is harmless in itself but may not be acceptable to all. These methods of conservation certainly require some extra effort on our part but they become relevant in times of water scarcity or in places where water availability itself is poor.



2. Bathing:

Between a bath with a bucket and a mug, and a bath with the shower, the shower is much more efficient and saves considerable amount of water (40-50%). It is more efficient because it hits the skin with force and thereby removes the soap more effectively. Besides the water hits the body in multiple streams and so the same volume of water as used in one mugful would cover a much larger area of the body. Where one takes a shower in the standing condition the water travels from top of the body down to the legs and therefore removal of soap is much more efficient. However, there are a few disciplines you have to observe:

a. Periodically clean the shower- head so that the spray holes do not remain clogged and the water comes in multiple streams. Often brackish water tends to deposit salts on the shower- head resulting in the holes being blocked. The showerhead can be easily cleaned by first unscrewing it and then directing a jet of diluted cleaning acid over its holes[35]. Frothing will occur and the deposited salt will be removed. Give a final wash with water

35. See boxed item below on "Cleaning Acid – Home Maker's Friend"

and re-fix the showerhead. It is a good idea to use fully stainless steel showerheads in areas where the water is hard or brackish.

b. Keep the flow in the shower stream just enough for your needs. Extra water will only go waste.

c. While soaping, close the shower.

d. If you have a hot water bath, open the hot water tap first partially and wait till the water is felt to be hot. Only thereafter open the cold -water tap and adjust the mixture to your comfort.

e. And do not forget to collect the initial flow of cold/tepid water from the hot water line in a mug or small bucket for other use. For that is also good water which will otherwise go waste.

While use of a shower in normal times uses much less water than a mug and bucket, using a mug and bucket is perhaps better during times when there is water shortage. The basis for saying so is that taking a shower does not tell us how much water we are using up whereas in using a bucket and mug, we know how much is the quantity we have for use and instinctively will use water more carefully. But if we are disciplined and observe the steps outlined above in a, b and c, a shower bath will be more economic even in times of water shortage.

Bath water and water used for washing of clothes can be stored for several days. At the worst, this water may emit a stale odour that will however be detectable only at close distance. Therefore storing of this water and using it for flushing of toilets can result in considerable saving of good fresh water.

A dedicated rainwater harvester and also an active campaigner for it in Chennai recollects how in his early days in his first job he was posted in a water - scarcity area of Andhra Pradesh and had to stand in a wide basin while bathing with a mug and bucket. The water so collected in the basin had to be stored and used for flushing the toilet. An architect in Bangalore who is also a rainwater enthusiast and active campaigner for the same has diverted the bath and clothes wash water from his first floor bathroom to a loft tank in the ground floor bathroom and he uses this water for flushing the closet there. Such water can also be stored in a big bucket and used for hand flushing of Indian water closets or for watering the garden plants.

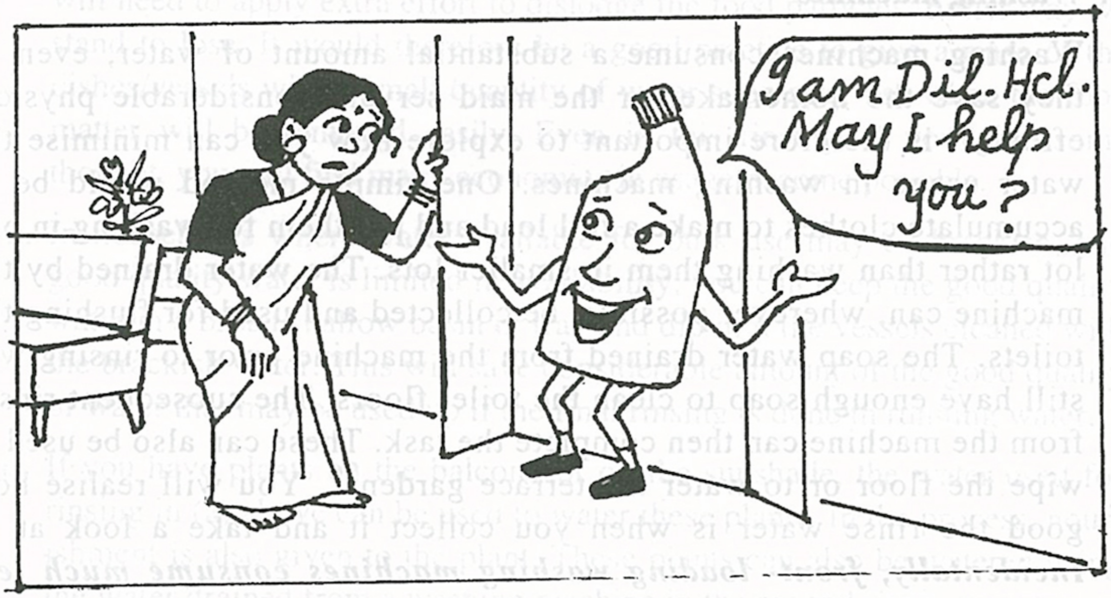
CLEANING ACID: THE HOME MAKER'S FRIEND

Acids are invarialby assumed by people to be very corrosive and dangerous to handle. This is true generally of all inorganic acids but not of organic acids e.g. citric acid, acetic acid (vinegar). Of the three widely used inorganic acids, nitric acid and sulphuric acid in their concentrated form should indeed be handled with great care – For, if spilled on the skin, they will eat it away. But the third, concentrated hydrochloric acid, poses no such danger. Even if one puts a finger into it by mistake, nothing catastrophic will happen. Not surprisingly therefore hydrochloric acid can be bought off the counter from grocer's shops, under the name of "cleaning acid". This is indeed a very appropriate name for it as it can do a number of useful cleaning jobs for the homemaker. The acid available from grocer's shops is actually hydrochloric acid already diluted from the original 30% to about 20% strength.

In a glass or plastic tumbler, take some water. Add to it half its volume of cleaning acid directly from the bottle or from another plastic or glass tumbler. Do not keep your face close to the tumblers as an acid gas might be generated momentarily while mixing the water and the acid. There will be slight warming of the water because of the mixing. Keep this diluted solution in an empty washed Harpic or Lizol bottle or in a similar bottle with a nozzle. Cap it, label it and store it. The following are some of the uses for this diluted solution:

1. If your ground water is hard, salt sediments will deposit on plastic buckets used for washing clothes, or on stainless steel vessels in which you may boil water for drinking. Squirt some of the diluted acid over the sedimented spots. Frothing will take place and the sediments will disappear. Alternately you can take an absorbent piece of cloth, wet it with the diluted acid and wipe the sedimented spots. And watch them disappear.

2. Salt deposits on granite kitchen counters can be similarly removed. Salt deposits on Cudappah kitchen counters or flooring of sinks can also be given the same treatment but it is better to use a cloth wetted with acid to remove the sediments on Cudappah, as dilute acid does have a minor impact on it *on extended contact.*



3. Chrome plated taps tend to be covered with a whitish or creamish coating of salts, particularly those that are not used daily. Wiping these with a cloth wetted with the diluted acid will render them shiny and free of the salts. There is no need to apply any pressure. Gentle and patient wiping will do the trick. The chrome plating will be unaffected by the diluted acid.

Never try to remove salt sediments from chrome plated fittings using any scouring powder or steel wool. This abrasive action will remove minute particles of the chromium plating and expose the brass below ('pittings') that will start forming a green patina thereafter. *This damage is irreversible*

4. The diluted acid removes salt sediments from ceramic tiles. Hard to remove sediments can be removed by wiping with a more concentrated acid solution (one volume diluted with equal volume of water). Care should be taken to avoid much contact of the acid with the tile joints as the cement in the joints is affected by concentrated acid.

5. The fine holes of the shower-head are often clogged by salt deposits and reduce the effectiveness of the water spray. Dropping some diluted acid on the spray plate will eat away the sediments and the spray head will become effective again. An effective spray not only results in a more refreshing bath but also saves water usage. The shower-head should not be of aluminium or steel as these are corroded by dilute hydrochloric acid.

6. Iron stains on ceramic tiles also can be removed by wiping with the 1:1 diluted acid.

In all the above cases, after cleaning with the acid, rinse with water to remove any traces of the acid. If there are any cuts on the skin, contact with the diluted acid would cause irritation of the skin in that place which will cease on washing with water. While handling the acid with bare hands is safe, as a measure of abundant precaution, one can wear plastic gloves like those that come with hair dyes.

PRECAUTIONS: (1) Both the dilute and concentrated acids attack mosaic and marble floorings, aluminium vessels and iron. Therefore both should be stored in tightly stopped plastic bottles. (2) Any accidental spillage on mosaic tiles or aluminium vessels must be diluted with water immediately and drained or mopped up with cloth quickly and then washed with water. (3) Keep both the concentrated and diluted acid bottles in a safe place, tightly stoppered in plastic bottles and away from the reach of children.(4) Avoid contact of both the concentrated and diluted acid with good clothing as the acid will weaken the fibres and cause holes in them or tear them.

3. Washing machines

Washing machines consume a substantial amount of water, even as they save the homemaker or the maid servant considerable physical effort. It is therefore important to explore how you can minimise the water usage in washing machines. One simple method would be to accumulate clothes to make a full load and put them for washing in one lot rather than washing them in smaller lots. The water drained by the machine can, wherever possible, be collected and used for flushing the toilets. The soap water drained from the machine prior to rinsing will still have enough soap to clean the toilet floors. The subsequent rinses from the machine can then complete the task. These can also be used to wipe the floor or to water the terrace garden[36]. You will realise how good the rinse water is when you collect it and take a look at it. ***Incidentally, front- loading washing machines consume much less water than top loading machines.***

The author's method of collecting the outflow from the washing machine was to attach a second identical flexible drain- pipe to the one already provided by the manufacturer and collect the water in 13 litre buckets.

36. See Appendix 7 for details of the Terrace Garden

4. **Wash-Basin**

The full force flow of water in a washbasin yields water at a very fast rate which is totally unnecessary for washing the hands face etc. Maidservants too tend to keep the tap at full flow to render their task of cleaning the wash basin easier. There is considerable wastage of water because of this. In all well-designed plumbing systems, there will be a valve (called "angle cock") that controls the flow of water from the washbasin tap. This is usually located below the washbasin and at the back. By keeping this valve only partially open, the rate of flow at full opening of the wash-basin tap can be reduced. For this, close the angle cock fully, then open the wash- basin tap fully and then slowly open the angle cock, until the flow from the tap is just enough for all normal uses Then close the wash basin tap. You will save a considerable quantity of water with this adjusted flow without sacrificing any comfort of usage.

5. **Washing of Vessels**

a. Many of us tend to leave vessels/dishes used for cooking or eating as they are after a meal for the maidservant to clean. If the cleaning is not done immediately, the food particles sticking to the vessel dries up and to remove them, the vessel had to be wetted and kept wet for some time for the particles to loosen up. Thus not only is more water used up but extra time also needs to be allocated to the cleaning process. Alternately, to save time, one will need to apply extra effort to dislodge the food particles. Either way we stand to lose. It would therefore be a good practice to give a rinse of the dishes/vessels with a small quantity of water soon after use when the food matter will be removed easily. Even in this rinsing, if you give some thought, you will find many economies in usage become possible.

b. In households where water available for bulk use may be brackish, and good quality water is limited in availability, you can keep the good quality water in a broad shallow basin or tray and dip in it the vessels cleaned with the brackish water. This will save considerable amount of the good quality of water that may be used up if the final rinsing is done in running water.

c. If you have plants on the balcony or on the sunshade, the water used for rinsing in (a) above can be used to water these plants. In the process, nourishment is also given to the plant. These plants can also be watered using the water drained from a washing machine in the second rinse.

6. **Watering the garden plants**

a. The water drained from washing machine and the water used for bathing can be diverted to the garden by rigging up the system given on page -98 (Picture 12.8). See Para 14 on page -104.

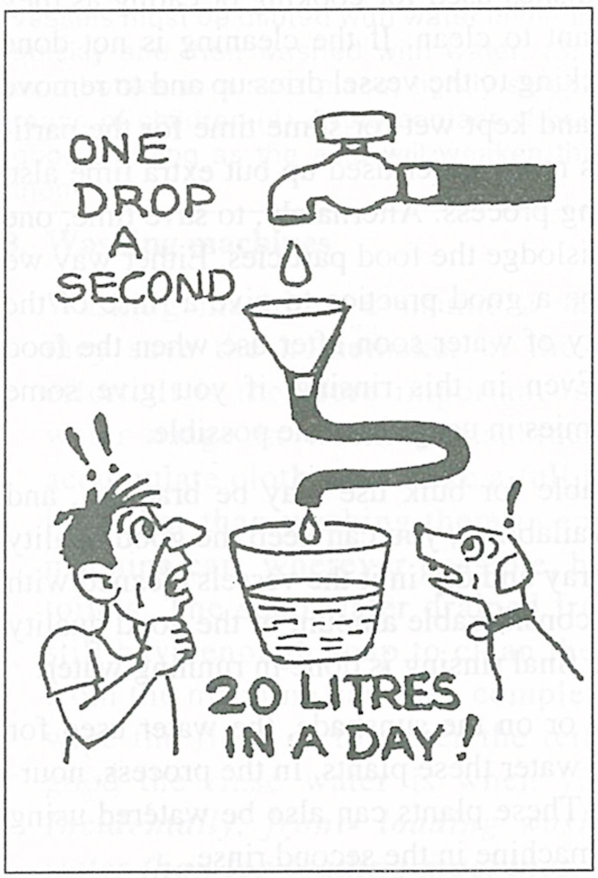
b. If you water the plants in the evening, the water lost by evaporation due to sunlight will be saved and so the watering will be more efficient.

c. The quantity of water needed for watering plants in pots can be considerably reduced by covering the top of the soil in the pots with a layer of dry leaves (the smaller the better). This layer avoids the direct fall of sunlight on the soil and thereby the loss of moisture from the soil due to evaporation is considerably reduced. This is called 'Mulching'. Over a period, these leaves get converted into manure and add to the healthy growth of the plants.

7. Vehicle Cleaning

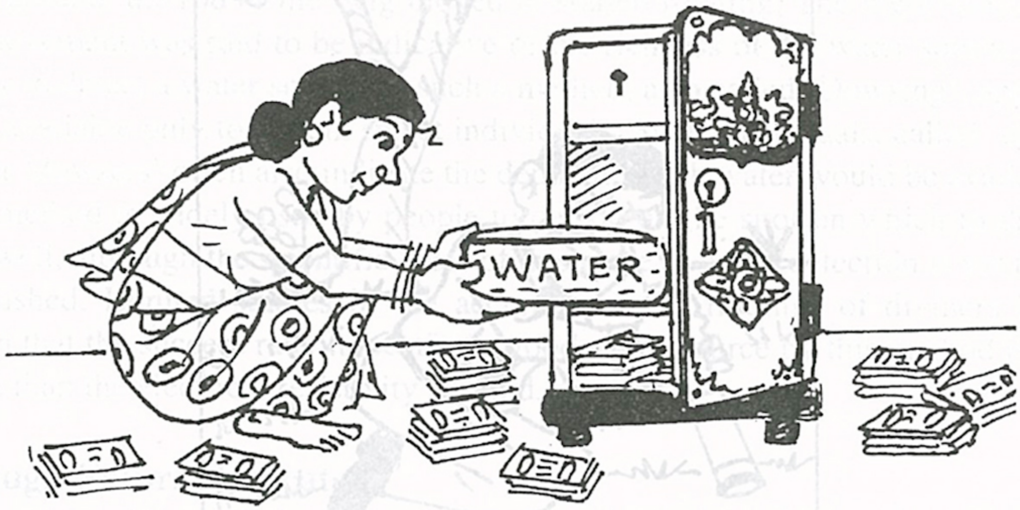
Please do not use a running hose but use a mop and <u>two</u> buckets - one bucket for the first wiping and the second for the second wiping. You will avoid considerable wastage of water. The water after cleaning can be used for watering the plants in the garden.

8. Leaking Taps and Shower Heads



Little drops of water do indeed make the mighty ocean. If you want to test it, keep a bucket under a tap or a shower- head from which drops are dripping and see how much water is lost through these leaking drops. A drop a second will mean a loss of 20 litres of precious water in 24 hours - enough for a comfortable bath. You can check it yourself. If the drops come faster, all the greater is the loss of precious water. If several taps are leaking thus, you are probably losing an entire day's supply of water. So close the tap tightly after use so that it does not drip. **Do not ignore a leaking tap or a shower head. Have it repaired as quickly as possible.** A plumber may not be accessible readily. So, till a plumber becomes available, keep a bucket below the leaking tap so that the water collected from the drops can be used for any general purpose and does not go waste.

DON'T THROW AWAY STORED WATER: IT'S PRECIOUS!



In many apartment complexes, water from the over -head tank is supplied to the flats only for a limited period in the day. In order to secure for themselves enough water for the rest of the day, residents often tend to store more water than they really need in drums/pots/vessels and buckets. And the next day, when the supply is switched on, they often throw away all the water remaining in the drums and the buckets and fill them up with fresh water. This practice stems from the widespread but totally erroneous belief that water kept in storage deteriorates in quality and therefore should not be used. We do not realise that water drawn from the sump below the ground is more often than not water that has been in it for many days. For, even before the sump is fully empty, fresh water either flows in to it from municipal supply or drained into it from tankers.

Actually, water stored in closed containers improves in quality over time due to two reasons: 1) If there are any organisms in it, they die over a period of time, and 2) Suspended impurities like fine mud settle at the very bottom and do not come with the water if undisturbed. It is only water that contains some organic matter – whether in suspended or dissolved form – which deteriorates on storage. Treated water supplied by the water authorities, ground water that is pumped up and rainwater collected in clean containers like buckets, drums or sumps can be stored for weeks without any deterioration in quality and then used. If the containers are kept covered away from sunlight, the water can be stored for even months.

*FIX A NOTE ON THE WALL ABOVE THE KITCHEN WITH THE WORDS:
SAVE WATER, IT'S PRECIOUS! PUT UP A SIMILAR NOTE IN THE BATHROOM TOO.
YOU WILL BE SURPRISED AT HOW SUCH A NOTE CAN HELP YOU SAVE WATER.*

CHAPTER 16

LOCATING UNDERGROUND WATER SOURCES

(Can we locate accurately in our premises, the right spot to dig a shallow well or a bore well that would give us water of good quality in good quantity? This objective is dealt with in this chapter.)

Self-reliance in water becomes meaningful only when we have reliable water sources in our own premises for tapping groundwater. But how does one go about locating the right spot to dig a shallow well or to drill a deep bore well which will yield us water adequate in quantity and quality to meet our needs? Unfortunately no sure-shot techniques are available even today, which can pin-point such spots.

By Water Divining

Traditionally a water source was located by "Water Divining'. In this method, an individual holding a Y-shaped or a V-shaped copper rod or a twig between his two index fingers moved slowly over the plot where the water spot was to be located, with the rod or the twig hanging vertically downwards. When the individual passed over an area below which there was a good quantity of water underground, the rod or the twig moved or started rotating. The vigorousness of the movement was said to be indicative of the richness of the water source. The ability to detect a water source by such a method, also called 'Dowsing', appears to be available only to certain select individuals. Such individuals, called 'diviners' or 'dowsers' often also indicate the depth at which water would be available. This method is widely used by people to decide on the spot on which to drill a bore well, although the scientific basis of this route to water detection is yet to be established. Limited studies of the accuracy of the findings of diviners have shown that the success rate in locating a good water source by this method is not worse than the electrical resistivity method.

Through Natural Indicators

The ancient Indian astronomer, Varahamihira, in his magnum opus titled 'Brihad Samhita' has devoted two chapters to describe the detection of underground water sources through natural indicators such as the presence or absence of termite mounds, the intertwining of certain trees etc. However, Varahamihira's guidelines are typically applicable to environments where the natural elements like trees and shrubs would not have been disturbed. Such environments can only be found in rural India. Thus they are of limited value as investigative tools in the urban context, except perhaps in the suburbs or the peripheral areas of an expanding town or city where the natural elements would have still not been disturbed much. Some of the indicators of Varahamihira are given in Appendix 7.

From Soil Data

We had noted earlier that water is held under the ground only by soil strata like gravel, sand and weathered rock. Rocks like sandstone (formed by aggregation of sand particles) and limestone can also act as good sources. Massive rocks, which have fissures and fractures (created by geological processes over the ages) also often hold water in the fissures and fractures. Therefore, if we can get an idea of the nature of the soil at various depths in our premises, we can get a reasonable idea of where to dig for water and how deep. The task is unfortunately complicated by the fact that, even over a limited area, due to the geological processes that would have occurred in that area over ages, the subsoil profile (or lithology) is not necessarily uniform. It is therefore vital to build up subsoil profiles in various localities of a town or city. Often such data are available with governmental agencies like the PWD but these are not readily available to the ordinary citizen.

Similarly in recent years, the presence of water bearing strata below the ground is being detected by aerial remote sensing techniques over wide areas, but these data too are not readily available to the ordinary citizen.

In the last two decades, numerous bore wells have been dug in individual houses as well as in the ever-proliferating apartment complexes in various towns and cities, but unfortunately the soil strata encountered in the process are rarely recorded. Sadly most residents would not have any data on these nor would the builders have taken the trouble to get these data from the well diggers.

Given this situation, let us see what best can one do to locate the site for a good dug well or a good bore well.

The Shallow Dug Well

A shallow dug well normally does not exceed a depth of 40 ft (except in soft rock areas where it may reach a depth of100 ft or even more). Therefore, in order to select a good spot for digging a shallow well, one needs information on the soil strata up to about 10 metres or so. Good building practice requires that a soil investigation be done in any premises to design the foundation of the building that is going to come up in those premises. In this investigation, two or more test bore holes are drilled in the plot involved, at some distance from each other, and soil samples from specific depths (say 1.5m, 3.0m, 4.5m etc.) are collected using special boring equipment and the samples analysed. The soil components and their percentages are recorded under four headings: gravel, sand, silt and clay. Samples are usually collected up to 7.5 or 10m depth for 4 storey buildings and up to 15m for multi-storeyed buildings and buildings with basements. This report provides a good idea of the scope for a dug well serving as a reliable water source. The report also provides information whether water was encountered within that depth and what its quality was. If such soil investigation data are not available, one can have test bore holes dug in one's premises. A test borehole would cost a few thousand rupees perhaps. Details of how a test borehole is dug are given in the next section on bore wells.

An even simpler and valuable indicator of the subsoil profile at shallow depths is the presence of other dug wells in the surrounding areas. If these are yielding, the scope for a yielding dug well of similar depth in the premises under consideration is bright. Even if these wells are dry, it only means that the soil conditions are favorable but the water table has been depleted and needs to be recharged before the dug well becomes a yielding one.

In such places, for immediate needs, a tube well or a bore well may have to be dug to meet the water needs in the short term and a shallow dug well fed by rainwater can be introduced for raising the water level in the long term. Very often, depending on soil conditions, such rain fed wells will yield water immediately after the rains for a part of the year at least. If they absorb rainwater but still remain dry, they are in effect feeding the bore well and sustaining its yield.

The Deep Bore Well

The bore well, as we noted earlier (page 30), taps several layers of water bearing soil deeper than those tapped by the dug well. Therefore knowledge of the soil structure at deeper levels is required to select a point at which to dig a bore well. Electrical soundings of the soil ('resistivity'studies) conducted by hydro geologists over the premises give this data from which the hydro geologist recommends the point(s) at which the bore well(s) can be dug and the depths at which the favourable layers are located. This data is known as 'inferred lithology'. The soil layers actually encountered at various depths during the drilling of the bore well may not fully tally with that inferred from the resistivity studies in all cases.

Nowadays the bore well invariably forms the key water source in most households and many of us would have passed by spots where a bore well was being drilled. But how many of us would have watched the sequence of operations involved? It is well worth getting to know this, for even if you already have a bore well in your premises, the need may arise for a second bore well and this knowledge will come in handy. It also comes in handy in designing a rainwater harvesting system involving a recharge bore well.

Construction of a Bore Well

A bore well is nothing but a narrow diametre hole (4.5 to 10 inches) drilled into the earth and going down to substantial depths ranging from 50 ft to 600 ft and even more and having access to one or more aquifers (See sketch on Page 30). To prevent the hole from collapsing, a PVC pipe (slightly smaller in diametre than the hole drilled) is inserted into the hole and the space between the pipe and the edge of the hole is filled with pebbles. The PVC pipe is known as the casing pipe of the bore well. To draw water, a suction pipe is inserted into the casing pipe. If a jet pump is used, two suction pipes need to be inserted. The top of the casing pipe is covered with an 'end-cap' to prevent extraneous matter falling into the casing pipe.

In non-rocky soil, the hole can be dug manually up to a maximum depth of 60-70 ft. using what is called an 'auger'. In non-rocky areas, bore holes deeper than this can be dug by a set-up called the 'Rotary Rig'. Drilling in rocky soil is carried out by a pneumatic drill i.e. a drill driven by air at high pressure. In popular parlance, this is known as D.T.H. i.e. Down To Hammer. No casing pipe is required for the hole drilled in rock, as the hole is self-supporting and will not collapse.

Let us now look at the first stage in the construction of a bore well in non-rocky soil by a hand-auger. For this, the bore-digger sets up a tripod firmly on the ground around the spot at which the bore is to be drilled. The auger is suspended vertically from the tripod by a wheel and pulley arrangement. The auger is nothing but a 5 ft long strong steel tube of diametre slightly bigger than the proposed bore with threading at one end and a suitably shaped edge at the other end that can pierce the soil. A small pit about 1 ft deep is dug in the earth and the auger lowered into it. An iron rod is inserted horizontally through two holes in the auger and the rod rotated manually by two persons. When the auger has gone down to its full length, it is lifted up and cleared of the soil embedded in the hollow auger. The auger is then reinserted and its length increased by threading to it a 5ft long extension rod with two holes at the top. By rotating the extension piece with the rod similarly, the auger moves further down.

This sequence of operations is repeated and the depth of the borehole is increased till the desired depth is reached. At this point, if the objective has been only to find out the sub-soil profile for designing a suitable rainwater harvesting system, the auger line is now lifted up and the extension rods are progressively taken off until finally the auger itself is lifted up and removed

Samples of the soil brought up by the auger at regular depths are kept aside for either qualitative or rigorous assessment of their components. If water comes along with the soil, this also can be analysed.

If however the objective is to drill a bore well for purposes of water extraction, a 5ft long hollow steel pipe, about slightly narrower than the diameter of the hole is now suspended from the same tripod and inserted into the hole. When it has gone down practically fully, a second hollow pipe of the same diameter is threaded to the first one and the duo lowered further. The process is repeated using more extension pipes till the bottom of the hole is reached. A PVC pipe section of diameter ½ an inch narrower than the protective steel pipe is now lowered into the protected hole. Additional PVC pipe sections are glued to the pipe section and the piping is lowered into the protected hole until the bottom of the hole is reached. The protective steel pipe is now lifted up gradually and the extension pieces removed. Even as this pipe length is lifted up, pebbles are poured in the annular space between the two pipes. When the protective piping is fully lifted up in this manner, we have a PVC casing pipe from the bottom of the hole up to the ground level, kept rigid by the pebbles all around it from top to bottom. The casing pipe generally comes in 20ft sections which are either plain or have machine-made slots. Slotted sections of the PVC pipe are introduced at those depths where the soil layers had been found to be either water bearing or favourable for holding water. The joining of one section of the pipe with another is a simple operation. The pebbles around the casing pipe apart from serving to maintain the rigidity of the casing pipe, serve also to ease the movement of water from the soil around the bore well downwards and then into the casing pipe through the sections that have holes or slots.

The sequence of manual operations detailed above gives us a bore well constructed manually in non-rocky soils and reaching a depth of around 60-70 ft maximum. Bore wells of such depths can alternatively be constructed by using the mechanical equipment called the Rotary Rig. With a rotary rig, bore wells of depths deeper than 70 ft can also be drilled. But once rocky strata are reached, neither the hand auger nor the rotary rig is of use and only the DTH equipment has to be used for drilling in rock.

Assessment of Soil Samples Set Aside on Site During Drilling/Digging

When test bore holes are dug for the purpose of designing the foundation of a building, the soil samples collected at various depths up to the point where hard rock is reached are sent for rigorous analysis to find out their make-up in terms of gravel, sand, silt and clay. A similar analysis can be also done if a test bore hole is dug in order to know the soil profile and decide whether a shallow dug well is feasible or a recharge bore in a percolation pit is necessary. However facilities for such an analysis of soil samples may not be readily available in all places. Or it is possible that you are digging a bore for rainwater recharge and want to reach the minimum depth at which the soil layer is favourable for receiving water. In such a case you cannot hold up the digging until you get the analytical results. A quick and ready method to move forward in such situations is given below:

Gravelly soil obviously can be recognised without any special effort. The make-up of non-gravelly soil sample can be reasonably arrived at by the following simple procedure:

1. Take a small handful of the soil sample and slowly add small quantities of water and mix the two well. Stop adding water as soon as the wetted sample ball begins to stick to your palm.
2. With the above sample, try to form the shapes pictured below; See how many shapes you can progressively form. When you find you cannot form a particular shape, look at what the texture of the soil is given for the previous shape. That identifies the sample you have in your hand.

   a. The soil remains loose and single-grained and can only form a heap on the ground

Sand

   b. The soil is somewhat cohesive and can be shaped into a ball, which however breaks down easily.

Loamy Sand

c. You are able to roll the sample in the form of a thick cigar

Silt Loam

d. You are able to convert the thick cigar into a thin cigarette of about 15cm in length

Loam

e. You are able to bend the cigarette into a U shape

Clay Loam

f. The U shaped sample can be converted into a circle, but the circle has cracks.

Light Clay

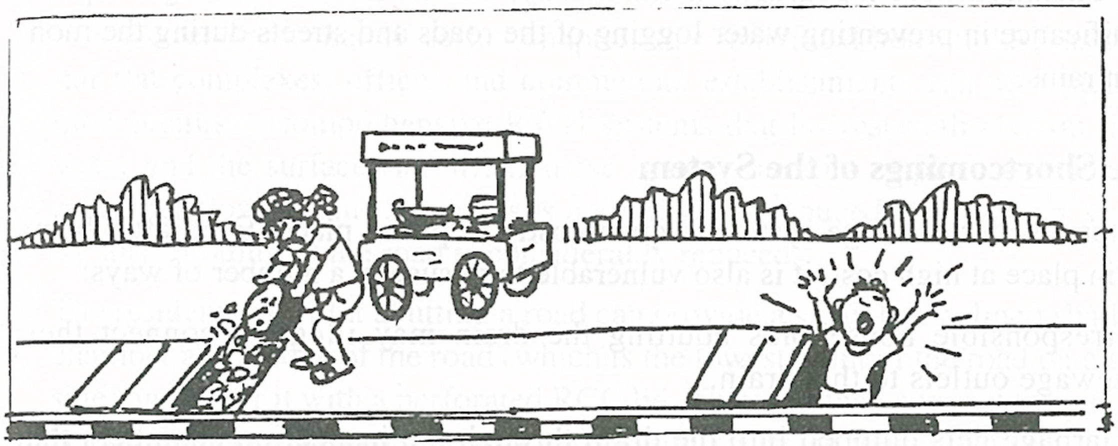
g. The circle can be formed without any cracks

Heavy Clay

Gravelly soil is the most favourable for water storage. Thereafter the soils falling in the categories ~~1 to 4~~ a to d are favourable in that order. The rest are not.

It is to be kept in mind that systematic efforts made in the manner detailed above do not guarantee that a good water source can be detected. This is particularly true with bore wells reaching hard rock areas, as water will be struck only if there are fissures in the rocks (See Borewells 1 and 2 in Sketch 4.1 on page -30. where the depths of both are the same but one taps water from a fissure in rock and other has merely hit a rock). It is also to be kept in mind that the test bore holes drilled for designing rainwater harvesting systems need not go deep into the soil. They need to go only down to the depth where the soil layer encountered is found to be favourable for holding water or already holds water.

CHAPTER 17



STORM WATER DRAINAGE–A COSTLY WAY TO WASTE WATER ?

(The storm water drain takes away good rainwater from our towns and cities and drains it into a water body that ultimately drains it into the sea. This chapter explores how this situation can be modified and the water put into the soil, retained within the town and the water table augmented.)

The Purpose of a Storm Water Drainage System

The storm water drainage system in a city or a town is distinct from the sewerage system. The sewerage system was intended originally to carry only the sewage from the houses and the flats abutting the various city roads but nowadays carries *all the used water* from the kitchen and the bathroom as well. The storm water drainage is a separate system installed only to carry away all the rainwater from the roads in a town or city to an appropriate water-body that is capable of receiving all the rainwater with ease, so that the roads do not get water logged. The water-body could be a pond or a stream or a lake or a river or a canal. In many towns, it is not unusual to find a single open drain running along the edge of the roads carrying not only rainwater but also all the grey water from the houses.

In urban centres, which have an undulating topography, the need for a rigorous drainage is much less as the water naturally drains off the slopes. In urban areas like Chennai whose topography is flat mostly, the storm water drainage acquires significance in preventing water logging of the roads and streets during the monsoon rains.

The Shortcomings of the System

A storm water drainage system is quite costly to put in place. Even after being put in place at high cost, it is also vulnerable to misuse in a number of ways:

1. Irresponsible households abutting the drain may illegally connect their sewage outlets to this drain.
2. Garbage gets dumped into the drain through the inspection chambers that need to be provided at periodic short intervals. This results in obstructing the smooth flow of rainwater during the rains. Roadside vendors particularly, tend to set up shop near such inspection chambers and use them as convenient outlets for dumping the liquid and solid waste generated in their trade.
3. In streets where the sewage may overflow from the sewerage line, residents tend to divert the overflow into these drains.
4. Apart from the above, if the slab covering the inspection chambers are broken or taken away by irresponsible citizens, the openings present a major safety threat to pedestrians.
5. The drains have to be periodically desilted i.e. the mud accumulated in them and materials like leaves and plastic carry bags thrown into them, have to be removed to ensure efficient and smooth flow during the rains. If this is not done, the storm water drain ceases to serve the very purpose for which it is built for at a heavy cost and city roads get flooded even after a moderate shower disturbing traffic and inconveniencing citizens.

Therefore even a good storm water drain laid at great cost, would not serve the purpose for which it is laid unless it is maintained properly and these abuses and misuses to which it may be put are prevented.

More fundamentally, even if the storm water drainage is maintained well, all the good usable rainwater is taken away from the city and wastefully drained into the waterways and thereafter led into the sea. To reverse this situation and to ensure that the huge volumes of water that go criminally waste presently are put back into the soil for drawal and usage later, the following simple and inexpensive corrective measures are possible.

Remedial Measure Possible

At the Micro-level

1. We had recommended in earlier chapters that individual households, residential flat complexes, offices and commercial establishments can all install in their premises, comprehensive RWH systems that harvest both rooftop rainwater and the surface run-off. If these systems are put in place widely, the rainwater flowing onto the roads is automatically reduced and the very scope for any flooding of the road is considerably reduced.

2. The residents of a plot abutting a road can provide a small brick- lined shallow chamber at the edge of the road (which is the lowest point of the road on either side) and cover it with a perforated RCC lid. They can then connect this chamber through a concealed pipe to a percolation pit inside their premises (which can be the same pit that they may have provided in their rainwater harvesting system). With this arrangement, the rainwater on the road gets drained off into the pit and supplements the recharging of the ground water table. Coarse sand can be put in the chamber to retain the fine mud coming along with the water prior to its reaching the percolation pit. Before the onset of every monsoon, the sand may have to be either replaced or washed free of any silt in it and returned to the chamber. The chamber can be kept closed with a cover slab during the dry months, to prevent entry of leaves, mud etc. and opened up only during the monsoon. Such a drainage system has proved to be effective in eliminating water logging on the road abutting the author's own colony.A picture of this chamber provided at the author's own colony can be seen on page -65 (Pictures 7.11 and 7.12).

At the Macro-level

1. Wherever, there is a park or play ground or a public building (Government or Municipal), abutting a storm water drain, adequately sized dug wells can be provided in these and the water from the road drain led into these wells through pipes laid below the ground. The wells can be covered with a solid heavy-duty cover so that it enables free and smooth activity at the ground level. Such a diversion would result in substantial augmentation of the ground water table in those neighbourhoods and thereby confer considerable water security to the entire neighbourhood.

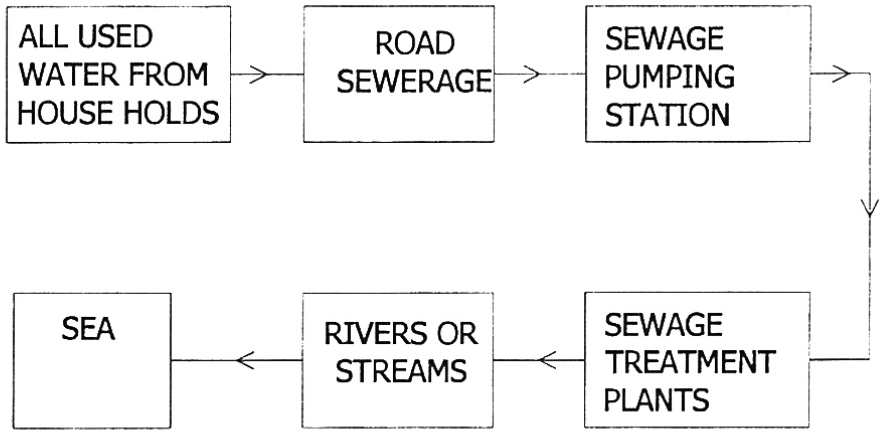
2. Most cities and towns have many temple tanks, which have gone dry over the years. This is because in former years, rainwater from open areas around the tanks was ingeniously channelled into these tanks. These tanks also had arrangements in them whereby the silt coming from these collection areas was retained in selected sections of the tanks from where it could be removed periodically. With the proliferation of habitations in the neighbourhoods, these feeders got clogged. Storm water drains around the tanks can however be advantageously connected today to these tanks thereby not only bringing them

back to their old glory, but also in the process augmenting the water table in those neighbourhoods. Such revival of neglected tanks has been successfully done in a few places in Chennai. Similar diversion of water from storm water drains into ponds, lakes and other public tanks can also be done. Needless to state, such measures will endure only when the storm water drains are maintained in good repair and cleaned up whenever and wherever necessary.

3. In small side streets, (preferably at the point where the road level is lowest) a percolation pit can be dug in the pedestrian pavement area lying between the road and the residences on either side. The pit can be covered with a heavy-duty cover and grilled openings can be provided on the side and/or the top as may be convenient. The rainwater tending to stagnate in the street will flow into these percolation pits and enrich the water table in that street. The grills may be closed up due to leaves and dust but the residents in the area will be motivated to clear these in the rainy season, as the consequent impact will be to make their street free of water logging. This system has proved effective in several streets in Chennai where dedicated individual rain-harvesters had introduced them.

Such a percolation pit will not be vulnerable to the several types of misuse detailed earlier in the case of a storm water drain. For efficient functioning, it may need only desilting once in a few years prior to the onset of the monsoon. Such percolation pits will be much cheaper to install than the conventional storm water drains. They will be much easier to maintain, are not vulnerable to misuse and most importantly, they will recharge the water table in the neighbourhood thereby contributing to self - reliance of the residents in those neighbourhoods in respect of their water needs.

CHAPTER 18



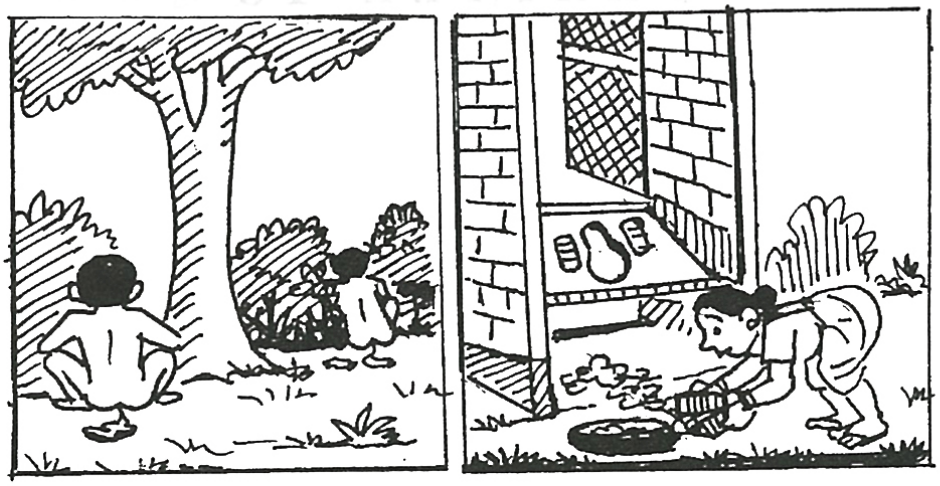
SEWAGE DISPOSAL–A MEGA WAY TO SPOIL WATER!

(The sewerage system in our cities is mainly responsible for their water shortages as it takes all the used water from households miles away from the city and the water tables fall steeply in consequence. What can be done to alter this situation at the individual as well as the governmental levels is considered in this chapter.)

The Water-borne Disposal of Faecal Matter and Its Ills

Much as it may surprise us, the sole reason why towns and cities in our country are facing water shortages is the water-borne system of sewage disposal, introduced in our country in the 19th century. As noted earlier, the most hygienic and efficient route to sewage disposal is by defecating on soil and covering the faecal matter with soil. And till the water-borne system was introduced, defecation was indeed done in India only on soil and is still done so in villages. There was an intermediate stage in many towns and cities when people defecated on cemented pits with the faecal matter being removed manually. This was not only an unscientific technique but was also a retrograde and reprehensible social practice that deserved to be condemned. Its replacement by the water closet was in that sense a very welcome change socially, but from the point of view of water usage, it must be considered an extremely backward one. This may seem a strong and controversial statement but its validity will be seen if a dispassionate analysis of the system is made. The following are the serious long-term negative consequences of our present system of sewage disposal:

1. This system requires the installation of the requisite infrastructure and its sound maintenance, both of which are very expensive. The infrastructure involves laying an extensive network of underground sewer pipelines that



carry the sewage or the outflow from our water closets to sewage pumping stations by gravity flow. From these pumping stations, the sewage has to be pumped over long distances at considerable expenditure of electricity to the outskirts of the city or town where the treatment plants are located. And the sewage then has to be rid of all organic materials and the pathogens present by a combination of mechanical, chemical and biological processes. With the population of the cities constantly on the rise, the capacity of all the three components – sewers, pumping stations and treatment plants needs to be periodically increased, which the municipal authorities are unable to do.

2. In many towns and cities, the treatment plants are aged and work much below their capacity. In many others, there are no treatment plants at all. The sewage is therefore simply let off into the nearest tank or lake or river, thereby polluting those water-bodies and rendering their water unfit for any use, apart from making those water-bodies, sources for the spread of water-borne diseases.

3. Even that portion of the water that has been properly treated, cannot be readily used for human use, as it is still not sterile. This water is therefore either let off in the same water-bodies or used for growing eucalyptus plantations as eucalyptus trees consume large quantities of water!

   Such a system is therefore not only very expensive to install and maintain but results in polluting water bodies and diverting enormous quantities of water away from the towns and cities. Is it any wonder that the ground water levels in towns and cities are steadily going down?

4. Compounding this is the diversion of all the grey water also into town sewerage system that substantially increases the volume load on the treatment plants.

5. In the Indian Standards for water needs, the Bureau of Indian Standards allocates a whopping 1/3rd of the total per capita requirement (45l per individual) for mere flushing of the closets. Often it is more than this. How many of us realise that when we pull the chain or press the flush button, we put anywhere

from 7 litres of good water (in recent models of cisterns) to as much as 16 litres (in older models) into the sewerage five or six times a day and also increase the volume load on the sewage treatment plants?

Can we do something about this utterly wasteful diversion of enormous quantities of good water from the cities and towns and that too at great financial cost and at the further cost of spoiling our water bodies and depleting the ground water levels in the towns and cities? We must give serious and urgent thought to this, laymen and experts alike, citizens and administrators alike. No doubt, it is impracticable to do away with the present system wholesale. But several actions are feasible that can substantially reduce the wasteful diversion of good water away from the cities and towns - actions that can be taken at the micro level as well as at the macro level, with little expense or effort.

Actions Possible at the Micro Level

1. **By using an Indian water closet**

   Doctors are categorical that the squatting position needed for the Indian style closet is much more suited for the human anatomy and facilitates easier defecation than the sitting position on the western style closet. Besides, the faecal matter can be flushed out with much less water than in most western style closets. Unfortunately however, recent trends show an increasing preference for western style closets. Even if the western style closet is used for defecation, use of the Indian style closet for urination can contribute a lot to water conservation. For, urine can be flushed out from the Indian closet by using a mug having a capacity of 800 ml to 1 litre. Thus by using the Indian closet for urination and hand flushing it, one can save considerable quantity of water every day and also reduce the load on the sewerage system.

2. **By using a steep-angled Indian Water Closet**

   The Indian water closets presently marketed have a slope of about 15° from the front down to the water seal at the bottom. If this is increased, the faecal matter can be flushed out with much less water than in the 15° model. The Bureau of Indian Standards, in fact, details a Rural Squatting Pan where the angle of the slope is 25° and this requires just 2 to 3 litres of water for flushing by hand. Such closets are available in the market and can be conveniently used in individual houses and in the ground floors of apartment complexes. However, they cannot be provided on upper floors of apartment complexes as the sunken flooring provided in the bathrooms on the upper floors can accommodate an angle of only about 20^{o}.

3. **Other Routes**

   By treating and re-using grey water (Chapter 12) and by practising the conservation techniques listed in Chapter 15, not only can the utilisation of fresh water be reduced by 50–60%, but the volume load on the sewage treatment plants can also be reduced substantially.

Actions Possible at the Macro Level

1. Sanitaryware manufacturers can market steep-angled Indian water closets with about 20° that can be flushed by a cistern using just 3 to 4 litres against the present 7 to 12 litres.

2. Recycling grey water in hostels, airports, railway stations, university and IIT campuses and hotels where the water usage is very high. In all these places, there is enough soil area required for grey water recycling and we can have excellently landscaped gardens in these places using part of the recycled water. In fact, part of the used water can be utilized for gardening even without any treatment.

3. In most towns and cities, large land areas are set aside for sewage treatment. But in actual fact, treatment is done in very few of them. This land can be utilized to install on a large scale, the kind of soil treatment units detailed in Chapter 12. Experiments conducted by the author in treating the effluent from up-flow filters has shown absence of E. coli in the treated water and even subjecting raw sewage to the same process have shown highly encouraging results. Therefore, if the raw sewage or partially treated sewage is given this soil treatment and the treated water is then led into water bodies, their contamination will be substantially reduced contributing to a better environment and also to increased ground water recharge.

Sanitary engineers do not take kindly to the idea of diverting grey water away from the sewerage, as they fear the 'self-cleansing velocity' will be affected in the sewer lines. This assumes that the system is operating ideally otherwise. The truth is that the system as it is operating is subjected to considerable abuse presently, such as entry of large quantities of mud during the rains when water overflowing from blocked storm water drains is diverted into the sewerage or cattle waste being routinely dumped into the sewerage. Besides it must be remembered that when sewerage was first introduced, only the black water stream or sewage was diverted into it from all homes. If the maintenance of the sewerage is improved, that by itself will bring about a salutary effect on the functioning of the system, and therefore it ought to function satisfactorily with a reduced flow of water through the sewer lines.

CHAPTER 19

POTABLE WATER AND QUALITY STANDARDS

(What constitutes potable water is discussed in this chapter.)

Why Standards for Potable Water?

The quantity of water used by us for cooking and drinking is very small compared to the quantity used for other purposes but the *quality* of that small quantity of water is most critical, for it has a direct relationship with our health and well-being. Therefore, over the years, a lot of time and effort have gone into evolving quality standards for potable water i.e. water which is used for drinking and cooking. These standards take into consideration: a) the nature and quantity of the inorganic salts dissolved in it that influence its palatability and their impact on body processes and also b) the nature of microbial contamination in it i.e. contamination by human and animal excreta which pose a direct risk to our health. Between these two, except in special cases, the risk to health is much greater from microbiological contamination than from presence of excess of salts.

The World Health Organisation has laid down detailed guidelines for potable water that codify safe parameters derived from long experience mainly in Europe and the United States. The Bureau of Indian Standards has on its part laid down separate guidelines for India, which largely tally with the WHO guidelines. However, what is desirable is often not feasible in the developing countries of the world, given the constraints of location, resources, and lack of technical facilities to achieve the desired standards. Therefore, given the fact that the chemical constituents normally found in water sources lead to acute health problems only through massive contamination, dilution of the WHO standards have been made in some cases taking into account the ground realities in the country. The Indian Standards thus prescribe two standards, 'desirable limits' for first quality potable water and 'maximum permissible levels in the absence of alternate sources' for potable water of second quality. There are many areas in our country where people have no choice but to drink water containing even more salts than stated as 'maximum permissible'.

Chemicals in Potable Water

Over the years, thousands of organic and inorganic chemicals have been found to be present in drinking water supplies around the world, but normally only such chemicals as are known to be widely present are tested for. Specific chemicals like arsenic, lead, chromium and fluorides, which are all harmful to the body, are tested for only if there is basically some reason to believe that these may be present. Besides there are few chemicals that can lead to health problems except through massive contamination of the water sources. Experience shows that in such cases of massive contamination, our system automatically rejects the water because its taste, odour and appearance are not acceptable.

In this context, it is pertinent to note that the unit for concentration of chemicals is in ***ppm*** i.e. parts of the chemical present in a **million** parts of the water sample concerned.[37] The main parameters tested normally for potability and the additional tests to be conducted for microbial contamination if suspected are listed at the end of this chapter along with the guidelines specified for each chemical by both the Bureau of Indian Standards and the WHO. In order to decide whether water from a particular source is fit for drinking, it would be advisable to first test it only for total dissolved salts (TDS). The ideal limit for this as per Indian Standards is 500 ppm and the maximum permissible limit is 2000 ppm. If the TDS content exceeds 2000 ppm, no purpose is served by testing for the other parameters.

Microbial Contamination

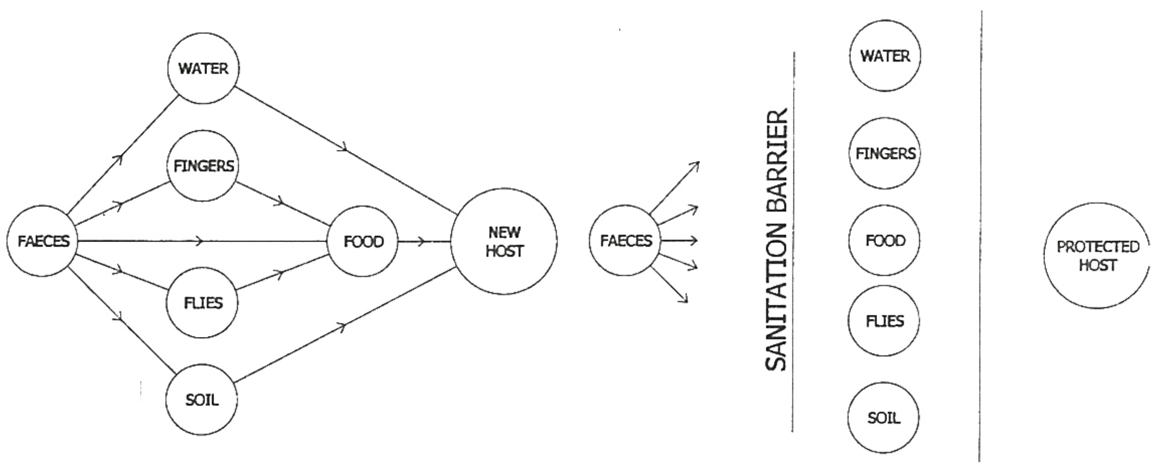
Microbial contamination however is much more serious, as it can lead to several illnesses at the micro level and to epidemics at the macro level. Microbiological contamination arises mainly from mixing of human excreta with the water sources involved. Contamination by animal waste becomes relevant only in specific areas where there is a high concentration of cattle or pigs or goats or poultry. The waste matter expelled by us from our intestines contains a variety of bacterial, viral and protozoan pathogens and helminthic parasites that, if ingested, will expose us to the risk of intestinal and other infectious diseases. Those at greatest risk of waterborne diseases are infants, young children, people who are sick and the elderly. For these people, infective doses are significantly lower than for the general adult population. For all these reasons, the control of microbial contamination in water used for drinking

37. This can be alternately expressed as mg/l or milligrams per litre

and cooking is extremely important. As it is not easy to detect the presence of these pathogens in water, the standard method is to look for the presence of coliform bacteria in the water. This is because human faecal matter contains large quantities of E coli bacteria excreted from our intestines and so when coliform bacteria are found to be present in any water sample one can assume that water to be contaminated by faecal matter. Further testing should be done to specifically confirm presence of E coli, as sometimes the coliform bacteria happen to be of non-faecal origin.

Microbial tests need not be normally done unless there is some reason to suspect contamination. The risk of microbial contamination is more in areas where there is no sewerage and the sewage is disposed off through septic tanks. Marginal contamination from human waste does not reveal itself through any easily recognisable or detectable symptoms. High levels of contamination will invariably be revealed by unpleasant taste and foul smell. In such a situation the water needs to be tested immediately and action taken to find out the cause of contamination and eliminate it. Consumption of such water should be avoided.

Sketch 19.1 The first sketch shows how faecal-borne diseases get transmitted from the sick person to a healthy individual. The second sketch shows how a barrier between faeces and the transmitting agents gives protection to the healthy individual. While this barrier can be achieved by protection of water supplies and food from contamination, by personal hygiene and by control of flies, *the most effective barrier would be the segrgation and hygienic disposal of faeces.*



Iron Salts

Water drawn from a dug well or a bore well generally ought to be clear and transparent. If it is found to be brownish, this could be due to fine mud or sand coming from the bottom of the well along with the water. This phenomenon is likely to be noticed more in the dry season when the ground water levels tend to drop. In such cases, if the water is chemically potable, it needs to be filtered through cloth first, then boiled, cooled and consumed. In fact, the safest course even otherwise would be to boil, cool and then consumed. However, if the filtered clear water again starts turning yellow or brown, it indicates the presence of dissolved iron salts in the ground water in more than desirable levels. Again, if the ground water, immediately on being pumped is clear and transparent, but starts turning yellowish or brown, this also means that the water contains dissolved iron salts in more than desirable levels. How to deal with the problem of excess iron salts is detailed in Chapter 20. It is to be noted that if the water otherwise is chemically potable, it can be consumed after removal of the iron salts.

Given below are the detailed guidelines for potable water from the Bureau of Standards, India and the World Health Organisation:

Potable Water – Quality Standards

Table 19.1 CHEMICAL STANDARDS

S.No	Bureau of Indian Standards Guidelines and Comments				WHO Guidelines and Comments	Other Comments
	Parameters and Units	Desirable Limit	Maximum Permissible in absence of alternative sources	Undesirable effects outside the desirable limit		
1	Colour Hazen Units	5	25	Above 5, consumer acceptance decreases	No health based guidelines. Colour above 15TCC can be detected in a glass of water by most people. Colour below 15 TCC usually acceptable to consumers but acceptability may vary according to local circumstances.	In case of roof top rainwater directly put in a dug well, the colour sometimes may be yellow due to the leaves on terrace. This is harmless. Colour in absence of leaves needs to be investigated. Colour developing on storages indicates presence of iron salts in the water generally.
2	Odour	Unobjectionable			No health based guideline. Enormous variation in the level and quality of odour and taste regarded as acceptable. Unusual taste or odour needs to be investigated.	
3	Taste	Agreeable				

Table 19.1 CHEMICAL STANDARDS

S.No	Bureau of Indian Standards Guidelines and Comments				WHO Guidelines and Comments	Other Comments
	Parameters and Units	Desirable Limit	Maximum Permissible in absence of alternative sources	Undesirable effects outside the desirable limit		
4	Turbidity NTU	5		Above 5, consumer acceptance decreases	Water with turbidity less than 5 NTU is usually acceptable to consumers although this may vary with local circumstances. No health-based guideline is proposed.	Turbidity is often due to fine mud that can be removed by filtration Turbidity also arises from presence of iron salts. This needs special care for removal.
5	pH	6.5 - 8.5	No relaxation	Beyond this range, high pH will affect the mucous membrane and low pH will corrode supply lines of GI	No health based guideline. May range between 6.5 and 9.5	
6	Iron (as Fe) ppm	0.3	1	Beyond 0.3, taste /appearance are affected, has adverse effects on domestic uses and water supply structures and promotes iron bacteria	No health based guideline. Essential element in human nutrition. At levels above 0.3, stains laundry and plumbing fixtures. Promotes growth of iron bacteria that results in a slimy coating on the piping.	The Indian Standards are vague on what 'adverse effects' mean.

Table 19.1 CHEMICAL STANDARDS

S.No	Bureau of Indian Standards Guidelines and Comments				WHO Guidelines and Comments	Other Comments
	Parameters and Units	Desirable Limit	Maximum Permissible in absence of alternative sources	Undesirable effects outside the desirable limit		
7	Total Hardness (as $CaCO_3$) ppm	300	600	Encrustation in water supply structure and adverse effects on domestic use	No health based guidelines. Public acceptability of hardness may vary considerably from one community to another, depending on local conditions. Depending on other factors such as pH and alkalinity water with a hardness of above 200 ppm may cause scale deposition in the distribution system and will result on excessive soap consumption and subsequent scum formation.	The Indian Standards are vague on what 'adverse effects' mean.
8	Chloride (as Cl)ppm	250	1,000	Beyond 250, taste and palatability are affected and corrosion of supply lines can occur	No health based guideline value. However chloride concentration in excess of about 250 ppm can give rise to detectable taste in water. Consumers can become accustomed to concentration in excess of 250	

Table 19.1 CHEMICAL STANDARDS

S.No	Bureau of Indian Standards Guidelines and Comments				WHO Guidelines and Comments	Other Comments
	Parameters and Units	Desirable Limit	Maximum Permissible in absence of alternative sources	Undesirable effects outside the desirable limit		
9	Total Dissolved Solids (TDS) ppm.	500	2,000	Beyond 500, palatability decreases and may cause gastro intestinal irritation.	Total dissolved solids comprise inorganic salts (principally calcium, magnesium, potassium, sodium, bicarbonates, chlorides and sulphates) and small amounts of organic matter that are dissolved in water . Reliable data on possible health effects associated with total dissolved salts are not available and so no health based guideline is proposed. TDS can have an important effect on the taste of drinking water. The palatablity of water with a TDS less than 600 ppm is generally considered to be good. Drinking water becomes increasingly unpalatable at levels greater than 1200 ppm. Water with extremely low TDS may be unacceptable because of its flat, insipid taste.	
10	Magnesium (as Mg) ppm	30	100	Beyond 30, encrustation to water supply structure and adverse effects on domestic use		The Indian Standards are vague on what "adverse effects' mean.

Table 19.1 CHEMICAL STANDARDS

S.No	Bureau of Indian Standards Guidelines and Comments				WHO Guidelines and Comments	Other Comments
	Parameters and Units	Desirable Limit	Maximum Permissible in absence of alternative sources	Undesirable effects outside the desirable limit		
11	Calcium (as Ca) ppm	75	200	Encrustation in water supply structures and adverse effects on domestic use.	Contributes mainly to hardness. Public acceptability may vary considerably from one community to another, depending on local conditions. The taste threshold is in the range of 100 - 300 ppm. In some cases, water hardness in excess of 500 ppm is tolerated by the consumers.	The Indian Standards are vague on what 'adverse effects' mean.
12	Sulphate (as SO_4) ppm	200	400	Beyond 200, when magnesium or sodium is present, gastro intestinal irritation occurs.	No, health based guideline is proposed as it is one of the least toxic of anions. Presence of sulphate in drinking water can cause noticeable taste. Threshold values range from 250 ppm for sodium sulphate to 1000 ppm for calcium sulphate. It has also been found that addition of calcium and magnesium sulphate (but not sodium sulphate) to distilled water improves the taste. Optional taste was recorded at 270 and 90 ppm for the two compounds respectively.	

Note: Although Standards have been laid down for the following chemicals, these are tested for only in cases where their presence is specifically suspected: Copper, Nitrate, Fluoride, Mercury, Cadmium, Selenium, Arsenic, Cyanide, Lead, Zinc, Chromium, Boron and Aluminium

Microbiological Standards of the Bureau of Indian Standards

For water in the distribution system, ideally, all samples taken from the distribution system including the consumer's premises, should be free from coliform organisms. In practice, this is not always attainable, and the following standards are therefore recommended:

1. Throughout any year, 95% of the samples should not contain any coliform organisms in 100 ml.
2. No sample should contain E Coli in 100 ml
3. No sample should contain more than 10 coliform organisms per 100 ml
4. Coliform organisms should not be detectable in 100 ml of any two consecutive samples.

In supplies drawn from wells, boreholes and springs, the objective should be: a) to avoid pollution of the water by removing sources of contamination from the area, special attention being given to the safe disposal of excrement. Wells and storage tanks must be lined and covered; and b) if pollution still occurs, to reduce the coliform count to less than 10 per ml, but more importantly to ensure the absence of faecal coliform organisms. If these organisms are repeatedly found or if sanitary inspection reveals obvious sources of infection that cannot be avoided, then an alternative source should be found wherever possible.

References

1. *Indian Standard for Drinking Water: IS 10500: 1991 First Revision, Fourth Reprint, July 1999. Bureau of Indian Standards, 9, Bahadur Shah Zafar Marg, New Delhi - 110 002.*
2. *Guidelines for Drinking Water Quality: Vol.1, Second Edition, World Health Organisation, Geneva, 1993. Reprinted 1996.*

Disinfection and Sterilisation [38]

Disinfection of water means destroying or eliminating or inactivating pathogenic organisms to ensure protection against waterborne diseases. Sterilisation in its proper sense means the removal of all forms of life (i.e. microorganisms) in it including bacteria, amoebic cysts, algae, spores and viruses. Most of the disinfection processes in use tend to render the water safe as far as pathogenic bacteria are concerned and do not completely inactivate the hepatitic and polio viruses.

38. Sourced largely from the paper "Water Treatment Technologies Relevant to Developing Countries", presented by Mr. Bhisma Kumar Chugh, Delhi College of Engineering at the Indian Science Congress, 1998.

Ultraviolet radiation, the medium for disinfection in some types of domestic water filters is effective only if the water is exposed as a thin film or sheet of thickness up to 12 cm to UV radiation of 200-295 nm. But the water should be free from turbidity, colour, algae and suspended/colloidal material. Overexposure to UV radiation however does not have any harmful effects.

Carbon, sand and resin filters in a household system accumulate organic matter, if they are not regularly cleaned. The organic matter then serves as a medium for growth and release of microorganisms. Thus the filter will generate bacteria instead of eliminating them. Chlorine gas, used widely at the municipal level for water disinfection is very effective. However, overdose introduces an odour to the water and affects its taste also, as many would have experienced. There is also some concern about the formation of chloroform. At the micro-level, the use of chlorine gas is impractical. However, chlorine in the form of bleaching powder can be utilised to disinfect dug wells that may have been accidentally contaminated with sewage. Iodine is a better disinfectant, as it does not have any impact on odour or taste as chlorine has on water and it also kills amoebic cysts not killed by chlorine. It however imparts a greenish or yellowish colour to the water, and besides, it is costlier than chlorine.

An alternative process that does not involve any chemicals and is eco-friendly is ozonisation. In this process, Ozone, an energised form of oxygen, produced by passing a corona discharge of high voltage electricity on oxygen is mixed with the water to be treated. Ozone is a very effective bacteriocide and kills cysts and some viruses. In the process, it gets converted into oxygen. While these factors make it an attractive disinfectant, its cost of manufacture is quite high.

While water filters and purifiers commercially available may be attractive because they reduce the effort of the homemaker, the most effective method of rendering water free of all microorganisms is to boil the water vigorously for a few minutes and cool it prior to drinking.

Disinfection of a Contaminated Well

It is possible that at times, the water in a dug well starts emitting a smell of stale stagnant water or some other unpleasant smell. This tends to happen more in the rainy season. The smell is indicative of some contamination and naturally causes concern to the residents using it. The water can be disinfected by chlorinating it with bleaching powder. If the contamination is high, the water should be pumped out and drained into the internal sewage line till the smell reduces and the disinfection should then be carried out on the static water column. The steps involved in this are given below:

Table 19.2 Quantity of bleaching powder required for a specific volume of water

Water volume	Bleaching Powder	Liquid Bleach	High Strength (70%)
l	(25 - 35 %) gm	5% Sodium Hypochlorite ml	Calcium Hypochlorite gm
1000	2.3	14	1.0
1200	3.0	17	1.2
1500	3.5	21	1.5
2000	5.0	28	2.0
2500	6.0	35	2.5
3000	7.0	4 2	3.0
4000	9.0	56	4.0
5000	12.0	70	5.0
6000	14.0	84	6.0
7000	16.0	98	7.0

Notes: 1.The dosage is approximately 0.7 mg of applied chlorine per litre of water. 2.Keep the water in contact with the chlorine chemical for at least an hour or two before usage for con-consumption purposes. For consumption, boil thoroughly for 5-10 minutes and cool.3. If a bore well is contaminated, such a treatment is not practical. It is best to pump out the water and drain it off till the smell reduces and use the water thereafter for sometime for flushing the closets or gardening only. Source: A Guide to Sanitary Measures for Control of Enteric Diseases, S.Rajagopalan and M.A.Shiffman, WHO, Geneva, 1974

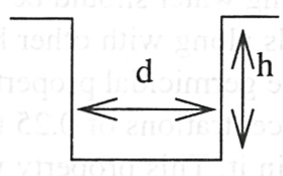
1.Determination of the volume of water column in the dug well

a) Type 1 Well with uniform diametre from top to bottom

$$\text{Volume of water} = \frac{22}{7} \times \frac{d^2}{4} \times h \times 28.32 \text{ litres} \qquad \text{where d and h are in feet}$$

or

$$\text{Volume of water} = \frac{22}{7} \times \frac{d^2}{4} \times h \times 1000 \text{ litres} \qquad \text{where d and h are in metres}$$

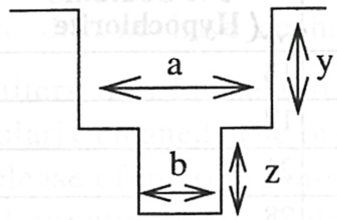


b) Type II Well where the diametre changes with depth

$$\text{Volume of water} = \frac{22}{7} \times \frac{(a^2y + b^2z)}{4} \times 28.32 \text{ litres} \qquad \text{where a,b,y and z are in feet}$$

or

$$\text{Volume of water} = \frac{22}{7} \times (a^2 y + b^2 z) \times \frac{1000}{4} \text{ litres} \qquad \text{where a,b,y and z are in metres}$$



The method of determining depths of wells using a knotted string and a stone or a jug has been explained on page -171.

The quantity of bleaching powder required for a specific volume of water can be taken from Table 19.2.

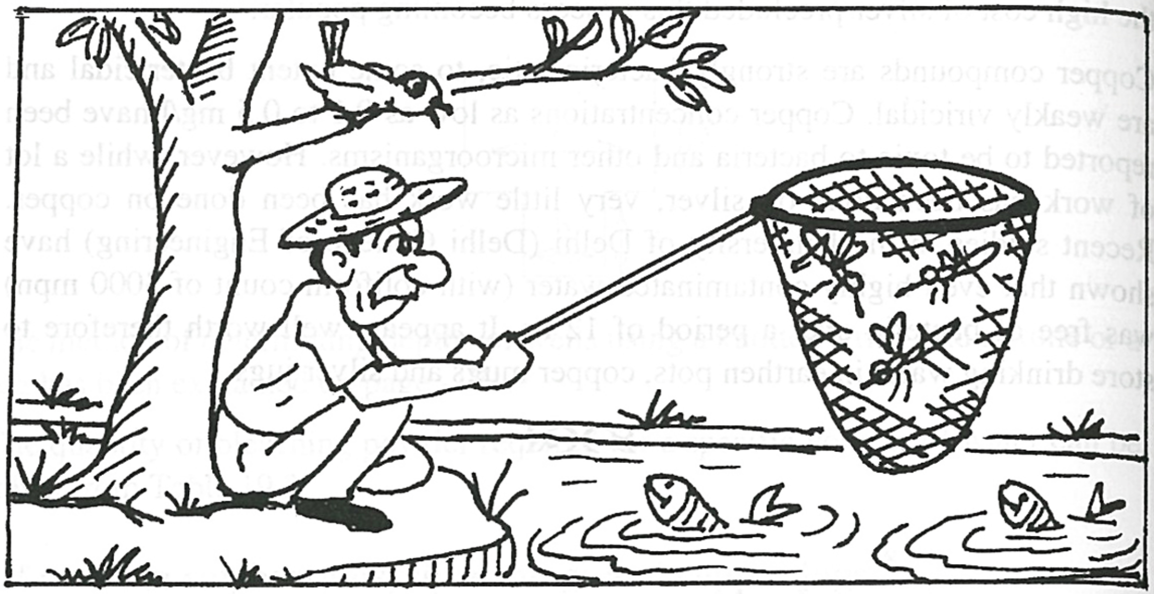
Of water in earthen pots, silver mugs and copper jugs[38]

Before the advent of refrigerators in India, drinking water was boiled, cooled and stored in earthen pots. And before the advent of stainless steel, copper and silver vessels were commonly used for storing water. Silver and copper vessels are still the preferred choice in religious ceremonies where the purity of the environment and of the materials used is of primary concern. Many of our traditional practices have a sound scientific basis and these two are amongst them. *Unglazed* earthen pots act as excellent cooling systems through evaporation of the water inside through the pores of the pot. Reduction of bacterial content on storage has also been noticed.

The Susrutha Samhita, the medical anthology put together by Susrutha and dating back perhaps to 2000 BC, states "It is good to keep water in copper vessels, to expose it to sunlight and filter it through charcoal." In the Negrund Bhushana, a chapter on water in the Atharva Veda dating back to 2500 BC instructs people to purify foul water by boiling it, exposing it to sunlight and by dipping into it a hot copper rod seven times, then to filter it and cool it in an earthen vessel,. Early Persian law required that drinking water should be stored only in copper or silver vessels. These two heavy metals along with other heavy metals like cobalt, mercury and nickel have remarkable germicidal properties even in very minute quantities. For instance, even in concentrations of 0.25 to 1 part per million of copper ions in water kills fish present in it. This property was first recognised by a German Botanist, Nageli in 1893, who gave the phenomenon the name of oligodynamism (Greek: dynamis = power (of) and oligo = the few, little). Subsequent work by several other workers has broadly confirmed this but the exact mechanism by which the bactericidal action takes place is not yet clear. Silver ions in concentrations between 0.006 and 0.5 ppm have been found to be lethal to E.coli with contact time between 24 and 0.5 hr. In this concentration, they impart no taste or toxicity to the water. A commercial purifier using this property was the Electro-Katadyn filter in use in the early part of the twentieth century. However the high cost of silver precluded this process becoming popular.

Copper compounds are strongly bacteriostatic, to some extent bactericidal and are weakly viricidal. Copper concentrations as low as 0.1 to 0.5 mg/l have been reported to be toxic to bacteria and other microorganisms. However, while a lot of work has been done on silver, very little work has been done on copper. Recent studies in the University of Delhi (Delhi College of Engineering) have shown that even highly contaminated water (with coliform count of 3000 mpn) was free of bacteria over a period of 12 hr. It appears well worth therefore to store drinking water in earthen pots, copper mugs and silver jugs

Chapter 20



IRON SALTS: THE 'MOSQUITOES' IN WATER AND THEIR REMOVAL

(Even very minute quantities of dissolved iron salts (5ppm), if present in ground water, create complications in using that water for our daily needs. What can be done to deal with this problem is dealt with in this chapter.)

Iron Salts or The Water 'Mosquitoes'

Imagine yourself to be in a plush air-conditioned room on a very soft bed in the best suite of a five star hotel. You have retired for the night and are half-asleep and you find that there are a few mosquitoes in the suite. Your dream sleep will be shattered in spite of all the luxury and opulence of the room and you are likely to get up angry and irritated and have a disturbed sleep thereafter. That is the kind of impact that iron salts in the ground water of your premises can have on you, if they are present in more than desirable quantities! And what are these 'more than desirable quantities'? Just between 2 and 15 parts of iron in a million parts of water!

Water drawn from soils containing iron salts will be deceptively sparkling and clear when freshly pumped from the dug well or the bore well. Keep the water in a clean glass tumbler and keep watching it periodically. The water would start developing a turbidity which is white initially and then turns brown or yellow. On further storage (ranging from 3 hr to as much as 30 hr even in some cases), first the entire quantity becomes brown in colour and subsequently the water becomes sparklingly clear again but you will find now a small brown layer at the bottom of the tumbler. If you try to decant the clear water from the tumbler, you will fail, as the brown layer will come along with the water. Try filtering it through a piece of cloth or a filter paper and you will feel the brown layer on the cloth or filter to be slimy but you won't be able to get even a bit on your finger. Clothes washed in such water are likely to be stained and the water may taste metallic on the tongue. And all this because the water may contain just 3 to 15 parts of iron in a million parts of the water!

An Ad Hoc Solution

The problem may aggravate in the dry season but may reduce and even disappear during the rains. Why does this happen and how does one deal with it? Can such water be consumed or used for cooking? These are questions that are troubling more and more people in recent days. Let us see what can be done about these highly irritant 'water-mosquitoes'.

The reason why the iron containing water is sparklingly clear when freshly drawn from the ground is because the iron salts are in what is called the 'ferrous' condition and therefore soluble in water. As long as the water is below the ground, they do not have access to air and therefore remain in the soluble ferrous condition. As soon as the water is drawn up, they are exposed to air (oxygen) that converts the ferrous salts into insoluble 'ferric' salts which start separating out. If such water is otherwise potable, it can be consumed after removing the iron salts. The iron-free water can be used for other needs also. If the iron salts are present only in marginally excess quantities, the water can be stored in a barrel or bucket for the period in which the brown layer had settled down in the glass tumbler. The clear upper layer can then be removed carefully without stirring the water or the water can filtered through cloth. This is however an ad hoc method and is not convenient. A similar ad hoc method can also be tried with larger quantities by pumping the water into the overhead tank late in the evening and using it only in the next morning. During the night, much of the iron salts would have settled down at the bottom of the tank. This ad hoc method would work even more effectively if the water is led into the tank through a sprinkler arrangement. The lower part of the water in the tank would have to be drained periodically to remove the iron salts settled there.

A Rigorous Solution

Such methods however are of no use if the iron content is high i.e. more than 4ppm. The rigorous method to eliminate the iron salts in such cases is to thoroughly mix the water with air, keep the aerated water in a tank for about 4 to 6 hours so that all the ferrous salts get ready access to oxygen and get converted into insoluble ferric salts. The mixing is achieved by making holes in a polythene pipe kept horizontally over the tank which is closed at one end and connected to the water source at the other end. The water thereby comes out in a fine spray and gets well mixed with the oxygen in the air. In the period the water remains in the aeration tank, a good part of the iron salts separates out and settles at the bottom of the tank. The water is then pumped through a pressure sand filter that retains the rest of the iron salts and the iron-free water goes into the over head tank. The filter is generally filled with pebbles of graded sizes and sand. Some times manganese dioxide is also put in to convert any unconverted ferrous salts into ferric salts.

Such a system can handle large volumes of water containing iron provided the aeration tank is sized appropriately. However, there are several irritants in the operation and maintenance of the system: 1) The aeration tank has to be periodically emptied and the settled iron salts removed. 2) The sand filter has to be periodically freed of the retained iron salts by passing iron-free water through it in the reverse direction and draining the water till it is free of colour. A fair amount of good water gets drained in this cleaning process which may have to be done even once a day. 3) The hole in the delivery pipe get clogged with iron salts. Reopening of the holes requires mechanical effort as also treatment with diluted cleaning acid. If, to avoid such cleaning, the water is put in the aeration tank directly, the separation of the iron salts remains incomplete because of inadequate mixing with air and the water in the overhead tank will become coloured.

In recent times, an alternate system has come into vogue where the water is passed through a cylinder packed with special media at a pressure slightly higher than atmospheric pressure. The media converts the ferrous salts into ferric salts as the water passes through and retains them as well. Even here, the media has to be cleaned in the reverse direction periodically by passing water through the cylinder in the reverse direction but the efforts needed to clean the aeration tank and the delivery pipe periodically are done away with. Small units of this type are also available which can be kept in individual flats to ensure complete removal of iron even as the water from the overhead tank is received from the tap.

Beneficial Impact of RWH

It is well-worth noting that if rainwater is harvested and charged into the same aquifer from which the water is drawn, the problem will be considerably mitigated due to dilution of the ground water by iron-free rainwater. And over a period, all the iron salts in the aquifer may be leached out and the water may not need any treatment at all.

Factors to Be Considered Before Installing Iron Removal Units

It is very important for those who intend to have an iron removal treatment unit in their premises to first get a **reliable** analysis of the iron content in their water source. To do this, the following precautions have to be taken: i) The water sample must be drawn directly from the dug well or bore well and not from the water stored in the overhead tank. ii) The water must be allowed to run out for some minutes and then only the sample must be taken. iii) The analyst must add a special solution to the sample immediately after it is drawn, in order to keep all the iron salts in solution and prevent their separation on contact with air. If these precautions are not taken, the analysis will give a misleading figure for the iron content as some part of it would have separated out on contact with air and the analysis for iron would be done by the laboratory technician on the water after filtration. iv)Besides the analysis is better done in the dry season when the iron content would be higher and the plant installed would be able to handle it.

In assessing the offers that may be received for an iron removal unit, the following aspects need to be examined carefully:- 1) Overall cost 2) Relative ease of maintenance 3) The quantity that can be handled in a day vis-a-vis the storage capacity available for storing the treated water 4) Whether any annual servicing is needed, and if yes, the cost 5) After what period will the media in the filter need to be replaced and the cost of such replacement. This periodicity has to be correlated with the quantity that will be treated daily and the actual iron content in the water, and 6) the guarantee for satisfactory performance.

CHAPTER 21

DESALINATION, REVERSE OSMOSIS AND DISTILLATION

(The processes of desalination, distillation and reverse osmosis are explained in simple language and their relevance to self-reliance in water is considered in this chapter.)

'*Desalination*' and '*Reverse Osmosis*' are two technical terms that have become familiar even to many non-technical individuals these days because of the water shortage experienced by them in their cities and towns. Macro level schemes are nowadays being mooted and reported in the media about desalination of brackish water that will provide water in plenty to all. At the micro-level, builders have in recent times started advertising that the apartment complexes constructed by them come with Reverse Osmosis Plants (or RO Plants), and therefore, prospective apartment buyers need have no worry about their water needs. Do RO Plants indeed represent the panacea for our urban water problem? And what is desalination? One also hears nowadays about how *distillation* of seawater through novel technologies like Ocean Thermal Energy (OTEC) is *the solution* to the world's water problems. And what is distillation?

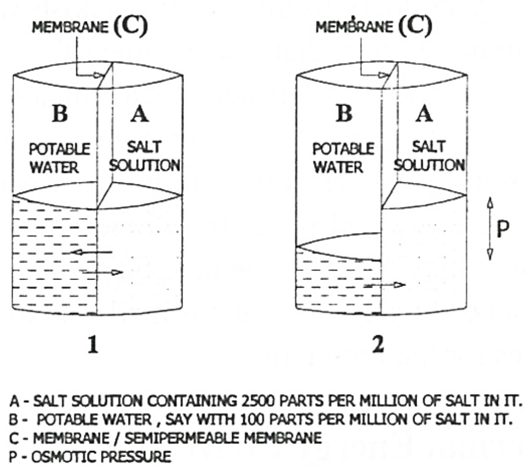
Desalination

De-salination as the word itself suggests is the removal of salt from water. The word is, in a sense, a misnomer because the methods in actual use to get good quality water from brackish or saline water do just the opposite i.e. They remove the water from the salt from the water instead of removing the salt from the water, even though, in most situations, salt is the minor component. Saline ground water, for instance, rarely contains more than 10,000 ppm of salt i.e. 10 parts of salt in 100 parts of water. Even sea-water, the saltiest among naturally occurring waters, contains only about 30,000ppm of salt i.e. about 30 parts salt in every 100 parts of water and yet only the water is removed from the salt. This is because there are no readily available techniques to remove the salt selectively from water. Distillation and Reverse Osmosis are two routes to desalination. Of these, distillation is yet to become economical. Reverse Osmosis is thus the route in fashion today.

Reverse Osmosis

Figure 1, in Sketch 21.1, shows a container separated into two compartments by an ordinary filter or 'permeable membrane'. Suppose we put in Compartment A, water containing about 2500 parts per million (ppm) of salt and put in Compartment B, an equal volume of potable water containing, say, only 100ppm of salt. Then, the two qualities of water will move across the filter, mix with each other and over a period, we will have water with about 1300ppm of salt in both compartments (2500 + 100/2). If, however, instead of the ordinary filter C, we have a special membrane or filter called a semi-permeable membrane', only the potable water will pass through the semi-permeable membrane and enter the compartment containing the brackish water. As a result, the level in this compartment will rise until a certain pressure or head is reached in this compartment (Figure 2). This process is known as *Osmosis* and the pressure is known as the Osmotic Pressure of that solution. The process occurs from the incentive of the two solutions to have the same concentration of salt. It is to be noted that the salt content in the brackish water has been reduced because of its dilution with pure water.

Sketch 21.1



If, on the other hand, we start with the same two qualities of water but apply pressure on the brackish water, this process reverses itself. Water now moves from the brackish water compartment slowly across the semi-permeable membrane into the potable water compartment, leaving the salt behind. Because of this, the brackish water compartment becomes more and more concentrated in its salt content even as the volume of potable water keeps increasing in the other compartment. This process is called *Reverse Osmosis.*

By applying the reverse osmosis process on your bore well water containing 2500 ppm of salt, we can get good quality water from brackish water with reduced salt content. The limitation in this process is that the brackish water by losing water gets more and more concentrated in salt content and so at a certain stage, the process has to be stopped, and the concentrated salt solution has to be discarded. The process can be carried out either to get potable water from the starting brackish water or to get water satisfactory for non-potable needs like bathing and washing of clothes. The process operates on electricity and its unit cost is not very low. In spite of this, this process is becoming increasingly popular in India for apartment complexes. Large scale RO Plants have not been very successful. One of the main problems is that of salt build up clogging up the filter media. This problem has plagued the largest RO Plant in the U.S. The Tampa Bay Water's $108 million plant in Apollo Beach was supposed to produce 25 million gallons of fresh water each day. The plant, opened in 1999, is currently shut down.

Relevance of RO plants in Apartment complexes

As far as small-scale plants are concerned, two consequences need to be given serious thought:

1. If 100 parts of brackish water are subjected to reverse osmosis, only about 60-80 parts can be got as usable water. The balance 20-40 parts, being highly saline, have to be rejected. As a rule, the smaller the capacity of the plant (in litres per hour), the greater is the rejected component. Besides, if the plants are not maintained properly, there are chances of bio-fouling on the filter media: that is, build-up of bacteria.

2.This process is utilised by many builders to treat very brackish water taken from deep bore wells. We had mentioned earlier that water mined thus is water formed from geological processes eons ago, and like petroleum is a valuable but exhaustible commodity. And the process converts a significant percentage of the water drawn from the earth into unusable saline water. However, in places where there is acute shortage of good quality water, getting good water from brackish water through the RO process may be to some extent inevitable for the time being as a route for accessing water for our needs, it cannot be the panacea that it is made out to be, and we have to pursue more sustainable routes for the long term.

Distillation and Ocean Thermal Energy Conversion

If you heat water in an open vessel, it soon begins to boil, turns into steam and disappears fully from the vessel. If you do not allow the steam to escape but pass it through a cooled tube (called a condenser), the steam condenses or is converted back into water that you can collect and use. This process of converting a liquid into its vapour and condensing it back into its original liquid state is called distillation. It is a useful process for purifying liquids that may contain solids dissolved in it. If you heat brackish water, for instance, in a vessel, the water becomes steam and by condensing the steam, pure water can be collected. All the water can be thus removed from the heated vessel and got in a pure condition. What will be left behind in the heated vessel will be only the salt that was originally present in the brackish water. The quantity left behind will be dependent on how much of salt was present in the sample of brackish water that you would have taken. The process is no doubt simple but the energy needed to convert water into steam and the steam back into water is considerable. This is the reason why salty seawater that constitutes 97% of the world's water stock has not been widely utilised for getting our water needs, except in the oil rich gulf countries.

Work has been going on in several places across the world to make this process economic by utilising the sea itself as the source of that energy that is needed for the task. In tropical areas, the temperature of seawater at the surface is about 27^{o}c and the temperature 3000 ft below the surface is about 45^{0} c. This differential in temperature can be used to drive turbines run on volatile liquids like propylene and generate electricity. The electricity thus generated is used to distil pure water from seawater. The process is known as Ocean Thermal Energy Conversion (OTEC). However, plants operating on this principle are just being developed in the U.S.A and it will be quite some time before they become meaningful in our country.

Relevance of Rainwater Harvesting

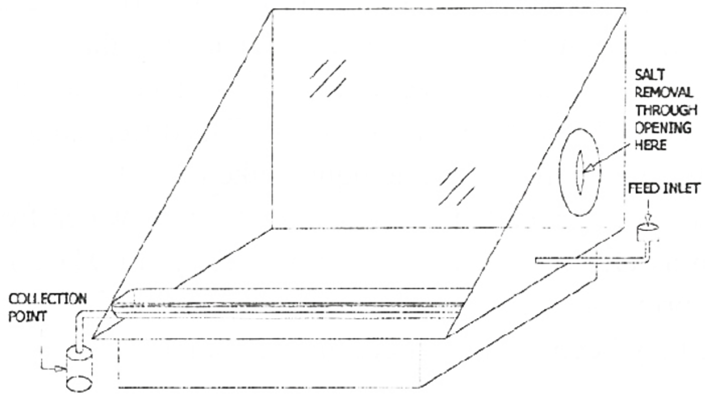
In both the RO and OTEC desalination techniques, large volumes of water are removed from very small quantities of salt. If we start, say with brackish water having 2500 ppm of salt content, it means that it is made up of 1 million parts of this water and 2500 parts of salt or every 100 parts of water contain 2.5 parts of salt. In reverse osmosis, we spend considerable energy to remove only about 60-80 parts of water from this 2.5 parts salt and reject 20–40 parts of water along with the salt. In OTEC, we spend considerable energy to remove the entire 100 parts of water from the 2.5 parts of salt! One may ask whether it is not more sensible and economic instead to remove the small quantity of salt leaving behind the large volume of water behind. Unfortunately, there are no methods readily available to selectively remove the salt alone from the water. But there is a simpler third alternative: Instead of trying to separate the water from the salt or the salt from the water, we can simply dilute the brackish water with potable water i.e. rainwater and bring down the salt content to levels acceptable for potable needs. We can similarly reduce the salt content levels that are acceptable for other general needs. This route not only is a sustainable route but is a very economic route as well. The only point to be kept in mind is that this route may not give immediate results. Therefore, methods such as RO may have to be considered as a necessary evil and utilised for the time being, keeping in mind their longterm limitations.

For the long term, we need to pursue the more sustainable routes of rainwater harvesting, grey water recycling and water conservation techniques detailed in earlier chapters that involve comparatively very low outlays and that are also practically self-sustaining.

The Cudappah Solar Still

The AMM Murugappa Chettiar Research Centre, Chennai, has developed a solar still (shown in the picture below) that uses the principle of distillation to obtain drinking water from brackish water using solar energy. Constructed from Cudappah slabs and glass, the still yields 2.5 to 3litres of pure water in a day from any kind of brackish water. The base is a Cudappah slab, 4.5ft long and 2.5ft wide. To this, another slab, 4ft long and 1.5ft wide is fixed vertically, using anabond or araldite. Two triangular slabs are then fixed on the two sides of the base. A plain glass sheet is fixed on the top.

Sketch 21.2



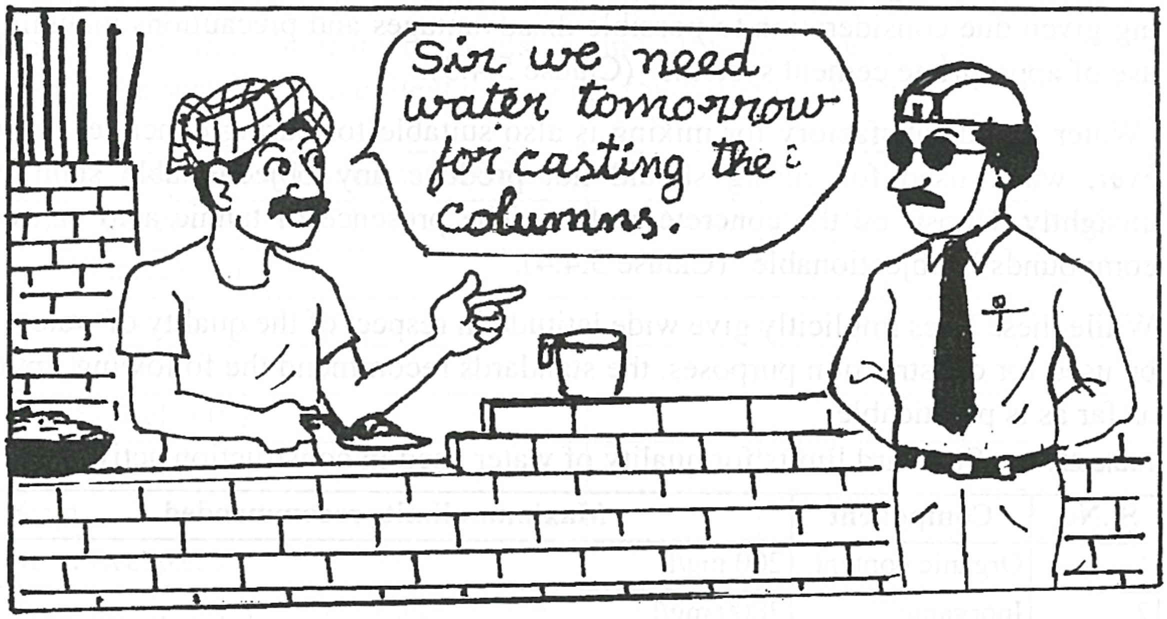
A saucer drain is fixed in the front of the base about ½ an inch above the base and touching the glass sheet. A hole is made at one end of the drain on the Cudappah slab and a pipe fixed in it so that any water flowing through the drain can pass through the pipe and flow out of the still. The whole set-up is kept about 9 inches to1ft above the ground level. The brackish water is fed and spread over the base using the funneled inlet pipe fixed on the other side somewhere around the middle and at a few inches above the level of the base. The still is kept facing the south.

Because of the solar heat absorbed by the black Cudappah slabs on its three sides and the base, water evaporates. When the vapour reaches the comparatively cooler glass sheet, it condenses back into water droplets that trickle down the sloped glass, fall into the drain and flow out of the still through the pipe at the end into a container placed outside. The salt remains on the base.

After some period of usage, the salt deposits on the base will have to be removed. The periodicity of this cleaning will depend on the salt content of the brackish water fed into the still. To remove this, a circular hole of about 6inches diameter is provided on the slab on the right side. This opening is normally kept closed with a wooden plug covered with aluminium foil.

The cost of fabricating this still is stated to be about Rs.3,000. According to the Centre, even polluted water can be fed into the still and pure and hygienic water can be obtained. Those interested in getting more details can contact the AMM Murugappa Chettiar Reasearch Centre, Tharamani, Chennai 600 113; e-mail- energy@vsnl.com

CHAPTER 22



WATER AND BUILDERS

(Builders need water for their construction activities. This chapter details how, by focusing on water management right at the start of their construction activity, they can meet this need and benefit themselves in the short term, and also benefit in the longterm those who will occupy the homes built by them.)[39]

Every builder who undertakes the construction of a building - whether it is an individual house or an apartment complex or a commercial building or an institutional building - is duty bound to provide adequate captive water sources for the ultimate users of the building. At the same time, the builder himself during various stages of the construction needs water. It is therefore prudent and beneficial for the builder to integrate his needs and the needs of the future occupants of his building and take appropriate water management initiatives right at the beginning of any project. Thereby not only does he improve the chances of getting water for his own needs economically but he will also be in a position to confer better water security to the future users of the building. Some of these initiatives are detailed below.

Quality and Quantity of Water Needed for Construction Purposes

The Indian Standards No. 456:2000 containing the code of practice for plain and reinforced concrete issued by the Bureau of Indian Standards states that "Mixing of or curing of concrete with sea water is not recommended because of presence

39. As the title indicates, this chapter is intended essentially for builders. Others therefore are free to skip this chapter, if they wish to.

of harmful salts in sea water. Under unavoidable circumstances, sea water may be used for mixing or curing in plain concrete with no embedded steel after having given due consideration to possible disadvantages and precautions including use of appropriate cement systems" (Clause 5.4.3).

"Water found satisfactory for mixing is also suitable for curing concrete. However, water used for curing should not produce any objectionable stain or unsightly deposit on the concrete surface. The presence of tannic acid or iron compounds is objectionable" (Clause 5.4.4).

While these lines implicitly give wide latitude in respect of the quality of water to be used for construction purposes, the standards recommend the following limits as far as is practicable:

Table 22.1 Standard limits for quality of water used in construction activity

Sl.No.	Component	Maximum limits recommended
1.	Organic content	200 mg/l
2.	Inorganic content	3000 mg/l
3.	Sulphate (as SO4)	400 mg/l (equal to 480 mg/l as Sulphate)
4.	Chloride (as Cl)	500 mg/l for reinforced concrete work and 2000 mg/l for concrete not containing steel
5.	Suspended matter	2000 mg/l

The quantitative and qualitative needs of water at various stages of construction are summarised below:

Table 22.2 Quantitative and qualitative needs of water at various stages of construction

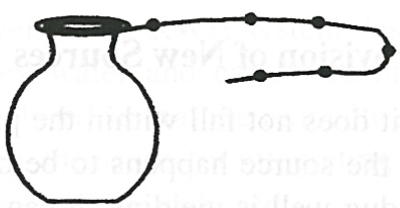
Stage	Purpose	Quantity and Quality needed
Laying of foundation	Mixing of concrete	Moderate quantity. Avoid water with high sulphate content
Consolidation	Consolidation	Moderate quantity. Quality not critical.
Construction of Superstructure	a) concrete mixing	Moderate quantity. Avoid water with high salt content preferably
	b) Casting of slabs & beams	Moderate quantity. Avoid water with high chloride content.
	c) Curing of slabs & beams	Large quantity. Avoid water with high salt content
	d) Plastering and curing	Quality not critical. Large quantity.
Finishing	a) Mosaic laying and polishing	Avoid water with high salt content
	b) Consolidation of driveways	Large quantity. Quality not critical.

Survey of the Neighbourhood

It is extremely useful to do a survey of the neighbourhood in which the site is located and find out from residents around how they are meeting their water needs. The surveyor can collect data in the following pro forma:

Site surveyed: House/Flat complex/Others	Date of Survey:		
Water Sources	Dug Well	Bore Well 1	Bore Well 2
In use /abandoned			
Diametre			
Depth			
Water Level at (ft)			
Quality			
Yield			
No of Occupants			
Are iron salts present in the water?			
Any other problem or comments			

Measuring Depths of Dug Wells and Bore Wells



Items 1, 2 and 3 in respect of dug wells can be measured wherever feasible and recorded. For this, one can use a metal jug or a stone tied to a strong thread and lower it in to the well. The thread remains taut till the jug or the stone touches the water level when it becomes limp and loose. Further lowering will make the thread taut again. When the jug hits the bottom of the well, the thread becomes limp again. Thus the depth of the well can be got. If a jug is used, a sample of the water can be also taken. Diametres of wells often get reduced as the depth increases. Therefore while measuring the depth of the dug well, it is necessary to lower the jug or the stone at a point as close to the centre of the well as possible. By lowering the thread near the boundary wall of the well, the depths at which the well diametres change can be obtained. If the thread is knotted at regular intervals, the depths can be read off straightaway.

Depths of bore wells and water levels in them can be obtained by similar direct measurement but using only a stone because of space constraints. However, the tops of bore wells are generally capped and therefore one may have to depend on information given by the residents, which information is not always accurate but nevertheless should be recorded. Yield information needs to be related to the occupancy levels in the site involved. The presence of iron salts, if known in advance, enables this factor to be included in budgeting for iron removal systems.

Soil Investigation

Soil investigation is done essentially to design the foundation but the data equally helps in designing the rainwater harvesting system for the project. Sandy or gravelly strata within 10 metre depths would enable tapping and storing rainwater at shallow depths and provision of dug wells. Clayey strata would necessitate ingestion of water through wells or percolation pits that have bores in them reaching deeper permeable layers. Often, water is encountered during soil investigation and its quality is an additional input for designing the harvesting system.

Hydrogeological Investigation

Electrical resistivity studies carried out by a hydro geologist also give information regarding the soil profile at deeper levels and help in the selection of favourable spots for drilling bore wells. The actual soil profile during the drilling of the bore well may not always match with the profile inferred from the resistivity studies but nevertheless it is a rough guide and often enables one to strike a good water source. In any case, the soil profile during actual drilling must be recorded without fail, as it is a vital input for designing any subsequent rainwater harvesting system. Efforts should be made to provide slotted sections in the casing pipe of the bore well at those stretches where the soil is favourable for holding water, irrespective of the presence or absence of water in those stretches.

Protection of Existing Water Sources and Provision of New Sources

If a dug well or a bore well exists on the site and it does not fall within the proposed building line, it should be retained, even if the source happens to be one that was yielding once but is currently dry. If the dug well is yielding, it can be desilted so that its yield and quality improve and it can be used for construction needs. Similarly the bore well can be flushed, if required, to improve yield. The samples from the available water sources should also be analysed to decide their suitability both for construction needs and for their use by the future occupants. It is to be noted that water unsuitable for construction in the dry season often becomes suitable for use in the wet season.

Even if the dug well happens to be located at the edge of the proposed building or a few feet inside, the scope for retaining it should be explored if the ground floor is to be reserved for covered car parking, by slightly modifying the column design[40]. A bore well in a similar location can be retained even more easily.

If no water source exists or the existing water sources do not yield enough, a bore well or a dug well should be dug straightaway for meeting construction needs. If any old extant structures on the site are to be demolished, special care should be taken to ensure that debris is not put into the dug well or the bore well. Yield tests

40. See picures 7.6 and 7.7 of such a well page -56.

on the water sources should be done to decide whether they are adequate for construction needs and how much of the needs of the future occupants will be met by these sources. For the latter purpose, the yield tests should be done both in the dry season and the wet season before forming any conclusion.

Designing the RWH System

Putting together all the available data, the number and nature of the water sources needed for the building under construction must be approximately decided and a comprehensive rainwater harvesting system worked out covering both the rooftop rainwater and the surface run-off. A shallow dug well should invariably form part of the design so that it may become a source of good water, in the future at least. The terrace slopes can be so decided that as many as possible of the terrace down-take pipes can conveniently be connected to a service dug well or bore well. While firming up the design, it has to be kept in mind that the concealed rainwater pipes may have to cross concealed electrical cabling and the internal sewage piping lines This however should not pose any problems as the rainwater pipes can easily go below electrical cables or above the internal sewage pipes.

Provision of Soil Space for Recycling of Grey Water

Even as the RWH system design is being firmed up, the scope for purifying the grey water and either reusing it or charging it into the water table must be explored so that the requisite soil space for the purpose can be set aside. In addition, the scope for integrating this objective with the rainwater harvesting system must also be explored.

All these efforts will not go in vain. As stated at the outset, they could well take care of the water needs for construction and at the same time confer substantial water security for the future occupants of the building after it is occupied, both at modest outlays. The marketability of these flats would also increase sharply.

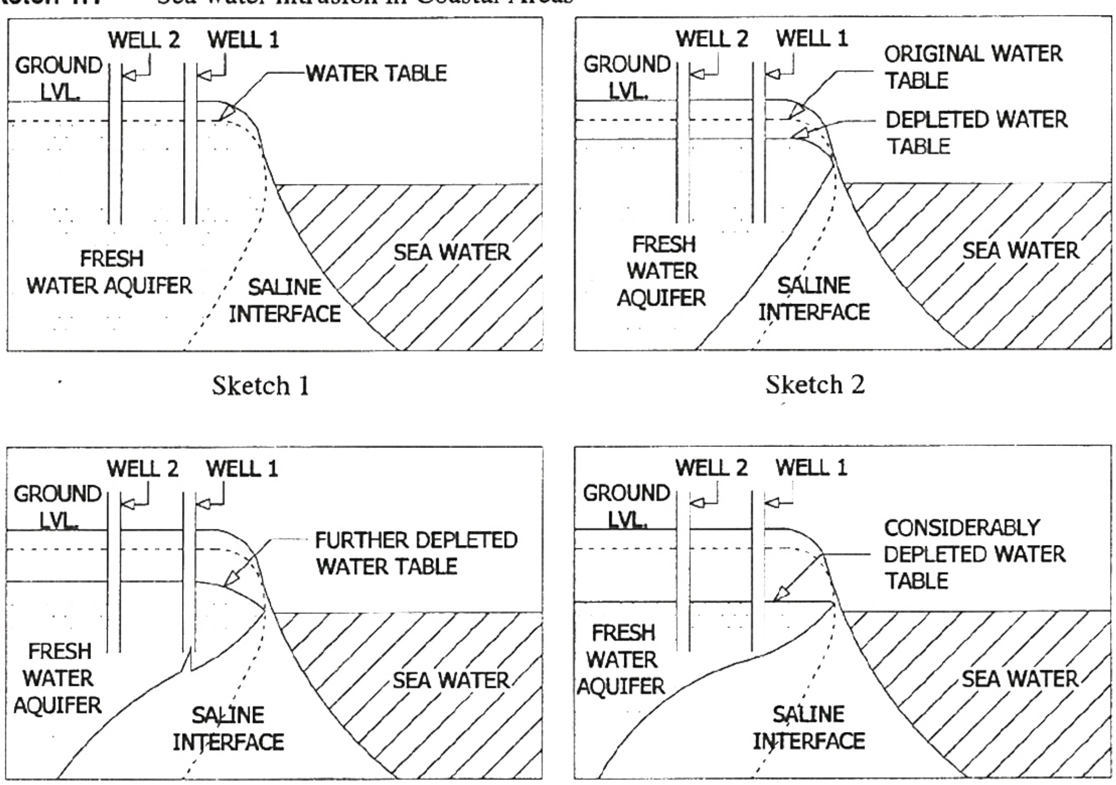
APPENDIX 1

COASTAL RESIDENTS, BEWARE OF SEAWATER INTRUSION!

Those who live in sandy stretches close to the sea would do well to remember the old Hans Christian Anderson's story of the Goose That Laid the Golden Eggs. A section of Chennai's citizens living close to the sea did not and have paid a heavy price for their lapse. It will be an object lesson for us to know why and how they paid that heavy price.

The land abutting or close to the Bay of Bengal in South Chennai is sandy in nature and therefore favourable for holding water. In fact, potable water can be found right on the beaches in Chennai just a few feet below the sand. Therefore people living close to the sea in Chennai have had the good fortune of getting excellent potable water from shallow wells in their premises. Not surprisingly, several of these areas became prime residential centres. One may wonder how potable water is available from places so close to the sea. The reason for this is the difference in density between seawater and fresh water. Because of its high salt content, seawater is heavier than fresh water.

Sketch 1.1 Sea water intrusion in Coastal Areas



The land level in all coastal areas is higher than the sea level[41]. Not only is the land level always higher than the sea level but even the ground water table is invariably higher than the sea level. Although fresh water is lighter than seawater, the higher column of the ground water on land is able to exert sufficient pressure vertically, as well as horizontally towards the sea to withstand the pressure the seawater exerts towards the land. Thus the seawater is prevented from entering land. However, because of the constant contact between seawater and fresh water, the mixing of the two forms an intermediate column of saline water. This water is also heavier than fresh water. This normal situation is depicted in Sketch 1.1.

Let us now look at the two shallow Dug Wells No. 1 and No. 2, located at a short distance from each other and in a line perpendicular to the coastline. Obviously both will be yielding good potable water. As long as the water is drawn at a moderate rate drawn from the region in which the two wells are located, the interface between the fresh water and the saline water remains unaltered. But if the water is drawn at a rate faster than that at which fresh water from the surrounding areas can replace it, the saline water will tend to fill up the gap created. And if such extraction of water continues, slowly, over a period, the saline water column will have moved towards the land and the result will be, as shown in Sketch 2.

Even after this has happened, water drawn from Dug Well No.1 will be initially of good quality but if pumping at a higher rate is continued for a longer period, the gap created by inadequate fresh water being available below the bottom of the well to replace the water pumped out, the saline water rises up like an inverted cone. This is called the 'upconing effect', which is depicted in Sketch 3. As a result, the water drawn as pumping progresses will be saline. At this stage, Dug Well No. 2 will still yield reasonable quantities of good water. But if the over- pumping of water in this region continues, the saline water column will have moved further inwards as depicted in Sketch 4 and even Dug well No. 2 will yield only moderate quantities of fresh water first and thereafter only saline water due to the upconing effect. But as the saline water column has intruded further, Dug Well No.1 will now yield mostly saline water only.

Such a movement of seawater towards the land has already taken place in a coastal area of Chennai called Besantnagar and there are ominous signs of similar saline water intrusion in another coastal locality called Thiruvanmiyur. The reversal of this i.e. pushing back the saline water column is not easy. The water authorities in Chennai had been drawing huge quantities of potable water from a coastal area north of the city that had an excellent shallow aquifer, for supply of treated water to the city. The water turned saline. Thereafter the authorities

41. Except of course in the unique case of Amsterdam where man-made dykes have enabled the land to be below sea level!

stopped pumping out water. Instead they had to start pumping huge quantities of good water into the ground under pressure to push the saline water back seawards. Reportedly this has yielded positive results. The reverse movement seawards is nevertheless a very slow one.

Therefore, those living in sandy coastal areas and having fortunate access to potable water at shallow depths in their premises would do well to beware of their precious water gold being lost forever. They should draw only moderate quantities of water from the soil in their premises and replenish it also by installing comprehensive rainwater harvesting systems covering both the rooftop and the surface run-off. Otherwise, as the Bible warns, 'Those who sow the wind shall reap the whirlwind!".

APPENDIX 2

THE WATER POISONERS: ARSENIC AND FLUORIDE

The presence of thousands of inorganic and organic compounds has been detected in drinking water supplies around the world at various times. However, most of them are not widely prevalent in water. Therefore, when any sample is tested for potablilty, the presence of organic compounds is not normally checked unless there are *prima facie* reasons to suspect their presence. As regards inorganic compounds, only five or six, which are widely prevalent, are tested for. These have been listed in Chapter 19. There are, however, two inorganic materials that tend to be present in water in certain pockets of India, which pose a serious risk to human health. These are Arsenic and Fluorides (compounds containing the element fluoride).

Arsenic

This element tends to contaminate ground water in eight districts of West Bengal (out of which the worst affected are Malda, Murshidabad, Nadia, North 24 Pharganas, South 24 Pharganas) and in neighbouring Bangladesh. Very recently, Balia district in UP has also been found to be affected. The WHO limit for arsenic in drinking water is 0.01 ppm. The limit as per Indian Standards is 5 ppm. About 60 million people are affected, the bulk of whom are in Bangladesh. Arsenic entering the alimentary canal of human beings initially causes skin lesions and dermatosis and over a period, internal cancer and death. It is estimated that at least 3 million people in West Bengal suffer from arsenical skin lesions. Sadly 5.3 million (nearly 8% of the total population of West Bengal) are dependent on arsenic contaminated ground water. ~~Very recently, Balia district in U.P. has also been found to be affected.~~

Removal of arsenic from water is not easy or straightforward. Both West Bengal and Bangladesh receive abundant rainfall. Therefore, rainwater harvesting provides a ready, simple and economic route to mitigate the problem substantially. Roof top harvesting and storage of the harvested water for cooking and drinking can prevent the ingestion of arsenic. The concentration of arsenic tends to be higher in water drawn from deep bore wells. Therefore, charging the shallow aquifer with rainwater harvested from the surface run-off will also mitigate the problem substantially over the years by its dilution effect and one can even look forward to the total elimination of the poison metal thereby.

Fluoride

Fluorides are compounds formed by the element called fluorine with metals. Small quantities of fluorides are believed to be good for strong teeth. Larger amounts are harmful. The permissible limits for fluoride in drinking water is 1.5 ppm by both WHO standards and by Indian Standards. The two most apparent health hazards of high intake of fluorides (or 'fluorosis') are dental and skeletal: Staining and pitting of the teeth enamel occurs first followed by pain and stiffness in the bone joints where the bone structure get changed and ligaments get calcified in severe cases. Other after effects are anaemia due to calcification of blood vessels and gastro-intestinal disorders, In advanced cases, the extremities become weak, moving of joints is difficult and the vertebrae fuse together. Premature aging occurs with wrinkling of the skin and a person of 30-40 years looks as if aged 60.

About 25 million people in about 17 states of India are affected by presence of fluoride in drinking water sources. Orissa, Tamil Nadu, Andhra Pradesh, Karanataka and Rajasthan are the worst affected. Other states, affected to a lesser degree, are Assam, Bihar, Chattisgarh, Delhi, Gujarat, Haryana, Himachal Pradesh, Kerala, Madhya Pradesh, Meghalaya, Punjab and Uttar Pradesh. No effective cure has been found for the effects of fluorosis.

Considerable work has been done on de-fluoridation or removal of fluorides from water such as usage of lime-soda followed by filtration and filtration through activated alumina but they are yet to become user-friendly. As in the case of arsenic, in the case of fluoride-containing water also, rainwater would be of tremendous advantage in mitigating the problem. As in the case of arsenic, fluoride concentrations too are low or negligible in waters of rivers, ponds, lakes and shallow wells but much more in water drawn from deeper levels through bore wells. Therefore rooftop harvesting and storing in drums, barrels, tanks and sumps for cooking and drinking needs would eliminate the problem substantially. Harvesting of surface run-off and charging of the shallow aquifer will dilute the fluoride content and over the years leach out the fluoride completely.

APPENDIX 3

MONSOON - THE AWESOME "MAUSEM"

Mausem a.k.a. Monsoon

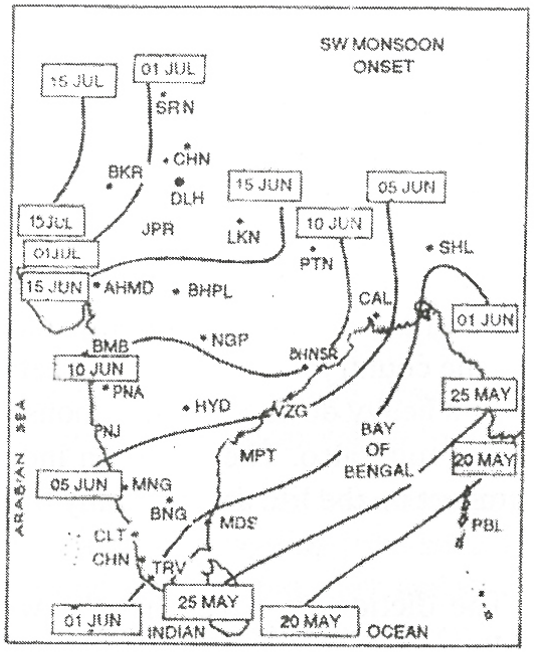
The term "Monsoon" frequently figures in the newspapers and the TV. If the share price index in the stock market has gone up, it is often attributed to "the good monsoon" that the country has had. If there are water crises in cities like Chennai, the water authorities attribute it (often conveniently) to the "failure of the monsoon". Floods in Assam or Orissa are reported as resulting from "the fury of the monsoon." The Annual Review of the State of the Economy by the Ministry of Finance often ascribes a low or high rate of growth of the economy during the year to the poor or the good monsoon that the country has had. If the streets in cities like Mumbai or Patna get inundated after a heavy downpour, then monsoon is cursed even though it fills up the city's reservoirs also. The monsoon indeed seems to have an awesome and widespread impact on the life and economy of the country.

What indeed is this "monsoon" actually? The dictionary states that the word means " a seasonal wind", The word is actually a corrupt form of the Arabic/Hindusthani word "Mausem" which has the same meaning of a seasonal wind. Its awesome impact arises from the fact that it is the monsoon, which is responsible for all the rain that India receives and if not managed properly (as our forefathers used to), it causes havoc and destruction, particularly in N.Andhra Pradesh, Orissa, U.P. and Bihar.

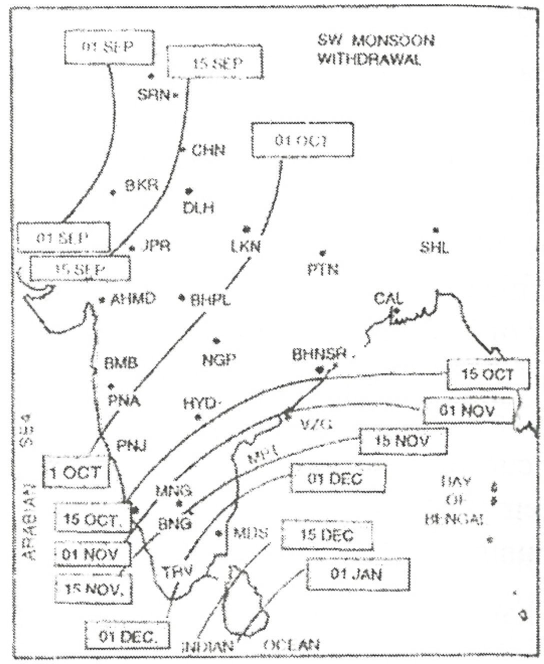
The Corialis Effect – The Causal Factor of the Monsoon

Because of the spheroidal shape of the earth, the equatorial regions are much more heated by the sun than the Polar Regions. As a result, to maintain the heat balance there is movement of air currents (and also ocean currents to some extent) between the equatorial and Polar Regions. The hot air in the equatorial region rises up and tends to move towards the colder air in the polar region with the colder air tending to move towards the equator from the Polar Regions at the lower level. Air streams moving north are deflected eastwards and those moving south are deflected westwards at the equator by the earth's rotation. This deflection is known as the Corialis Effect. Thus the winds coming from the Indian Ocean from the southeast get deflected over the Arabian Sea and approach India from the southwest. This is the South West Monsoon that brings over 70% of its annual rainfall to the country, except to Jammu & Kashmir and to the southeastern part of the Peninsula (mainly Tamil Nadu). The rains that this South West Monsoon brings are awaited with great interest (and often with great anxiety as well) by the entire country for the simple reason that the food output of the country is so much dependent on these rains. The onset of the rains from this south-west monsoon is fairly predictable, as indicated in the Sketches 3.1 and 3.2..

Sketch 3.1 Normal dates of onset of south-west monsoon



Sketch 3.2 Normal dates of withdrawal of south-west monsoon



The South West Monsoon

The South West Monsoon brings rain first to Kerala and to the North East in the first week of June and then moves northwards in two branches - the Arabian Sea branch and the Bay of Bengal branch. The Arabian Sea branch moves northwards towards Karnataka, Maharastra and Gujarat. The Bay of Bengal branch first covers the northeastern regions of the country and turns westward to advance into Bihar and Uttar Pradesh. Both the branches reach Delhi around the same time at end of June. The monsoon intensity increases from June to July and starts weakening by September.

The pattern of rainfall in this period clearly shows the impact of the geography of the Western Ghats, the Khasi Jaintia Hills, the Himalayas and the Vindhyas. The regions on the west of the Western Ghats receive heavy rains (e.g. Goa over 200 cm.) whereas those on the east of the Ghats get poor rains (e.g. Pune: less than 60 cm). In the Gangetic plain, the rainfall steadily decreases as one goes westwards from West Bengal (over 100 cm) to less than 10 cm in West Rajasthan. In the foothills of the Himalayas, while Himachal Pradesh receives over 150 cm, the quantum reduces sharply towards the west and northwest .The Ladakh Valley, which is on the leeward side of the monsoon wind, receives negligible rains. Sadly, devastating floods occur in this period in Eastern India year after year with tragic regularity. Often these floods are the result of the sluice gates of dams like the Hirakud in India or dams in Nepal being opened to reduce the water level in their reservoirs during heavy rains..

The North East Monsoon or The Receding South West Monsoon

The South West Monsoon current recedes southeastwards from the northwestern parts of the country by early September. This departure is again fairly predictable and is detailed in Sketch 3.2. In October – November, low-pressure areas develop in the Bay of Bengal and a northeasterly flow of air that picks up moisture in the Bay of Bengal is formed. Tropical cyclones form which often turn into severe storms that move west or northwestwards and hit Tamil Nadu, Andhra and Orissa coasts. Sometimes they take a sharp turn and strike Bengal or Bangaladesh. Often these storms cause severe devastation particularly in Andhra Pradesh, Orissa and Bangladesh. Tamil Nadu incidentally receives 65% to 70% of its annual rainfall from this receding Southwest monsoon.

APPENDIX 4

RAINFALL AND RAINY DAYS IN SELECT TOWNS AND CITIES

ALL RAINFALL DATA ARE IN mm

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Agra													
Total R. fal	15.4	11.5	10.6	3	10.6	52.3	217.1	283.4	124.3	30.8	6.2	3.5	768.7
Rainy Days	1.3	0.9	1	0.4	1	3	10.8	12	5.5	1.6	0.5	0.3	38.3
Ahmedabad													
Total R. fal	2.6	1.1	1	0.9	6	108.7	265.3	219.8	171.9	10.8	8.9	2.6	799.6
Rainy Days	0.3	0.2	0.1	0.1	0.4	5	11.3	10.7	6.2	0.7	0.6	0.2	35.8
Ahmednagar													
Total R. fal	0.9	0.1	4.9	7.5	29.4	100	94	97.5	143.9	70.1	27.2	10	585.5
Rainy Days	0.1	0	0.5	0.7	2	6.3	5.9	5.7	7.6	3.7	1.7	0.6	34.8
Ajmer													
Total R. fal	3.2	5.7	3	3	17.8	58.8	236.7	154.8	87.4	21.2	6.3	1.6	599.5
Rainy Days	0.4	0.7	0.4	0.3	1.3	3.3	10	9	5	0.9	0.5	0.2	32
Allahabad													
Total R. fal	19.2	15.6	9.2	5.7	9.9	85.4	300.1	307.6	189.8	40.1	11.7	30.4	1024.7
Rainy Days	1.6	1.4	0.9	0.5	0.7	4.4	12.8	14.4	8.7	2.2	0.5	0.5	48.6
Alleppey													
Total R. fal	20.4	42.3	60.4	154	383.1	616.5	588.9	349.3	291.5	380.1	193.2	65.2	3144.9
Rainy Days	1.6	2.1	3.1	8.7	14.6	22.5	23.9	18.8	15.1	15.5	9	3	137.9
Alwar													
Total R. fal	12.7	9.6	8	6.2	28.6	49.6	219	257.5	142.6	27.4	6.8	8.6	776.6
Rainy Days	1	1.2	0.8	0.8	2.1	3.6	10.3	11.9	6	1.7	0.5	0.7	40.6
Ambala													
Total R. fal	38.5	28.4	29.5	6.1	19.3	73.2	267.2	267.2	161.3	32.9	9.3	13.2	946.1
Rainy Days	2.6	2.1	1.8	0.8	1.6	3.7	9.6	10.5	5.1	1.3	0.4	1.2	40.7

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Amritsar													
Total R. fal	28	21.7	29	12.2	14.4	57.6	186.2	184.1	102.2	24.8	6.2	14.8	681.2
Rainy Days	2.4	2	2.6	1.5	1.3	3.1	8.2	8.1	3.6	1.2	0.6	1.2	35.8
Anantpur													
Total R. fal	0.2	1.4	3.4	16.2	65.4	57.8	60.9	62	134.8	117.2	31	10.7	561
Rainy Days	0	0.1	0.3	1.2	3.5	3.6	4.4	4.5	7.2	6.3	2.1	0.9	34.1
Aurangabad													
Total R. fal	2.2	2.9	5.1	6.3	25.5	131.4	167	165	135.3	52.6	29.3	8.4	731
Rainy Days	0.2	0.1	0.6	0.7	1.4	7.7	11.6	10.4	7.7	2.8	1.4	0.7	45.3
Bangalore													
Total R. fal	2.7	7.2	4.4	46.3	119.6	80.8	110.2	137	194.8	180.4	64.5	22.1	970
Rainy Days	0.2	0.5	0.4	3	7	6.4	8.3	10	9.3	9	4	1.7	59.8
Baroda													
Total R. fal	1.2	0.6	2.2	0.9	4.4	146.8	297.6	284.7	141.7	22	16.2	4.4	922.7
Rainy Days	0.1	0.1	0.2	0.1	0.3	5.6	13.8	12	7.1	1.3	0.7	0.2	41.5
Belgaum													
Total R. fal	0.2	3.8	8.8	54.3	111.9	232.4	488.4	286.3	129.3	141	44.5	6.2	1507.1
Rainy Days	0	0.3	0.5	3.8	5.2	12	21.9	19.7	9.8	6.9	2.7	0.5	83.3
Bellary													
Total R. fal	0.4	0.7	3.3	25.4	63	52.2	55.6	50.7	124.4	109.8	30	13.7	529.2
Rainy Days	0.1	0.1	0.4	2	4.1	3.4	4.5	4	6.3	6.1	2.4	0.8	34.2
Bhavnagar													
Total R. fal	1.2	1.5	2.4	0.4	4.6	114.9	180.5	152.9	117.4	26.1	10.8	2	614.7
Rainy Days	0.2	0.1	0.2	0.1	0.4	5.2	9.8	8.4	6.1	0.7	0.5	0.3	32
Bhopal													
Total R. fal	12.9	7.8	7.2	4.5	8	114	355.8	388.4	195.8	26.2	13.7	12.4	1146.7
Rainy Days	1.3	0.7	0.7	0.4	0.8	6.7	14.5	14.9	8.2	1.7	0.8	0.7	51.4
Bhuj													
Total R. fal	2	1.1	2.9	0.7	1.7	33.9	136.3	120.7	54.2	15.4	7.7	1.6	378.2
Rainy Days	0.3	0.1	0.2	0.1	0.1	1.6	6	4.7	2.8	0.8	0.5	0.2	17.4

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Bijapur													
Total R. fal	0.3	3.8	4.5	26.6	48.5	83.5	99.2	87.3	157.8	126	29.2	4.9	671.6
Rainy Days	0	0.3	0.6	2.5	3.3	5.1	6.8	5.4	7.7	6.5	1.7	0.6	40.5
Bikaner													
Total R. fal	5.7	8.1	6.9	3.1	14.2	30.9	73.1	72.7	53.4	4.9	3.6	3.2	279.8
Rainy Days	0.8	0.6	0.7	0.3	1	2.3	4.4	4.8	2.8	0.4	0.3	0.3	18.7
Bharuch													
Total R. fal	1.2	1	0.8	1	12.5	121	307.6	243.1	197.6	35.2	3.7	0.1	924.8
Rainy Days	0.1	0.1	0	0.1	0.4	6.3	14	12.1	7.9	1.6	0.3	0	42.9
Chandigarh													
Total R. fal	33.1	38.9	30.4	8.5	28.4	145.2	280.4	307.5	133	21.9	9.4	21.9	1058.6
Rainy Days	2.6	2.8	2.6	1.1	2.1	6.3	12.3	11.4	5	1.4	0.8	1.4	49.8
Chennai													
Total R. fal	16.2	3.7	3	13.6	48.9	53.7	97.8	149.7	109.1	282.7	350.3	138.2	1266.9
Rainy Days	1	0.3	0.2	0.7	1.6	4.1	7.3	9.5	6.6	10.2	10.1	5.5	57.1
Coimbatore													
Total R. fal	8.6	6.6	13	49	83.9	34.1	47.3	25.6	45.2	148.6	117.2	50.8	629.9
Rainy Days	0.7	0.6	0.7	3.2	4.8	3.1	4.7	2.9	3.3	8.9	6.7	3.1	42.7
Conoor													
Total R. fal	58.3	61.7	90.2	134.2	118.8	58	79.6	67.7	128.5	313.1	356.5	146.7	1613.3
Rainy Days	3	2.1	2.8	6.4	7.3	6.3	8.6	7	8.3	13.7	11.1	6.3	82.9
Cuddalore													
Total R. fal	36.7	9.4	15.6	14	47.2	43.1	82.8	150.3	123.4	273.6	383.5	198.5	1378.1
Rainy Days	2.1	0.8	0.7	0.8	1.8	3.2	5.9	8.1	6.1	10.4	10.8	6.8	57.5
Cuddapah													
Total R. fal	0.4	0.7	3.5	14.2	48.8	86.6	130.3	114.9	133.4	143.3	88.4	18.8	783.3
Rainy Days	0	0.1	0.3	0.7	2.9	4.9	7.3	6.9	6.6	7.3	4.8	1.5	43.3
Cuttack													
Total R. fal	12.6	23.3	23.6	27.1	69.7	197.6	326.4	340.7	260.4	166.4	23.6	3.9	1475.3
Rainy Days	0.7	1.4	1.7	2.1	3.9	10.6	15.5	15.6	12.6	8.1	1.6	0.3	74.1

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Darjeeling													
Total R. fal	27.4	13	51.2	84.5	157.3	476.9	774.8	543.4	418.2	105.4	12.2	2.8	2667.1
Rainy Days	1.6	1.5	4	6.6	12.3	20	26.1	23.1	16.8	5.7	1.3	0.4	119.4
Dehradun													
Total R. fal	51.6	48.1	51.3	17.3	36.2	225	718.6	734	321.7	47.5	11.3	23.2	2285.8
Rainy Days	3.8	3.2	3.6	1.4	2.9	9.6	21.2	21.5	12.1	2.8	0.9	1.6	84.6
Dwaraka													
Total R. fal	1	1	0.7	0.1	0.6	53.4	199.9	94.8	46.4	10.6	22	2.7	433.2
Rainy Days	0.1	0.2	0.1	0	0	2.8	6.6	4	2.5	0.6	0.4	0.2	17.5
Gadag													
Total R. fal	2.6	1.1	5.3	48.4	85.8	83.9	72.4	81.5	134.3	130.1	34.5	7.7	687.6
Rainy Days	0.1	0.1	0.4	3	5.3	5.6	7.9	6.8	7.2	6.9	1.9	0.5	45.7
Gorakhpur													
Total R. fal	21.7	11.4	10.2	13.7	27.4	163.6	322.3	349.5	213.9	83.8	4.5	6.1	1228.1
Rainy Days	2.1	1.1	1.3	0.8	1.7	6.8	12.7	14.8	9.1	3	0.2	0.5	54.1
Gulbarga													
Total R. fal	2.4	5	9.5	20.3	54.4	111.7	155.9	2.4	204.7	85.7	21.8	8.5	682.3
Rainy Days	0.3	0.3	0.5	1.9	2.9	7	10.2	8.9	9.6	4.8	1.3	1.3	49
Guwahati													
Total R. fal	11.4	12.8	57.7	142.3	248	350.1	353.6	269.9	166.2	79.2	19.4	5.1	1715.7
Rainy Days	1.2	1.3	4.6	9	14.3	16.1	16.8	13.9	10.3	5.3	1.5	0.4	94.7
Gwalior													
Total R. fal	16.5	8	7	2.6	8.9	77.7	261.6	312.9	146.2	42.6	4.2	7.7	895.9
Rainy Days	1.5	0.8	0.7	0.3	0.7	4.2	11.8	13.5	6.2	1.9	0.4	0.6	42.6
Hubli													
Total R. fal	1.5	1.5	9.4	36.6	70.1	81.8	113.3	87.6	100.8	111.5	42.9	11.9	668.9
Rainy Days	0.1	0.2	0.7	3.1	4.9	7.6	12.4	8.7	7.3	7	2.8	0.7	55.5
Hyderabad													
Total R. fal	3.2	5.2	12	21	37.3	96.1	163.9	171.7	181.5	90.9	16.2	6.1	805.1
Rainy Days	0.3	0.4	0.9	1.8	2.7	7.6	10.6	10.1	8.9	5.7	1.6	0.4	51

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Imphal													
Total R. fal	12.8	30.6	61.1	101.2	145.9	283.8	231.4	196.6	123.6	119.7	36	10.4	1353.1
Rainy Days	1.3	2.8	5	8.8	11.1	16	16.4	13.6	8.9	6.9	2.4	0.8	94
Indore													
Total R. fal	9	1.7	2.8	2	9.3	134.3	284.6	287.3	211.6	36.5	20	9.2	1008.3
Rainy Days	0.9	0.2	0.3	0.3	0.9	7.1	13.4	12.8	8.6	2	1	0.5	48
Jabalpur													
Total R. fal	19.5	16.2	16.1	5.8	11.9	169.2	382.8	458.1	188.7	39.3	12.1	11.9	1331.6
Rainy Days	1.5	1.3	1.4	0.7	0.6	8.2	17.1	17.4	9.8	2.6	0.6	0.7	61.9
Jaipur													
Total R. fal	7.9	11.7	6.1	4.1	16.2	66	216.3	231.2	80.3	22.6	3.2	3.3	668.9
Rainy Days	0.6	0.9	0.7	0.5	1.1	3.6	10.8	11.6	5.1	1.2	0.3	0.4	36.8
Jamnagar													
Total R. fal	1.7	1.8	1.1	0	0.9	91.6	197.6	180.3	62	28.6	7	0.8	573.4
Rainy Days	0.3	0.1	0.1	0	0.1	3.7	8.1	6	3.9	1	0.6	0.1	24
Jamshedpur													
Total R. fal	11.9	17.8	23.7	32	49.9	232	326.5	346.1	239.1	86	11.2	3.1	1379.3
Rainy Days	1.1	1.7	2.1	2.3	4.1	10.7	16.2	16	12.9	5	0.7	0.3	73.1
Kakinada													
Total R. fal	2.9	10.4	11	19.7	44	121.2	187.3	150.7	170	268.4	112	15.6	1113.2
Rainy Days	0.2	0.5	0.4	1.1	2.2	7.1	11.2	10.8	8.5	8.8	4	1	55.8
Kalimpong													
Total R. fal	16.9	9.9	33.7	65.9	123.5	402	665	504.5	335.9	112.8	8	3.4	2281.5
Rainy Days	1.2	0.9	2.7	4.8	8.4	16.3	21.5	18.9	11.7	3.4	0.7	0.3	90.8
Kanpur													
Total R. fal	21.1	12.5	6.2	4.5	9.8	65.4	229.8	289.5	124.4	60.7	1	7.7	832.6
Rainy Days	1.5	1	0.7	0.5	0.8	3.3	12	13.7	6.5	2.1	0.2	0.7	43
Kanyakumari													
Total R. fal	13.6	15.6	22.9	62.6	55.3	81.4	55.2	46.3	43.9	150.8	166.1	83.2	796.9
Rainy Days	0.7	0.8	1.7	3	3.2	6.6	5.2	3.5	3.1	7.6	8.3	4.4	48.1

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Karwar													
Total R. fal	0.4	0	1.4	10.2	173.1	928.2	1010	583.9	298.1	152.8	36.4	14.5	3209.7
Rainy Days	0	0	0.1	0.7	5.1	22.7	27.4	24.4	14.5	6.9	2	0.5	104.3
Kochi													
Total R. fal	21.9	22.9	35.3	124	395.7	720.7	697.2	367.8	289.4	302.3	175.1	48.3	3200.6
Rainy Days	1	1.4	2.3	7.5	12.9	23.4	24.2	19.4	15.3	14.4	8.1	2	131.9
Kodaikanal													
Total R. fal	33	28	56.3	163.4	148.1	88.4	136.7	135.4	179.5	259.2	221.6	144.1	1593.7
Rainy Days	2.2	1.9	3.3	8.6	9.8	7.6	10.6	10.6	11.3	15.3	11.2	7.3	99.7
Kolhapur													
Total R. fal	0.1	1.1	8.4	34.6	70.2	149.9	359.9	214.6	123.1	110.8	41.1	8.7	1122.5
Rainy Days	0	0.2	0.6	2.6	3.9	10	19.9	17.9	9.2	6.3	2	0.4	73
Kolkota													
Total R. fal	16.8	22.9	32.8	47.7	101.7	259.9	331.8	328.8	295.9	151.3	17.2	7.4	1614.2
Rainy Days	0.9	1.5	2.3	3	5.9	12.3	16.8	17.2	13.4	7.4	1.1	0.4	82.2
Kohima													
Total R. fal	13.6	21.3	49.2	72.2	164.6	324.4	380	382.4	243.2	120.4	38.1	4.5	1813.9
Rainy Days	1.7	2.2	4.7	7.2	14	19.8	22.5	20.7	16.6	8.7	2.5	0.8	121.4
Kozhikode													
Total R. fal	2.7	3.4	21.4	90.2	310.9	818.2	902.5	447.3	233.4	263.5	136.8	35	3265.3
Rainy Days	0.3	0.4	1.1	4.8	11.1	22.7	25.5	20.2	11	10.9	5.8	1.8	115.6
Kurnool													
Total R. fal	0.7	2.6	7.9	19.5	60.5	90.9	138.3	141.2	148.1	90.2	20.3	5.7	725.9
Rainy Days	0.1	0.3	0.6	1.7	2.9	5.6	9.4	9.1	8.2	5.6	1.9	0.4	45.8
Lucknow													
Total R. fal	21.3	14.3	8.7	5.6	24.2	103	286.2	316.6	180.4	36.7	2.7	5.8	1005.5
Rainy Days	1.8	1.2	0.7	0.5	1.4	4.6	12.1	14	7.9	1.9	0.3	0.7	47.1
Madurai													
Total R. fal	13.7	14.5	19.9	63.3	48.5	43.8	59.3	95.4	111	189.2	127.9	68.2	854.7
Rainy Days	2	1.4	1.2	0.5	1.5	3	9.1	11.3	4.9	1.6	0.3	0.6	37.4

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Mangalore													
Total R. fal	0.3	2.5	2.5	36.4	229	950.8	1124.5	702.2	298.9	191.1	68.2	24.4	3630.8
Rainy Days	0	0	0.2	2.2	8.2	24.3	29	24.7	14.5	10.6	4.2	1	118.9
Madgaon													
Total R. fal	0.2	0	0.2	9	75.7	782.1	874.1	444	237.5	113.3	28.6	14.2	2578.9
Rainy Days	0	0	0	0.5	2.9	21	25.8	22.2	13	5.8	1.9	0.5	93.6
Meerut													
Total R. fal	24.6	18.5	10.3	5.1	15	54	248	332.2	138.9	42.8	3.1	8.5	901
Rainy Days	2	1.4	1.2	0.5	1.5	3	9.1	11.3	4.9	1.6	0.3	0.6	37.4
Mumbai													
Total R. fal	0.6	1.5	0.1	0.6	13.2	574.1	868.3	553	306.4	62.9	14.9	5.6	2401.2
Rainy Days	0.1	0.1	0	0.1	1	14.9	24	22	13.7	3.2	1.1	0.4	80.6
Mysore													
Total R. fal	1.9	5.2	8.5	61	148.3	72.7	80.4	63.7	106.2	166.5	58	16.5	788.9
Rainy Days	0.2	0.4	0.5	3.9	7.4	5.6	8	5.7	6.3	8.9	3.6	1.1	51.6
Nagpur													
Total R. fal	10.2	12.3	17.8	13.2	16.3	172.2	304.3	291.6	194.4	51.4	11.8	17.2	1112.7
Rainy Days	1	1.1	1.5	1.4	1.2	9	15	14.4	9.4	2.8	0.7	0.8	58.3
Nasik													
Total R. fal	1.1	0.4	3.4	6.7	16.2	98.1	206.4	134.6	146.1	49	21.3	7.2	690.5
Rainy Days	0.1	0.1	0.2	0.5	1.2	5.7	12.8	11.2	8	3.2	1.3	0.6	44.9
Nellore													
Total R. fal	7.3	1.4	5.2	14.4	49.7	44.1	80	94.8	103.4	272	275.2	94.6	1042.1
Rainy Days	0.7	0.2	0.3	0.6	2	3.5	6.3	6.7	6.1	9.6	8.1	3.6	47.7
New Delhi													
Total R. fal	14.8	14.1	9.3	6.1	18.9	54.2	241.1	284.3	119.4	16.8	6.4	8.6	794
Rainy Days	1.3	1.5	1	0.6	1.5	3.5	10.9	10.7	4.9	1.4	0.2	0.8	38.3
Palakkad													
Total R. fal	2.6	7.3	24.3	89.1	162.4	401.9	562.5	342	156.2	243	122.6	26.6	2140.5
Rainy Days	0.2	0.5	1.2	4.6	7.4	18.3	22.3	18.2	10.5	12.2	5.7	1.4	102.5

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Panjim													
Total R. fal	0.2	0.1	1.2	11.8	112.7	868.2	994.8	518.7	251.9	124.8	30.9	16.7	2932
Rainy Days	0	0	0.1	0.8	4.2	21.9	27.2	23.3	13.5	6.2	2.5	0.4	100.1
Patiala													
Total R. fal	30.7	27.4	19.4	5.9	16.9	57.7	229.5	227	123.7	20.2	6.3	10.2	774.9
Rainy Days	2.2	2	1.8	0.7	1.3	3	8.7	8.8	4.5	1	0.5	0.9	35.4
Patna													
Total R. fal	20.5	6.9	9.1	11.6	24.7	139.6	253.1	248	216.3	63.4	6.8	0.4	1000.4
Rainy Days	1.2	0.9	1.1	0.6	1.5	6.1	12.4	12	9.3	2.8	0.3	0.4	48.6
Pondichery													
Total R. fal	7.4	7	27.8	8.9	32.7	23.9	77.8	111.1	122.7	290.9	394.4	159.4	1264
Rainy Days	0.8	0.5	0.7	0.6	2.3	2.5	5.1	6.3	5.9	10.2	11.7	6.5	53.1
Porbunder													
Total R. fal	1.3	1.6	3.4	0	0.4	128.5	245	149.5	71.3	27.6	9.9	1.4	639.9
Rainy Days	0.3	0.2	0.2	0	0.1	4.8	8.1	5.9	3.2	1.1	0.7	0.1	24.7
Pune													
Total R. fal	1279.8	0.5	5.3	16.6	40.6	116.1	187.2	122.3	120.1	77.9	30.2	4.8	721.6
Rainy Days	0	0.1	0.6	1.1	2.8	7.5	12.8	10.6	7.4	4.6	2	0.4	49.9
Raichur													
Total R. fal	0.5	1.7	4.6	25.8	41.3	86.9	145.6	140.8	170.7	115.7	13.6	7.4	754.6
Rainy Days	0.1	0.1	0.3	1.7	3	6.2	9.1	9	7.8	5.5	1.3	0.6	44.7
Rajkot													
Total R. fal	0.9	0.6	1.7	0.6	2.6	110.1	238.5	209.8	96.3	39.8	7.8	1.1	709.8
Rainy Days	0.1	0.1	0.2	0.1	0.3	5	9.3	8	4.6	1.4	0.6	0.1	29.8
Ranchi													
Total R. fal	22.5	29.9	26.6	31.7	54.5	199.3	345.9	329.1	282	89.2	8.7	6.1	1425.5
Rainy Days	1.6	2.3	2.6	2.2	4.3	10.6	18.1	16.3	13.3	4.8	0.8	0.6	77.5
Salem													
Total R. fal	5.1	8.1	10.5	41.4	106.9	78.9	113.4	136.8	170.9	208.7	91.7	41.1	1013.5
Rainy Days	0.4	0.4	0.7	3.1	6.9	5.2	7.5	8.8	9.1	10.4	5.7	2.6	60.8

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Shillong													
Total R. fal	15.2	28.5	59.4	136.4	325.4	544.6	394.9	334.6	314.9	220.2	34.9	6.3	2415.3
Rainy Days	1.6	2.8	4.6	9.1	17.9	21.9	19.3	18.6	17.3	11.2	3	0.8	128.1
Shimla													
Total R. fal	54.6	47.2	59.4	41.1	56.4	175.6	376.5	335.1	190.2	46.2	13.8	16	1412.1
Rainy Days	4.7	4.1	5.2	3.6	4.6	10.3	18.3	18.1	9.9	2.9	1.3	1.8	84.8
Solapur													
Total R. fal	2.2	4.6	3.8	11.2	36.9	111.5	138.8	137.3	179.8	97.4	23.2	4.8	751.5
Rainy Days	0.1	0.4	0.3	1.3	2.7	6.9	9.1	8.6	9	5	1.5	0.4	45.3
Surat													
Total R. fal	0	0.4	1.5	0.3	7.3	249.3	417.7	299.4	190.7	27.2	13	2.6	1209.4
Rainy Days	0	0	0.2	0	0.3	8	15.4	13.2	7.6	1.2	0.8	0.1	46.8
Thiruvanandapuram													
Total R. fal	22.7	24.4	40.4	117.4	230.4	320.8	226.8	138.1	174.6	281.7	184.5	65.9	1827.7
Rainy Days	1.6	1.6	2.9	6.9	11.3	16.3	14.6	11	8.9	11.9	8.6	4.1	99.7
Tiruchi													
Total R. fal	14.3	5.4	9.5	50.5	65.2	34.9	60.6	85.5	146.6	191.5	131.8	84.4	880.2
Rainy Days	0.9	0.5	0.6	2.6	3.5	2.3	3.2	4.7	7.3	10.2	7.8	4.4	48
Udaipur													
Total R. fal	7	2.6	9.6	3	8.6	85.2	195.4	177.3	117	18.5	9.7	2.3	636.2
Rainy Days	0.4	0.3	0.3	0.3	0.8	4.7	9.4	9.4	5.9	1.1	0.6	0.3	33.5
Udhagamandalam													
Total R. fal	10.3	8.3	19.9	70.1	167.1	120	177.9	108.3	130.9	191.9	133	56.1	1193.8
Rainy Days	0.8	0.9	1.6	6.2	10.1	9.9	13.9	10.1	9.1	12.9	7.3	3.1	85.9
Varanasi													
Total R. fal	20.3	12.5	10.4	4.3	11.5	85.6	303.8	281.3	214.9	39.8	15.5	3.4	1003.3
Rainy Days	1.8	1.1	1	0.5	0.9	4.5	12.5	13.3	9.4	2.2	0.3	0.3	47.8

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Vellore													
Total R. fal	9	7.1	5.9	21.8	83.9	71	117	124.9	149.6	176.9	155.2	78.6	1000.9
Rainy Days	0.8	0.5	0.4	1.3	4.7	5.3	6.6	7.8	7.6	9.4	7.7	3.9	56

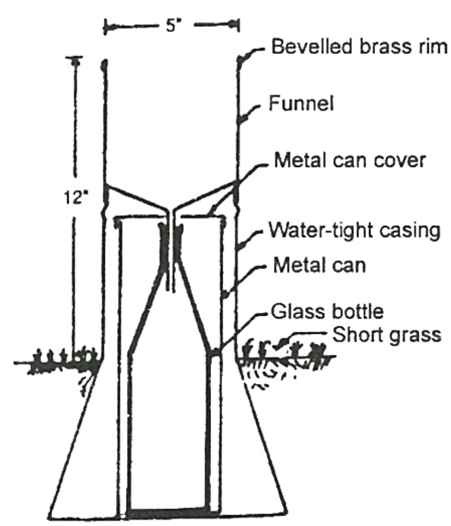
The above data were extracted from the following 1999 publication of the India Metereological Department, New Delhi: Climatological Tables of Observatories in India, 1951-1980. The data given were recorded for the period 1951 to 1980. In a few cases, they do not represent the data for this full period:- Alwar:1955-1980; Chandigarh:1954-1977; Gangtok: 1959-1980; Kanpur:1951-1976; Kanyakumari: 1961-1980; Lucknow: 1951-1974; Patiala:1951-1978; Pondichery: 1967-1980; Ranchi: 1955-1967;

APPENDIX 5

CONSTRUCTION OF A RAIN GAUGE

We had noted earlier that the average annual rainfall in your town or city and the pattern of its distribution over the twelve months influences the design of your RWH system (Chapter 6). It also gives you an idea of the potential available in RWH to meet your water needs. The Indian Meteorological Department meticulously records both these data in numerous stations all over the country, both in the rural and urban centers. Data on both have been given for select towns and cities all over India in the previous section. However, it is possible that such data may not be readily available to ordinary citizens. If you are interested, you can yourself construct a rain gauge and use it for getting these data in your area on an approximate basis.

We had noted in Chapter 3 that 50 mm of rain on a particular day would mean that rainwater would fill up to a height of 50mm in an empty container kept on your terrace. While this is the simple principle in measuring rainfall, care has to be taken to ensure that the gauge used for this is capable of measuring small quantities of water reasonably accurately. The India Meteorological Department collects the data between 8.30 A.M. on a particular day and 8.30 A.M. on the next day.



The rain gauge used by them has three components:1) A wide diameter funnel (of diameter 127mm or 159.6mm); 2) A collection flask of 4litre capacity with a narrow neck (to prevent evaporation of the collected water) and 3) An outer container in which the collection flask is kept (again to avoid evaporation by introducing an air gap). Besides, the funnel has a rim of about 250mm to ensure that winds do not impact on the collection accuracy. The water collected is then poured into a measuring cylinder. The cylinder is so sized that if 1cm of rain occurs, the collected water will fill up to 1cm height in it. The outer container is kept fixed in a masonry base so that it remains stable even during windy periods. While this is the rigorous method for measuring rainfall, you can set up a simple arrangement on your terrace to measure rainfall with accuracy adequate for your purpose.

All you need is to keep a broad brimmed plastic funnel (5inches in diameter) available in shops. The stem of the funnel is kept in a narrow necked bottle. Protect the bottle and the funnel with a hollow cylinder made of cardboard (covered with plastic sheet) or some other water- proof material. Keep the set-up away from tree branches and any civil constructions that may come in the way of the free fall of rainwater over the gauge. Set up your own 24hr period for making measurements. Find out the volume of water collected . Every 127 ml of water collected stands for 1cm of rain. To measure the volume, you can get a 250ml measuring cylinder from any caompany selling scientific supplies.

APPENDIX 6

HOW JANAKI STOPPED GOING DOWN THE HILL TO FETCH WATER

She is an illiterate, hails from a backward community and is a mother of five. But that has hardly stopped *neer* Janaki (*neer* means water in Kannada) from being innovative.

Seven years ago, when the view that land is the source of water reigned supreme, when jargon such as "watershed management" was yet to be coined, Janaki invented her saree technique to successfully harvest rainwater at her home in Kepulakodi (near Vittal), 32 km from Mangalore.

"The innovation was born not for fancy's sake, but out of necessity," says Janaki in chaste Tulu. She and her husband Narayan, who works as a farm hand in Kepulakodi, had moved into a new home on a hillock amidst boulders. Initially, Janaki without any fuss used to draw water from a farm owner's well located a kilometre away. But during the monsoon season, she had a problem. She risked losing her step while going down the slippery rain-slicked boulders. And the uphill climb was a tiring ordeal for the frail woman in her early forties.

"When fetching water began cutting into my time set aside for rolling beedies and other household chores, I had to decide on an alternative." says Janaki matter-of-factly. She does not remember on how she zeroed in on her old saree for the solution. But the trials that followed to the final model are still fresh in her memory. It was hard to keep the saree static in heavy wind and rains. Then her saree came apart, ripped down the middle. And she was at her wit's end on how to make rainwater flow to a common point and then into a pot.

Tethered firmly to four corners, the funnel-shaped saree tapers at the mouth of the pot. The sticks that hold the saree borders apart ensure that the collected water sieves down to the pot. The method - frightfully simple and without burning pockets - has been saving labour, time and space and has fetched potfuls of water for Janaki's family of six plus during the monsoons.

A four- hour spell of continuous rain is sufficient enough to fill up eight pots, the family's total water requirement. "Yesterday there was 15 minutes of rain but it was sufficient to make *ganji* (porridge)", she says.

Splitting her saree into equal halves, Janaki uses the ensemble throughout the entire season. After the monsoon the model is dismantled and kept aside for the summer.

Her technique, accidentally discovered by NGO Maithri Trust, is now being used as an example at awareness camps held in and around Vittal. - *The New Indian Express of 19-7-2002*

This story is inspiring for the ingenuity and enterprise exhibited by an illiterate villager in rigging up an appropriate and effective rainwater harvesting system that saved considerable time and energy for herself and made life that much more comfortable for her family as well.

APPENDIX 7

VARAHAMIHIRA'S NATURAL INDICATORS FOR WATER SOURCES

Varahamihira who lived 1500 years ago was a famous astronomer, astrologer and a mathematician as well. He has written several books in these fields. His magnum opus titled 'Brihad Samhita' which means 'A Giant Collection' is a treasure house of information on a variety of subjects. The 54th chapter of this anthology contains 124 couplets that are devoted to a) methods of detecting underground water sources through natural indicators b) methods of breaking rocks to reach water in rocky soils and c) methods to prevent floods by strengthening banks of water bodies with the right species of trees. He can therefore be rightfully called as the founder of the science of hydrology.

The natural indicators cited by him for presence of water are mainly trees, shrubs, grasses and termite mounds. Termite mounds cannot last without moisture in the soil and therefore where there are termite mounds there has to be water. Vegetation too cannot survive without water and it is not surprising that they can assist us in locating water underground. Work done in the Department of Geology of the Venkateswara University, Tirupati, Andhra Pradesh, by Dr. E.A.V.Prasad has shown that they indeed can be useful guides for water detection. However since these are all natural indicators, they acquire relevance only in areas where the natural elements have not been disturbed. Thus they cannot be of much value in the urban context where man would have interfered with the natural elements substantially. They can however be of value in the peripheral areas of cities and towns which are under development and which have still not lost their pristine rural characteristics.

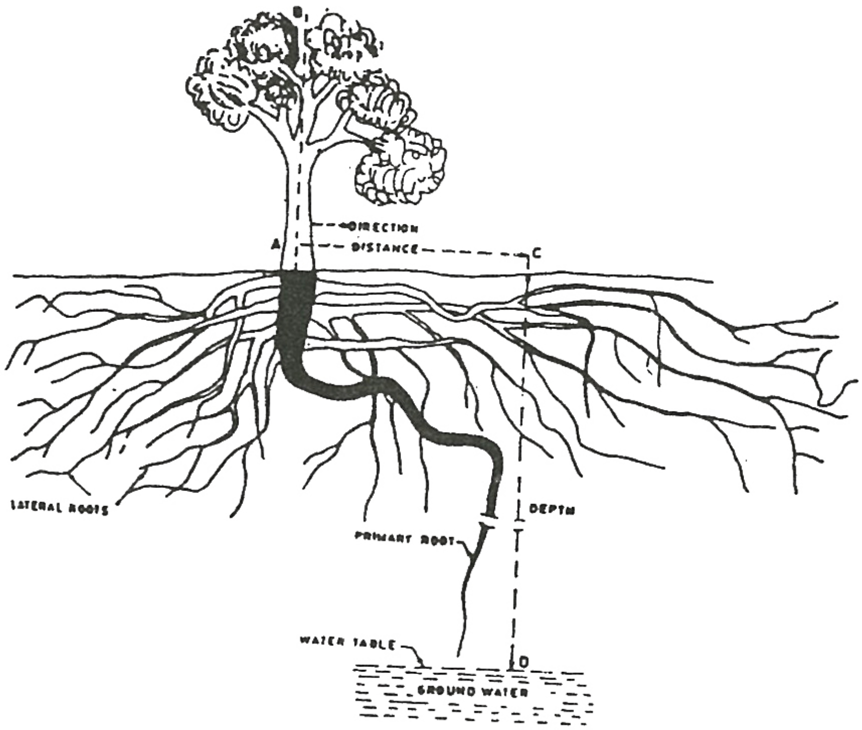
Some of these indicators are detailed below:

Table G.1 Trees Alone as Indicators

Sl.No.	Tree Species		Location of Water Source
	Botanical Name	Popular Names	
1.	Calamus rotang or Calamus extensis	S: Vetasa; T: Nochi or Nirkorai H:	5 ft west of tree at 12 ft depth
2.	Eugenia jambulana or syzypium cumini	H: Jamun;T: Naval;M. Jambul	5 ft north of tree at 16 ft depth
3.	Ficus glomerata Konea dumber	E: Fig; S: Udumbara; T: Athi; M; Anjir T.Peyathi H.Kakudumber	
4.	Bignonia indica/ Bignonia ceaf	S: Shonaka; T: Vallarai	
S = Samskrit; T= Tamil; K=Kannada; H=Hindi; Te=Telugu			

According to Dr. Prasad, the primary root of a phreatic plant i.e. a plant that thrives on ground water and is not dependent on rain, deviates at some point below the ground from the axis of its trunk and reaches the water table and the distances given by Varahamihira are based on this factor.

Sketch 7.1 Phreatic Root



5. Trees that have smooth trunks with branches touching the ground and spreading around indicate presence of water nearby.

6. If one of the branches alone of a tree is touching or almost touching the ground, or if the tree has acquired a pale white colour (not natural to it), then water will be found at 24 ft depth to the east of this tree.

7. If in an area of thorny trees or plants, one sees spots with thornless trees or plants, or vice versa, then the ground below west of such spots will have water at shallow depths.

8. If the flowers or fruits of a tree are found to be different from their normal natural characteristics, then water will be found at 34ft depth, five feet east of the tree.

9. If the prickly Kantakari tree (Solanum suratense; T:Kandankathiri; H: Ringni, Katin;) is found to be thornless and its flowers white instead of purple, water will be found at 24 ft below it.

10. If a date palm or a coconut palm or a palmyrah tree is Y-shaped i.e. its trunk has branched into two, water will be found at 24 ft to the west of the tree.

Intertwined Trees as Indicators

By the actions of birds, seeds of one tree fall at the base of another different tree, and it grows in such a way that the two trees are intertwined. According to Varahamihira, certain pairs of intertwining trees are strong indicators of aquifers in their neighbourhood.

1) If either two of the following are intertwined, there will be water at 5 ft depth in the soil there.

a) Banyan Tree (Ficus bengalensis; T:Alai; H: Bor; M: Wad; S: Nyagrodha)

b) Phalasa Tree (Butea frondosa or Erythrina indica (K:Dadap Pongira. T:Mullumurungai.)

c) Fig Tree (Ficus glomerata; T: Athi; M: Anjir;)

2) If the Banyan Tree is intertwined with a Peepul Tree (Ficus religiosa; T: Arasaimaram;) water will be found at the same depth as above.

3) If the Arjuna Tree (Terminalia arjuna; T: Maruthai; Te: Yermaddi.) is intertwined with a) the Karira Tree (Capponis decida;T: Thuthuvalai.) or the Bilva Tree (Aegle marmelus; H: Bel; T: Vilva; /Te: Maredu.), there will be water available at 15 ft below it.

Grasses as Indicators

1. If in an area (apparently) devoid of water, one finds plants which one normally would find only on the banks of water bodies e.g. Vettiver(H: Khus), Durva grass (T: Arkukampul), and Maruvu, water will be found in those spots at shallow depths.

2. In an area devoid of grass, if one sees spots having grass, the soil below those spots will have water at about 34 ft.

Table G.2 Combination of Trees and Termite Mounds

Sl.No.	Tree	Termite Mound	Location of water source
1.	Jamun:Eugenia jambolina; T: Naval; H:Jamun.)	East of tree	5 ft west of tree and at 12 ft depth
2	Fig: Ficus Glomerata T:Athi; M: Anjir	Nearby	5 ft west and at 20 ft depth.
3.	Arjuna Tree: Terminalia arjuna;T:Maruthai; Te:Erramaddi or Maddi. M. Srdhawal	North of tree	5 ft west and at 28 ft depth. As you dig, you will encounter ash coloured soil first, then black, then yellow and white and finally gravel. Thereafter, you will get plenty of water

Table G.2 Combination of Trees and Termite Mounds

4.	Aegle marmelos; H: Bel; T:Bilva K Belpatri; T: Maredu		
Note: Varahamihira's verses give the Samskrit names of the various trees. The corresponding popular names in other Indian languages and the botanical names given above are as given in the following two books: 1) Nilathadi Nir- Kandupidikkum Muraigal, (Ground Water- Methods of Detection), N.Devanathachariar, Ratnam Enterprises, 79, Big Street, Triplicane, Chennai 600 005. 2) Ground Water in Brihad Samhita, Dr. E.A.V.Prasad. Published by Sri Venkateswara University			

TURNING WASTE INTO WEALTH: THE TERRACE GARDEN

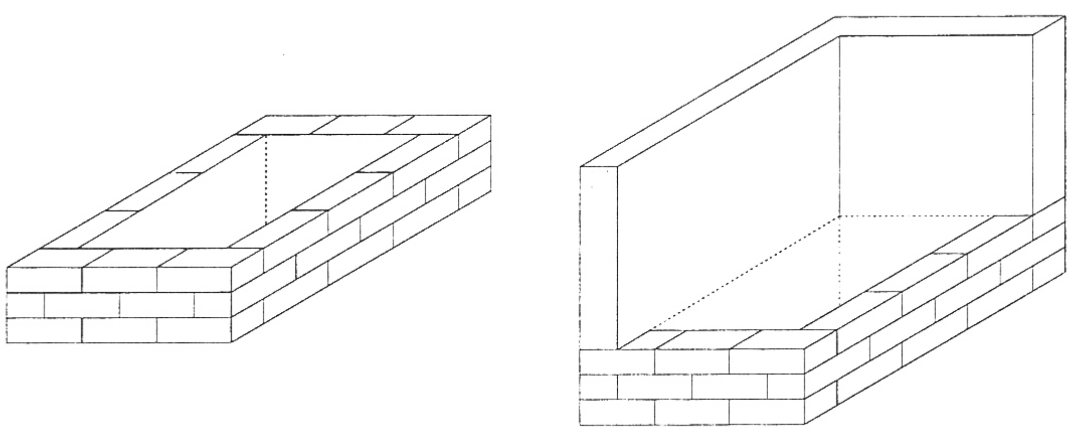
The dictionary states that a hat- trick means taking three wickets in cricket with three successive balls or achieving three consecutive successes. If you become a terrace gardener, you can achieve an ecological hat-trick:- i) You can dispose off your kitchen waste hygienically in your terrace garden ii) You can collect the water used for washing your vessels and use it for watering your terrace garden and iii) in the process, you can harvest fresh vegetables for your kitchen.

The terrace garden is easy to develop, needs very limited effort and expense and contributes to your family's good health by giving you pesticide-free organically grown garden-fresh vegetables (and even fruits, if you wish). If you are a flower lover, you can have fresh and lovely flowers to adorn the gods or your drawing room. How does one go about it? Read on[42].

Preparation of the Soil Bed

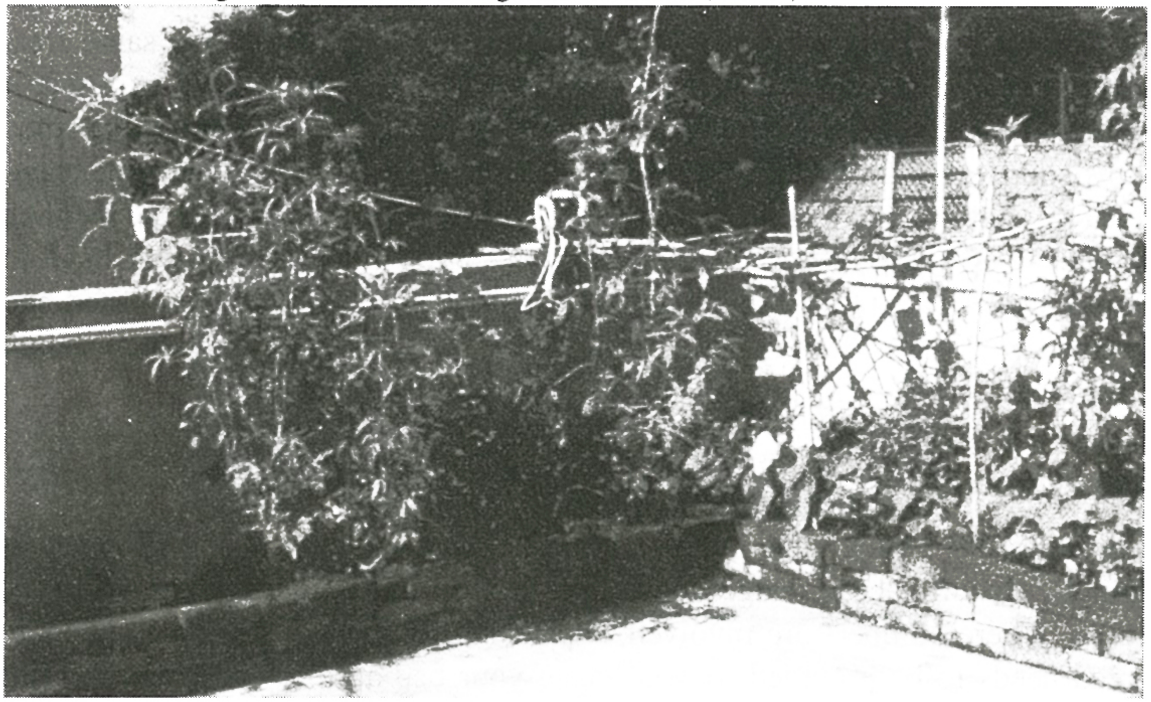
The soil bed can be either in the form of a rectangle or a square. You can locate the bed either along the parapet wall of the terrace or away from it. If you locate it along the wall, then the wall forms one side of the bed. If you locate it at a corner where the two walls meet, then the two walls form the two sides of the bed. You can also have it as an independent entity as shown in the sketch below:

Sketch 8.1



42. This technique for terrace -gardening was pioneered by Dr.Uday Bhawalkar of Pune. However, Dr. Bhawalkar used a special type of soil called vermicompost for growing the plants. This soil was stated to contain cocoons of earthworms from which earthworms were generated and contributed to the success of the garden. The author has found that ordinary garden soil is good enough and works without earthworms. If desired, earthworms can be physically introduced into the soil layer. Earthworms can be found in most soil areas at shallow depths by just digging in moist soil.

Picture 8.1 The terrace garden of the author. The tall plants on the left are "Okra" or "Ladies Fingers" and those on the right are Colacasia ("Arvi").



First lay a sheet of plastic on the floor to cover the entire area over which you want to plant. If the sheet is not thick, you can lay two layers of thin sheet. This is to avoid stagnation of water on then terrace floor. Prepare the support structure of the soil bed now by keeping bricks one over another in the manner shown below. Three to four tiers of bricks are enough for growing vegetables and small flowering plants. For larger shrubs and fruit trees, six to eight tiers will be needed.

Form a layer of twigs and small stones over the plastic sheet to a height of 1 to 2 inches. Put sand over it till the twigs and stones are covered. Put a 6 to 9 inch layer of garden soil over the sand. Put a layer of dried leaves over it (1/2 to 1 inch) or a thin layer of manure. Water it for a week to ten days. The bed is now ready for use.

Planting

Plant the samplings of the vegetables or flowering plants on the bed. Water daily with the water collected in a basin or bucket used for rinsing your vessels to free them from food remnants sticking to them or the water used for final rinsing of the vessels. Once the saplings are stabilised, throw the kitchen waste generated by you over the soil bed. Avoid coconut fibre, coconut shells, groundnut kernels, bones and mango kernels. Collect the vegetables or the flowers. For watering the plants, you can also use the water from the second rinses of the washing machine.

Maintenance

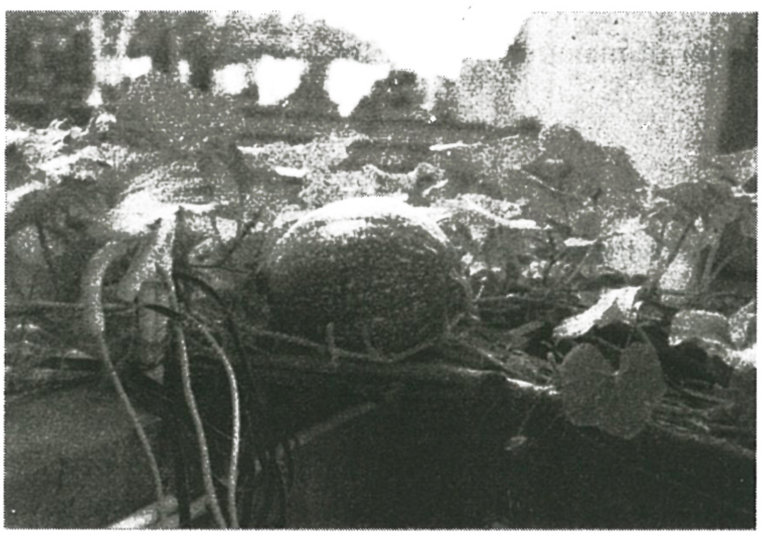
On sunny days, daily watering is a must because the soil thickness being limited, the soil moisture available for the plant is limited. The kitchen waste is simply strewn over the bed. If you wish, you can cover the soil area with leaves (bigger leaves preferably) and push the leaves to one side from a small area, expose the soil thereby, put the waste over it and push the leaves back over the same area. Thus, you can avoid exposure of the waste. Even if the waste is left exposed, it does not generate any smell and does not attract any flies. The waste is absorbed by the soil slowly and consumed by the plants. In case you don't segregate coconut fibre, shells, groundnut kernels, bones and mango kernels and throw them on the bed along with the rest of the waste, no harm is done. You will have to remove them from the bed occasionally, as they are not easily composted and absorbed by the soil. The mango kernels may sprout into saplings, which should be removed.

Your Choice of Produce

Vegetables like Brinjal (egg plant), Chillies, Tomatoes, Okra (Lady's Fingers or Bhendi), Cucurbitaceae (ridge gourd, ash gourd., bitter gourd,) can easily be grown. Where climbers are involved, supporting framework for the climbers to spread needs to be provided. If you locate your bed at a corner where the two walls meet, these walls can be used as supports for providing the framework (See Picture 8.1). Fruits like Guava, Pappaya, Seetha Phal (Anona squamosa) and grapes can be also grown with higher soil layers (15 to 20 inches).

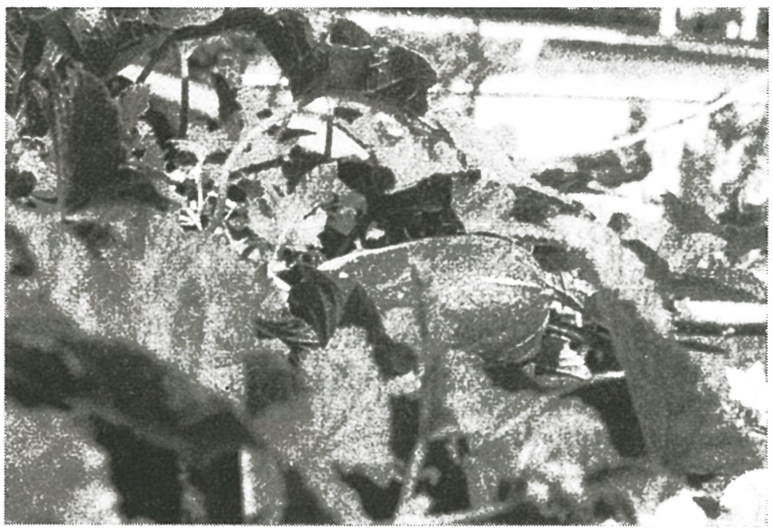
School children can become terrace gardeners, learn the magic of Mother Nature's sustainability and experience the joy of providing fresh vegetables or flowers for their mothers. Adult terrace gardeners will be able to enjoy the fresh air of the terrace and also get some exercise in the process.

Picture 8.2 A 4kg heavy red pumpkin in the author's terrace garden



Picture 8.3 Okra in the author's terrace garden

Picture 8.4 Malabar Cucumber in the author's terrace garden



EFFICIENT WATER MANAGERS IN NATURE

It is indeed fascinating to see how plants and animals manage water efficiently when exposed to hostile environments where water is in acute short supply. A few examples of these efficient water managers are presented below:

The Saguaro Cactus of Arizona

This cactus is a leafless plant in the Sonora Desert of Arizona, U.S.A. and in Mexico. It grows no taller than 10 metres but its roots are longer than 20 metres. These roots spread out laterally just below the surface and thereby quickly absorb the rain that might occur once in a blue moon. A full-grown Saguaro Cactus can be as heavy as 10 tons in which 8 tons are only water. A real water-hoarder indeed! And it protects this water with the abundant prickles it has.

The African Baobab

The Baobab tree of the African Savannah and Madagascar (Adamsonia digitata) has a peculiar shape with a thick bark and a sponge-like core that can hold 120 tons of water! Not surprisingly, people around it use it as a source of water. When the interior of this plant decays, the hollow of its trunk is often large enough for people to use it as a dwelling place or as a place to store things.

Sketch 9.1 The Baobab (Adansonia digitata)

The Mesquites of Texas

This has large leaves surprisingly and grows along dry rivers ('wadis'). The secret of their survival is their roots that may be available at 80 metres! Until the roots hit ground water, the portion above the ground does not grow much at all.

The Water-Holding Frog

The Cyclorama frog in Australia can hold 50% of its body weight as water in its bladders. During long spells of dry weather, it replenishes water from its own urine. Other desert frogs can absorb water from wet sandy areas through their stomachs!

Turtles

Turtles living in the Sonara and Mohave deserts of the U.S.A. are herbivores. They eat lots of watery young buds in the rainy season and store the water in a tank-like structure in their bodies. In the dry season, they go into a hole and live on the water they have saved.

The Camel

The camel is popularly called 'The Ship of the Desert' – an appropriate name for several reasons. One reason is that it enables people to cross the difficult terrain of the desert just as a ship enables people to cross the daunting distances of the ocean. Another reason is its movement. Unlike other animals, it moves both the feet on one side forward first and then both the feet on the other side. This gives the camel a swaying movement similar to that of a small ship moving over the ocean waves.

But the most important reason has to do with water. A ship carries the stock of water needed for long journeys across the salty waters. The camel too carries its own stock of water and can go without water in the extreme heat of the desert for days on end in summer and for weeks on end in winter. It can do so because it is a real water-hoarder! At a watering hole, a camel can slurp up 140 litres of water in 10 minutes flat! It gets moisture from the desert plants that it eats and stores the moisture within its body tissues.

It is also an efficient water user. When the ambient temperature increases, its body temperature also rises, thereby reducing water loss from its body through perspiration. It reduces water loss further by extracting the water from its body wastes before discharging them. While humans cannot survive a water loss of more than 12% from our bodies, the camel can survive as much as 30% water loss from its body! They also have a filtering mechanism in their body that allows them to drink water that has a 5.5% of salt content – more than that of seawater, which has only 3-4%!

EPILOGUE

Most of what has been presented in this book has been derived from actual experience. This experience shows in no uncertain terms that the almost universal shortage of water experienced by our towns and cities is not because Mother Nature has been niggardly in providing us with water, but only because we urbanites – both at the micro and at the macro level – had been taking her bounty for granted. We had never valued it adequately, and have been managing/using it inefficiently and wastefully. If, Dear Reader, **your** excuse for having done so is lack of information, hopefully this book has helped in filling up that gap. If it has sensitised and changed you, hopefully, you too will sensitise and change others — By practice first and then by preaching. By such action at the micro level, change at the community level will follow logically and naturally. This in turn will inevitably bring in change at the neighbourhood level and thereafter at the governmental and societal level as well. And we all can then enjoy substantial self-reliance in respect of our water needs on a sustained basis, in harmony with nature.

Dear Reader

Some errors have crept into the book unfortunately. Please correct them before perusing the book in detail, particularly the non-typographical errors listed first below:

All the non-typographical errors have already been corrected. Please correct the typographical errors listed on the other side and then throw away this sheet

1. Page 1 : last line: Add 'town' before' dwellers'
2. Page 7 : line 9: Add 'treat' after 'able to'
3. Page14 : line 28: Delete "However because of this, the evaporated water becomes softer."
4. Page 16-17 : Interchange Foot-notes 7 & 8.
5. Page 19 : line 17: Alter 170 x 106 to 170×10^6
6. Page 20 : line 22 : Add 'harvesting' after 'rainwater'.
7. Page 30 : In Sketch 4.1, make Borewell 1 as 2, and Borewell 2 as 1.
8. Page 34 : Foot-note : Add 'in Chennai' after 'playgrounds'.
9. Page 47 : Penultimate line : Replace 'Sketch 7.2 and 7.3' by 'Pictures 7.1. and 7.2'.
10. Page 49 : The Rapid Sand Filter : line 4-5 : Replace the words 'The filter with the dimensions given in the figure above' with 'A filter with one square meter filter area'.
11. Page 52 : Sketch 7.5 : The pipe below the valve on the left side should not touch the ground; Also in line 2, replace 'the portion marked A' with 'the 140 mm pipe'.
12. Page 52 : Delete the portion starting in brackets from line 11 from the bottom from the words 'see note.....' upto the end of the page, and replace by 'See boxed item on page 110).
13. Page 56 : Delete the boxed para at the bottom.
14. Page 64 : line 22: Alter 'Picture 7.9 (Page 60)' to 'Sketch 7.9 (Page 66)'
15. Page 67 : line 8 from bottom: Replace 'on page 60' with 'above.
16. Page 93 : line 13 : Put a comma before and after "as will be seen below"
17. Page 95 : lines 3-4: Replace "through a horizontal pipe" with "from the pipe bringing the grey water to the bed".
18. Page 95 : last line : Replace "Picture 12.6" with "Pictures 12.5, 12.6"
19. Page 100 : Write-up of Sketch 12.9 : After' 1 ft'., add 'wide'.
20. Page 108 : In sketch 12.3, connect the gate trench to the inspection chamber (small square).
21. Page 110 : line 2 : Alter "Picture 12.4" to "Pictures 12.1 and 12.2"

Please see the other side also

22. Page 112 : line 5 from bottom : Put hyphen after 'body
23. Page 120 : Interchange Sketches 14.3 and 14.4.
24. Page 131 : last line in the lower boxed item; Add "pleasantly" before "surprised"
25. Page 135 : Para 3 line 3 : Add '30' after 'page'.
26. Page 138 : line 9 : Replace '1 to 4' with 'a to d'.
27. Page 157 : The units in column 1 to 4 are respectively Kl, gm, gm and ml.
28. Page 177 : Delete last sentence of para 2, starting with 'Very recently'.
29. Page 180 : line 3 : Delete "and 3.2"
30. Page 181 : line 6 : add "Sketch 3.2' after 'detailed in'.
31. Page 182-191 : All rainfall data are in mm.
32. Page 194 : line 2 : correct 'neer' to 'neeru'.
33. Page 200 : Put "Appendix 8" above chapter title
34. Page 201 : line 4 : Replace "below" by " in Sketch 8.1"
35. Page 202 : line 1 : Add "dry" before "leaves".

Typographical Errors

1. Table of Contents: a) Ch. 17: 'drainage' to 'Drainage'; b) 'Watery Facts ...: about 'to 'About'; c) And the Fantastic ....: 'in it' to In It'.
2. Page i : line 9: '57' to '58'.
3. Page 8 : Picture 1.2: 'canal' to 'Canal'.
4. Page 13 : Full-stop after end of line 11.
5. Page 21 : Upper Box, line 7: 'the rainwater' to 'The rainwater'.
6. Page 22 : line 5 : 'harvest' to 'harvesting'.
7. Page 43 : Penultimate line: 'si' to 'is', 'hloding' to ; 'holding'; 'biulding' to 'building'.
8. Page 49 : line 10 : 'groundwater' to 'Groundwater'.
9. Page 55 : line 5 : 'blocoks' to 'blocks'.\
10. Page 67 : line 14 : 'recieve' to 'receive'.
11. Page 76 : line 9 : 'abd' to 'and'.
12. Page 121 : line 4 : 'then' to 'the'
13. Page 149 : Sketch 19.1: 'segrgate' to 'segregate'
14. Page 197 : line 7: 'caompany' to 'company'
15. Page 201 : line 3 : 'then' to 'the'
16. Page 52: Sketch 7.5: The 75mm dia drain pipe below A should terminate above ground level.

Our apologies, Dear Reader, and Thank You

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About The Author

Indukanth Ragade holds a Ph.D. in organic chemistry from the Presidency College, University of Madras (1963) and was a post-doctoral fellow in the Universities of Illinois and South Carolina from 1964 to 1967. He worked with M/s Atic Industries Ltd., manufacturers of synthetic dyestuffs in Gujarat from 1968 to 1984. Since 1984, he has been with M/s Alacrity Foundations (P) Ltd., Chennai, an organization reputed for its construction of quality apartment complexes and good corporate practices.

A keen urban environmentalist and a passionate believer in sustainable development, he has, over the past decade and a half, pioneered the practice of eco-friendly methods practicable in the urban environment for water-management. In recent years, he has been involved in the development of simple methods of managing domestic waste and has also developed a re-engineered proto-type of a solar water heater that can be made available at a low cost.

About This Book

Water is most essential for our healthy, hygienic and comfortable living. But it is in short supply in most towns and cities of India. So, how can a city or town dweller get access to the water that he needs both in quantity and quality? This book seeks to give the answers. It tells you in simple language, free of jargon, all that you need to know about water. How, with only a modest outlay, you can harvest the rainwater that falls over your house and garden and get not only good water for drinking and cooking, but water for your other needs also. How you can purify more than half of the water you have used, through a simple, self-sustaining soil process in your premises without employing any chemicals or power, and have it for your use again. It gives you details of a versatile system of storage and distribution of water that enables apartment complexes to store and distribute even three different qualities of water, including brackish water, for appropriate uses. It gives you practical methods for using available water more efficiently so that the water available to you lasts that much longer.

How do you locate the right spot in your premises to dig a bore well? How can you influence its construction so that you can charge it with rainwater efficiently? What is potable water? Is mineral water the same as bottled water? How does one decide that the water available during travelling is safe for drinking? What can one do, if the water from one's well or bore well becomes yellow on storage and soils clothes washed in it? How can one tackle the problem of water stagnating on the road in front of one's home after the rains and in the process get more water for one's own use? If your town does not have a sewerage system, how do you dispose off your sewage hygienically without contaminating your water sources? What is desalination? How relevant is Reverse Osmosis to you? Why does sweet water in sandy coastal areas turn saline? These and many other questions that you may have been confronted with are answered. The first of its kind, this book is a one-stop source for information and practical guidance for every town and city dweller who would like to have more water for himself and his family, reduce dependence on external sources, and live comfortably.