RAINWATER HARVESTING – NEED, RELEVANCE AND IMPORTANCE OF GROUNDWATER RECHARGE IN URBAN AREAS WITH PARTICULAR REFERENCE TO COASTAL CITIES.

By

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ABSTRACT

Rain being the predominant source of water on this planet, Rainwater Harvesting (RWH) is the only way to sustain both our surface and sub-soil sources in a large portion of the earth. RWH has two broad aspects – collection of rainwater for immediate use and groundwater recharge (GWR). This paper deals mostly with the need, relevance and importance of GWR, particularly in urban areas where, due to urbanization rainwater can be harvested only as groundwater. The Methodology and benefits of GWR is also discussed in this paper.

I. INTRODUCTION

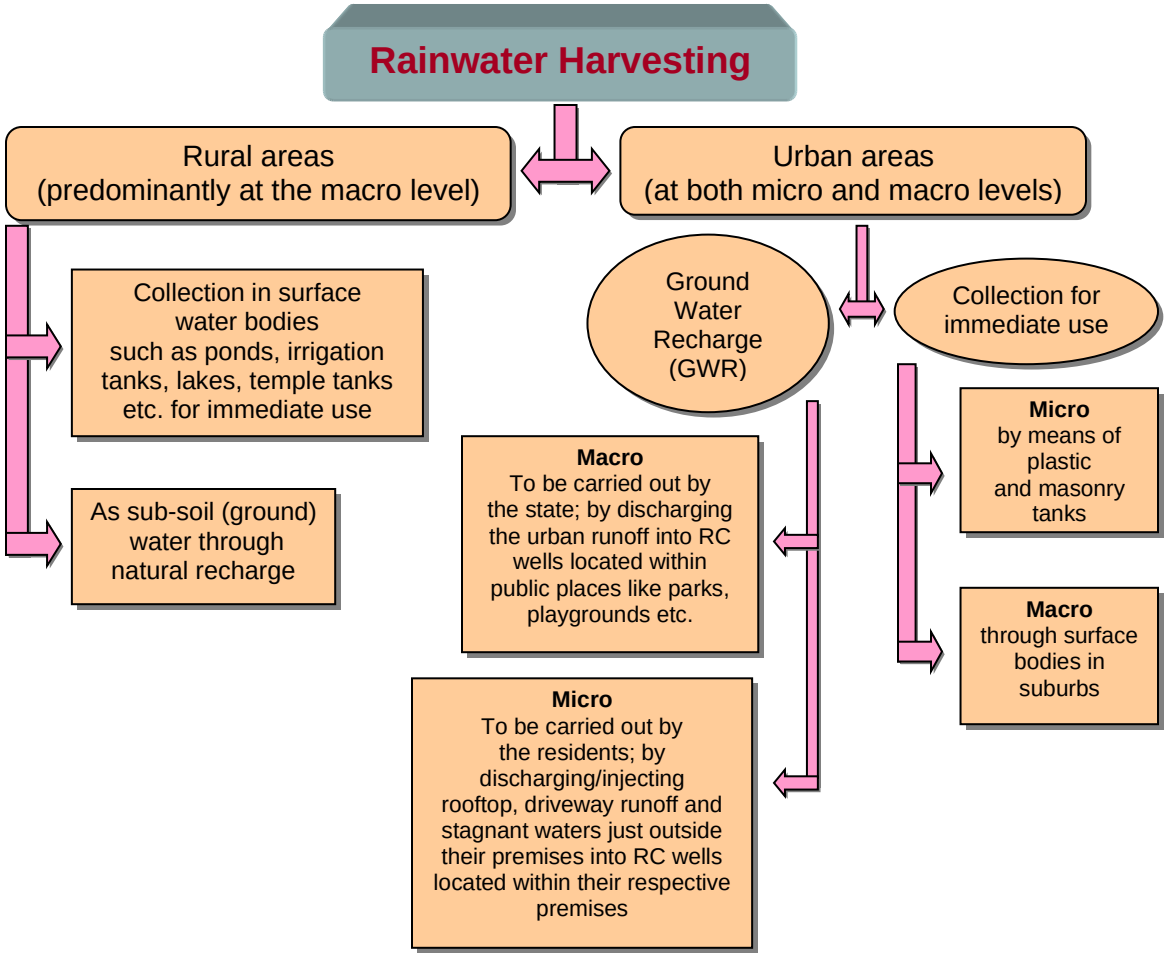
Water is perhaps the most precious asset on earth. It is one of the five basic elements of nature, the others being air, soil, fire and space. Fresh water is essential for human survival and rainfall is its single largest source. The part of rainfall that is trapped in surface and groundwater sources is all that is available for human consumption. This is what has come to be known as Rainwater Harvesting (RWH).

So far as rainwater harvesting in India is concerned, the entire past can be divided into three time capsules. From (-) infinity upto say, 3000 B.C is the first capsule and in this time period, rainwater got harvested naturally without any human intervention, in rivers and natural depressions. Rivers were the first known secondary source of fresh water. It was during this period that civilizations flourished on the banks of rivers not only in India but the world over. Egypt rose on the banks of Nile, Mesopotamia rose on the banks of Euphrates and Tigris, Europe on the Danube and China on the Yellow river. In India, the Harappan civilization flourished on the banks of Ravi and Mohenjodaro on the banks of Indus.

Paper presented in the International Workshop on Rainwater Harvesting held in Kandy, Srilanka during 27-29 September 2006

During the second period extending from 3000 B.C. to 1800 A.D., rainwater was harvested with human intervention. Man must have learnt his first lessons in RWH by looking at natural depressions where water got collected on its own and constructed more of them and learnt to live away from rivers. Bestowed with a good annual rainfall in a large section of the country, different parts of India had their own traditional harvesting systems. These millennia-old traditions of RWH have been well documented in a Report titled "Dying Wisdom" published by the Centre for Science and Environment, New Delhi (1997).

While the first two periods formed the golden era of harvesting, the third period from 1800 onwards till date saw the destruction of traditional harvesting systems, mismanagement of water resources, repeated occurrence of floods and droughts, introduction of technology water like in the west and more and more dependence on the government for fresh water. RWH in most parts of India was not given the importance that it richly deserved. The last 30 years in this period has seen the revival of RWH in the country as a whole and the introduction of RWH in urban areas in general and in Chennai, a coastal city in Southeast India in particular.



The plan of the paper is as follows. In the next section the importance of groundwater source in urban areas is highlighted, while in section III the need, importance and benefits of groundwater recharge (GWR) to sustain the groundwater is discussed. The methodology for GWR both at the micro and macro levels with the different structures used and the base data required for effective GWR is explained in section IV. Characteristics of a good GWR system is discussed in section V.

II. GROUNDWATER SOURCE IN URBAN AREAS

According to the "The World's Water 2000-2001 Biennial Report on Freshwater Resources" prepared by Peter H.Gleick, the total volume of water on earth is approximately 1.4 billion cubic kilometers and only 2.5 percent of it, or about 35 million cubic kilometers is fresh water. The usable portion of these sources is estimated to be less than 1 percent of which 0.76 percent is in the form of groundwater.

It is my strong feeling that whatever water we encounter below the soil as groundwater is nothing but rainwater infiltrated in the last few decades, last few centuries and last few millennia. The exploitable quantity and quality of groundwater depends on the nature of the soil, the former being good in highly permeable and porous soil such as sand, silt and weathered rock and not so good in impermeable soil like hard rock and clay. The quality on the other hand is good in sand and hard rock strata, where there is very little interaction between soil and water, while in clayey and other weathered rock areas rainwater during infiltration interacts with the soil and picks up a few salts and even metals.

Sustenance and improvement of groundwater source can be achieved only through infiltration of rainwater and this process is what is known as recharge. This can happen either naturally, wherever large tracts of open space is available like in rural areas or by artificial means in places where open spaces have given way for builtup areas and where surfaces are paved by impermeable material. The latter is often encountered in urban areas. In this paper whenever we mention groundwater recharge (GWR) we only imply artificial recharge of the groundwater source (aquifer) by means of suitable recharge structures.

Talking about groundwater, we should know that it is available, broadly in two different sections below the ground: The first in the layer extending from ground level up to the occurrence of hard rock, which in technical language is known as *alluvium* and the other within hard rock. It may be puzzling to readers as to how water could be present within hard rock. This is possible through fissures in hard rock and water in this region flows through such fissures and because of this the catchment for such water may not be right above the area but in a distant place. Hence it is more difficult to sustain the water in the second layer through GWR and will have to be more cautious in exploiting it.

III. GROUNDWATER SOURCE SUSTENANCE THROUGH RECHARGE - NEED, RELEVANCE AND BENEFITS

The annual rainfall over India, for example, is around 1170 mm. However, this rainfall occurs during short spells of high intensity. Because of this most of the rain falling on the surface either floods the area or flows away rapidly resulting in very little or no infiltration into the soil. This is all the more serious in coastal cities as mentioned above, where it ends up in the sea and gets wasted. This is probably true in other countries like Srilanka, Bangladesh and Pakistan among SAARC countries and Japan etc.

III.1 NEED FOR GWR

There is a definite need for GWR in urban areas and they are listed below:

1. To sustain and improve the exploitable quantity and quality of groundwater source. Most of the cities not only in India but the world over depend on the groundwater source to meet their potable and/or non-potable needs and is therefore necessary to sustain them.
2. To mitigate urban floods. Most of us are aware that urban flooding is of a recent origin. The two important reasons for it are shrinking of open spaces and indiscriminate paving activity carried out in urban areas by both the state and the society. Rainfall, remaining the same over time, does not find a place either above the soil or below to get collected and hence floods the locality. Only making use of all the floodwaters to recharge the groundwater source can solve this.
3. To prevent any saline intrusion in coastal cities. In any coastal city with sandy beaches, which receives a reasonable amount of rainfall, an area of width 2 kilometres from the coastline and with the *alluvium* extending upto ten metres and above for the entire length of the coast is bound to have a freshwater aquifer. The reason for this quite obvious: This area consisting of sandy and/or other permeable soil would have allowed all the rainwater to infiltrate. This aquifer is very sensitive and if over-exploited would lead to intrusion of sea water into it, which causes a permanent and almost irreversible damage to it. This will have to be prevented rather than cured and is best done by allowing rainwater to percolate into the soil either naturally or by artificial means (GWR).

III.2 RELEVANCE OF GWR

It should be borne in mind that groundwater source is like a bank and its extraction is like withdrawing money and GWR can be thought of as making deposits and failure to do so would lead to depletion of the source or saline ingress in coastal areas. It is also important to realize that GWR is relevant only in urban areas and definitely not in rural areas. What is relevant in rural areas is improvement of its already existing surface storage bodies where if rainwater is collected efficiently, would result in natural recharge of it. GWR is relevant in urban areas, which satisfy one or more of the following conditions:

a. Which are not rain starved, which depend on groundwater both at the macro and micro levels and where there is no scope for any natural recharge.
b. In coastal cities in general and coastal suburbs in them with sandy beaches in particular.
c. Where the alluvium extends upto ten metres or more and where the post-monsoon water table is low. This condition requires collection of data about its pre and post monsoon water levels and the nature of soil (also known as soil lithology) in different localities of the city. As we will see later in the section on Methodology, that the latter information would be useful in determining the depth of recharge structures.

III.3 BENEFITS OF GWR

1. As mentioned above, one of the benefits of groundwater recharge is the increase in the exploitable quantity of groundwater and this can be seen by the rise in groundwater level in places where such groundwater recharge has been taken up. In Chennai, the residents had implemented GWR about two years back, in order to comply with the law enacted by the government. This in addition to the record rainfall that the city received during October to December 2005 resulted in the groundwater level rising in the entire city by almost 6 to 8 metres. This was revealed in a survey conducted by our Rain Centre.
2. The other benefit of GWR is the improvement in the quality of groundwater. This is quite obvious if we realize that rainwater being of a very good quality will dilute the groundwater of its excess salts and also the presence of metals. Hence, in areas where the groundwater contains metals like iron and arsenic and injurious salts like Fluoride, GWR will dilute them and even leech them out. This was exhibited in a few areas in Chennai, which are close to the sea and where groundwater had become saline. After the last monsoon, the Total Dissolved Salts (TDS) came down to less than 500 ppm and the groundwater even became potable.
3. Yet another benefit of GWR, which is indirect and hidden, is flood mitigation. In fact Chennai city did not experience that much floods this year, as it used to in the previous years in spite of the excess rainfall that it received.

IV. GROUNDWATER RECHARGE - METHODOLOGY

IV.1 BASE DATA REQUIRED FOR GWR

Any city, which wants to implement GWR effectively, both at the macro and micro levels should understand its aquifer at the shallow and deep levels. The following information about the aquifer would prove to be useful in this regard.

1. Nature of the soil in different localities of the city upto atleast 10 metres depth. The percentage of sand silt and clay should be found out through a soil analysis. The occurrence of weathered and hard rock and the depth at which it occurs should be ascertained. This will help us to design the depth

of RC wells, besides furnishing information about the effective volume of the shallow aquifer.

2. Details about the water table (depth at which groundwater is available) in different localities of the city with the help of monitoring wells and/or borewells and its fluctuation during the year should be systematically noted and documented.
3. The quality of groundwater from these monitoring wells and/or borewells should be analysed for both its salt content including TDS and presence of metals (and for any bacteriological contamination) and documented atleast four times in a year.

Information obtained in (2) and (3), besides providing us with base data will also help us to quantify the benefits of GWR in places where it has been implemented.

IV.2 GWR AT THE MICRO LEVEL

In every premises, whether it be a house, multi-storeyed residential and/or commercial complex, office, factory etc., rainwater falls only on two places: 1) Rooftop 2) All around the builtup area, which could be a Driveway, Garden etc.

IV.2.a ROOFTOP HARVESTING

Rooftop rainwater is of a good quality (except in factories) as it falls on clean terraces and is brought down by the drainpipes called rooftop pipes.

I) Direct at least one or more of these pipes located close to the existing below-ground-level masonry tank (also called sump, which in Chennai is meant for receiving water supplied by the municipality) into it through a first-flush arrangement or a filter or both.

II) Any overflow from the sump can be led into an open/dug well, if any, within the premises for GWR purposes. Pipes not directed to the sump can also be led into the well (fig.1)

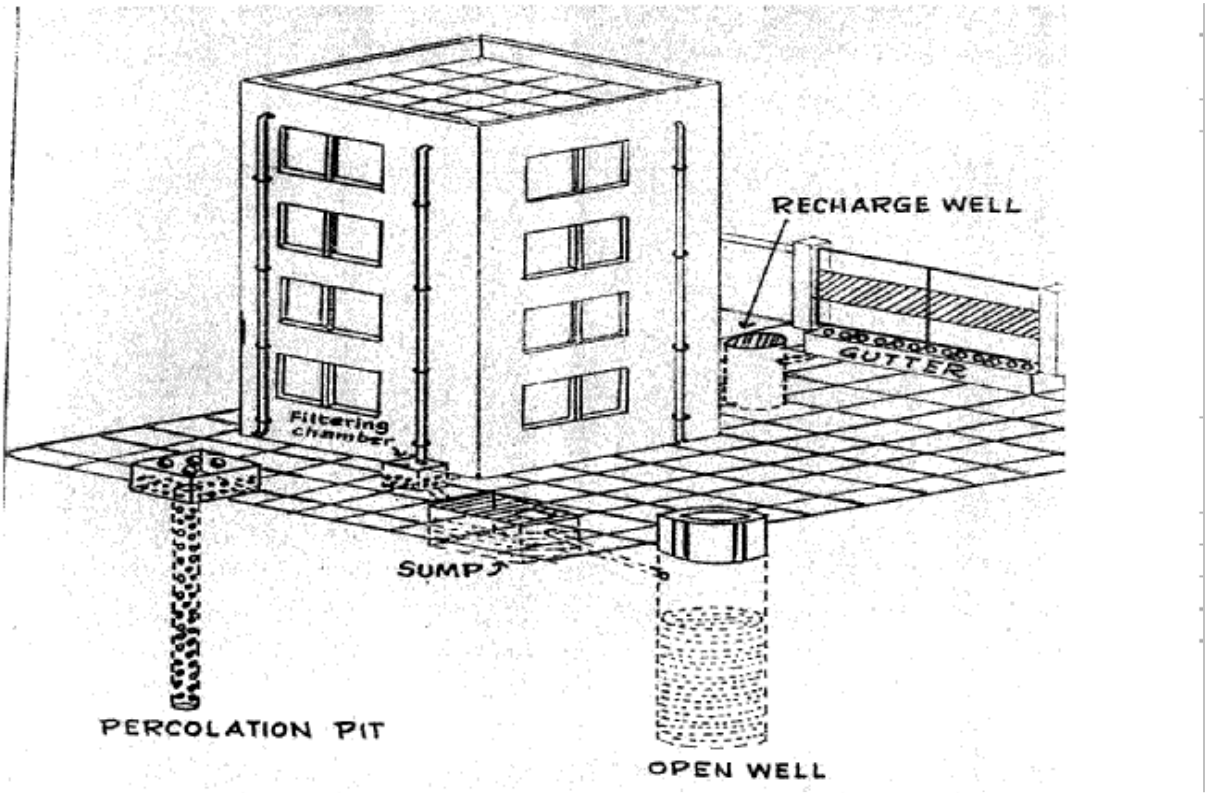
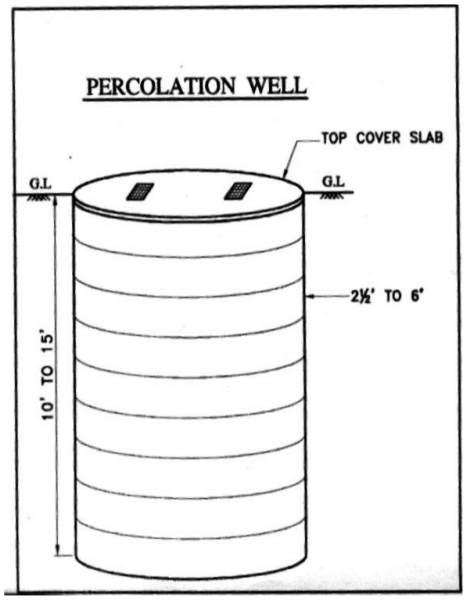


Fig.1

III) In the absence of an open well, a percolation/recharge (RC) well could be dug within the premises (fig.2) to inject rooftop water into it for GWR.

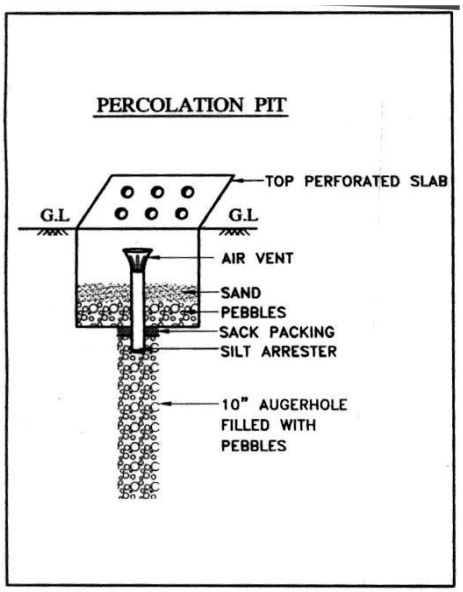
Fig. 2 Percolation / recharge well



These are constructed using cement rings readily available in the market. The diameter of these rings range from 2.5 ft. to 6 ft. The depth to which these wells are dug depends on the nature of the soil and the diameter on the volume of water that is likely to be ingested in each one of them. They are left unfilled and are covered with RCC slabs of suitable thickness to facilitate vehicular movement on them.

IV) In houses/flat complexes where there is not enough space around the built-up area to dig a recharge well, a percolation/recharge (RC) pit could be made (fig.3) for the purpose of putting rooftop water into it for GWR.

Fig.3 Percolation / recharge bore pit



A percolation/recharge pit is a hand bore made in the soil with the help of an augur and filled up with pebbles / blue metal and river sand on top. The depth of these pits will be anywhere between 4 and 8 metres depending on the nature of the soil. The pit has to be dug to a depth till a reasonably sandy stratum is reached. The diameter of the pits will be 25 cm. (10in.). A square/circular collection chamber with silt arrestor is provided at the top. Instead of filling up with pebbles, which is done only to prevent caving in of the bore, a PVC pipe of 6 in. diameter can also be inserted for the entire depth.

The depths indicated in figs. (2) and (3) are relevant to the soil profile found in and around Chennai and they will have to be suitably changed depending on the nature of soil found (up to a depth of 10 metres) in places where harvesting/GWR is attempted. It should be borne in mind that RWH, as groundwater recharge is soil specific and the soil will have to be reasonably permeable to take in all the water that is injected into the GWR structures.

IV.2.b DRIVEWAY RUNOFF HARVESTING

There is a general feeling among people including the Municipal engineers that only rooftop water is fit for harvesting and not the driveway runoff. This is so because surface runoff both at the micro and macro levels appears to be dirty hence thought unfit for harvesting. It should be borne in mind that it is only suspended impurities that makes it appear to be dirty and can still be put into recharge wells both at the micro and macro levels, where the soil will be able to filter it. It is true that surface runoff water should not be led into a sump for immediate use or to a source well.

In a large number of houses/flat complexes, office complexes the driveway area (all around the builtup area) will be as much or even more than the rooftop area. Rainwater falling on this area will be quite large and in addition a sizeable quantity of rooftop water will also contribute to this, which eventually runs off to the street through the gate(s). Hence harvesting driveway runoff in such places becomes very important. This should be harvested by intercepting it with the help of a shallow gutter (covered with a perforated

RCC slab) or a bump (which will be a cheaper alternative to the gutter) near the gate(s) and directed to a recharge well(s) (see fig.1) for GWR. Such driveway runoff should not be led into a recharge pit since the runoff will contain large amounts of silt and will lead to clogging of the pit. These and other drawings are also available in a booklet titled "RWH in Urban Areas", which can be downloaded from our website www.raincentre.org

IV.2.c STAGNANT WATER HARVESTING

Rainwater may stagnate in front of a few houses, apartment and commercial complexes causing great inconvenience to the residents and visitors. This being rainwater will be of a good quality but the colour due to suspended impurities will make it may appear look bad. This water can also be used for GWR by constructing a shallow collection chamber just outside the premises, where water stagnates on the road, a recharge well within the premises (or into the same RC well constructed for harvesting the driveway runoff and put up near the gate within the premises) and connected by means of a concealed PVC pipe taken across the compound wall. This would not only solve the problem of flooding of the street but also help to recharge the groundwater source.

IV.3 GWR AT THE MACRO LEVEL

The responsibility of harvesting rainwater in general and GWR in particular lies with both the society and the government. The former will have to get it done completely at the micro level by harvesting the rooftop water, the driveway runoff and the stagnant water in front of the premises, as explained in detail above. The latter will have to harvest all the rain falling in public places such as parks, playgrounds, flyovers, and thoroughfares. Of these, the rains falling on thoroughfares is substantial in volume, which is discharged into rivers through a network of storm water drains constructed either on one side or both sides of the road and finally to the sea and gets wasted. This can be used for GWR by constructing a baffle wall across the drain to intercept the runoff and discharging the water into RC wells located within neighbouring premises. If any city is to attain self reliance in water every drop of rainwater will have to harvested either as direct collection or as GWR by both the state and the society.

V. CHARACTERISTICS OF A GOOD GROUNDWATER RECHARGE SYSTEM

The rainwater harvesting system that has been put up in the house/flat must ensure that not a drop of rainwater falling within the premises should either go into the sewerage or runoff to the street. This can be achieved only if the method adopted for RWH within the premises satisfies the following criteria:

1. **Completeness**

Rainwater Harvesting in any premises is complete only when rainwater falling on both rooftop as well as all around the builtup area (driveway) is harvested. This has not been done in a large majority of premises even in Chennai where it is claimed that RWH has been implemented in almost every premises.

2. **Apportioning of Rooftop water**

Harvesting rooftop water consists broadly of two activities: Interconnection of the rooftop/downtake pipes and two leading it to collection and/or recharge structures. Care has to be taken to apportion it to different structures such as a sump (for collection and use), an open well if available and other recharge structures such as wells and pits for GWR instead of injecting the entire water into just one structure. This may result in overflow and will go unnoticed since most of the residents do not observe these structures during rains. This is true of driveway runoff also, which in premises with more than one gate will runoff through them. All this have to be used for GWR.

3. Design of Structures

The third important aspect is the design of recharge wells and pits. Their depth needs to take into account the nature of the soil in the particular area, and be sufficient enough for the water injected into them to reach permeable strata and get absorbed by the soil. For example, wells and pits in clayey soil will have to be deeper than in places where it is sandy.

4. Maintainability

Lastly, the fact that RWH structures need to be cleaned and desilted as the case may be, will have to be given importance. Over a period of time, the RWH structures, whether it is a filter or a RC well or a pit will get filled with fine silt, which is brought by rains from rooftops and driveways, and affect its performance. For this reason they should be identifiable and accessible within the premises. This was not the case in most of the houses and flat complexes that were inspected during the survey carried out by our center.

VI. CONCLUSION

Most of the localities in a large number of cities and towns in India do not have piped water supply and hence there is a heavy dependence on groundwater both at the macro and micro levels. This will have to be sustained only by GWR and therefore GWR is popular and widespread in a few states in India if not the entire country. This is probably not true in most of the developed countries, where piped water supply by the Municipal authorities is well organized. It is also true that in such countries there is also a ban on individual residents tapping their groundwater at the micro level. In India there is no such ban and hence it is the responsibility of the resident to sustain the source within one's premises through GWR.

A few environment conscious people all over the world indulge in RWH, mostly in the form of collection and use and meet some of the non-potable needs like car washing, gardening, toilet flushing etc. with the harvested rainwater and reduce their consumption of treated piped water. Thus they are able save on their water charges. On the other hand in India RWH in general and GWR in particular is required for their very survival to meet their potable and non-potable needs. It is also unfortunate that in India, which is known for its traditional water harvesting systems, RWH is being reinvented in urban areas.

GWR is an important aspect of Rainwater Harvesting and will have to be preached and practiced in every city around the world for more than one reason. The groundwater

source, good or bad, whether it is being exploited or not should be sustained and improved as a source for the future by practicing GWR. Secondly, large quantities of rainwater could be saved through GWR in the bank called Groundwater source, instead of allowing it to runoff and get wasted. Cities, which are not rain starved, could be prevented from becoming concrete deserts by practicing GWR.