GROUNDWATER RECHARGE BY ROOF TOP RAINWATER HARVESTING FOR AUGMENTING WATER SUPPLY IN BHOPAL CITY, MADHYA PRADESH

L.K. Mathur, *Scientist*; Anu Radha Bhatia, *Scientist*
Central Ground Water Board, North Central Region, Bhopal, Madhya Pradesh

1.0 INTRODUCTION

Rain water that falls on the roof tops of houses, which normally drains out into sewage and storm drains, is the best source of water available to urban dwellers for water harvesting. This roof top rainwater can be conserved and used for recharging of groundwater, thus bringing much needed relief to the water scarcity areas of the city, as also reducing the stress on the drainage system of the city to some extent. Roof top rainwater harvesting encompasses methods to collect and store rainwater from roof for beneficial use and has been practiced in India for centuries. These practices have been relegated into relative insignificance with the introduction of large scale centralized water supply systems through reservoir storage or tubewell supply. Rapid urbanisation and industrialisation in the cities of India has brought about adverse impact on the Municipality or PHED water supply. Shortage of drinking water especially urban areas has become a cause of concern. With the ever-increasing population in urban areas, sufficient quantity of good quality water is generally short of demand. To meet the shortage of water supply, private borewells are being drilled in large number, leading to the declining trend in water level. There is an urgent need to recycle and conserve all the available fresh water and also for recharging the ground water.

In the urban area where 70-80% area is under pavement, natural recharge to the ground water has reduced over the years and recharge structures like stop dams, percolation tanks, water spreading etc. are not feasible. The only source of abundant fresh water i.e. water that falls from the sky in the form of rain has to be stored by some such means that it becomes a perennial source of readily available water. The best way of collecting the rainwater in urban area would be to collect the water that falls on the roofs of the buildings making up the city. The best storage space for this roof top water would be underground sump, or still better, the unsaturated aquifer space, which can be accessed through borewells/dugwells. Needles to say that this traditional way of rain water harvesting system is based on sound principles. Its improvement incorporating modern technology and scientific inputs would make it even more efficient as contribution to solving the problem of drinking and domestic water in urban area as also in restoring the declining water level.

2.0 BHOPAL URBAN AREA

Bhopal city, the capital of Madhya Pradesh has been facing a fast rate of urbanisation and industrialisation, which has brought about an adverse impact on the available precious water resource, thereby posing a problem to the planners for arranging sustainable supply of good quality water for public health. The population of Bhopal city as per 1991 census was 1,062,771 persons, which is estimated to have grown to almost 1,650,000 persons in the year 2000. Bhopal city encompasses an area of 296 Sq. Km and Bhopal Municipal Corporation (BMC) includes 56 Municipal wards, of which the colonies coming up in the outskirts of the city around Kaliasot, Gandhinagar and Narela Shankari encompass a major area of the city.

The area of Bhopal city is highly undulating with elevation ranging from 485 mamsl to 600 mamsl reaching a maximum elevation at Singarcholi hill (625 mamsl). The average elevation is about 500 mamsl. The area is an extension of the Malwa Plateau and the Vindhyan Range and is occupied by Vindhyan Sandstone and Deccan Trap basalts. Sandstones are exposed on hills like the Char Imli Hill, Shyamla Hill, Idgah hills and the Arera Hill while Deccan Trap occurs as basaltic lava flows which flooded the pre-existing Vindhyan Topography, occurring in valleys or low flat topped hills not exceeding an elevation of 530 m.amsl., e.g. the MACT hill, the Shahpura Hill and the Walmi Hill etc. The soil of the area is black cotton soil, which is barely 0.5 to 2.5 m in thickness.

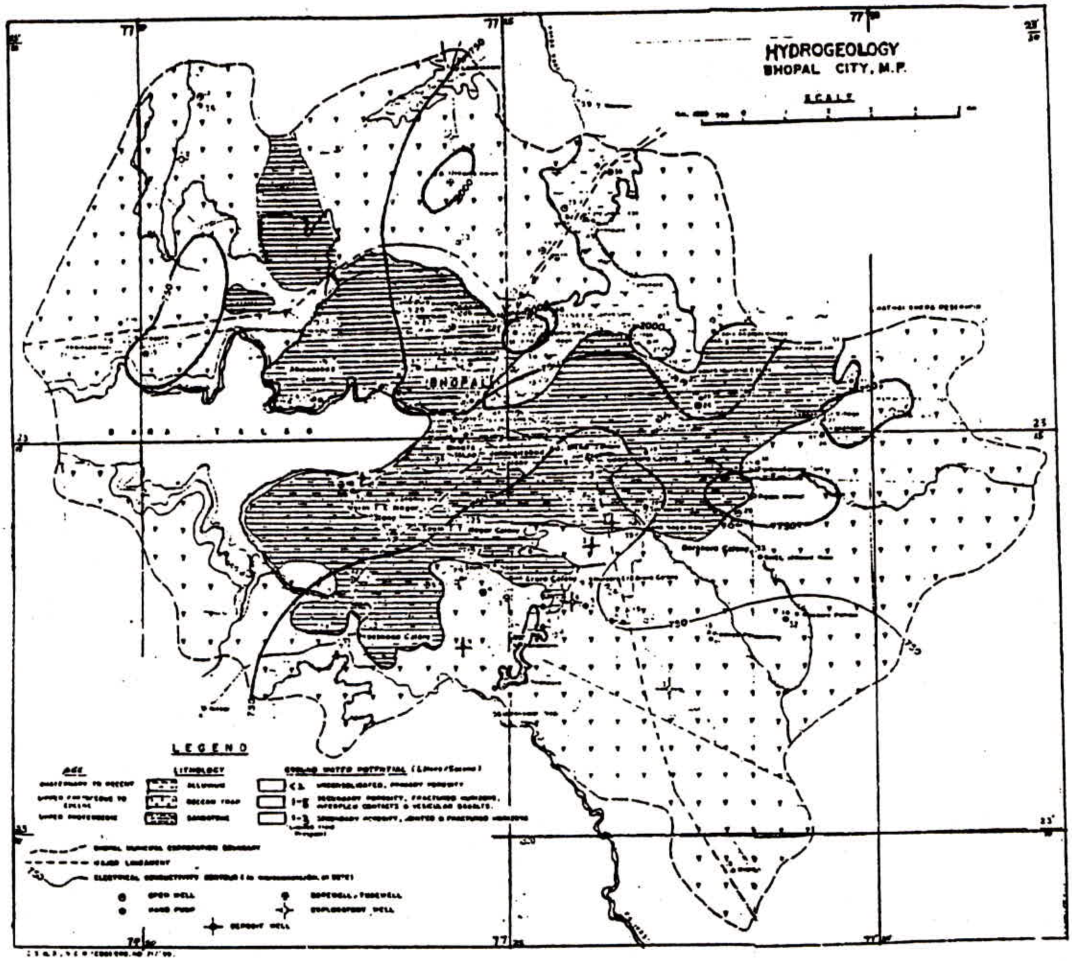
The city is drained by small rivers and nalas draining into the Betwa river (Ganga Basin). The Southern area is drained by Kalisot river, the western part of the city is drained by river Kolans and the northern part by Patra nala. There are three large surface bodies in the city, namely, the Upper Lake or the Bara Talab, the Lower Lake or the Chhota Talab and the Shahpura Lake.

The normal annual rainfall of the Bhopal city is about 1260 mm; the southern part of the city receives more rainfall than northern part of the city.

3.0 HYDROGEOLOGY

Promising aquifer zones are confined to shallow depths, comprised of weathered, jointed or fractured basalts, jointed vesicular basalts or weathered jointed Vindhyan Sandstone. The bedding planes also contribute to the permeability of the Vindhyan Sandstones and at places yield of deep tubewells on the slopes of Vindhyan sandstone hills can be attributed to the bedding planes. The yield through groundwater structures in the city varies from 1 to 5 lps.

Almost 65 % of the area of the city is underlain by Deccan Trap basalts and only 35 % of the area is occupied by Vindhyan Sandstones. It being a hard rock terrain, site feasibility has to be assessed for construction of tubewells. In Deccan Trap basalts, aquifers are encountered at shallow depth. The density of successful tubewells is very high. Most tubewells tap the second basaltic aquifer, which is confined to semi-confined in nature. The Depth of tubewells in Deccan Trap range from 30 to 75 m.bgl. Vindhyan Sandstones, which occupies the elevated region in the central part of the city, is hard and compact and aquifers occur at depth of about 100 to 150 m.bgl. The cost of construction of tubewells in Vindhyan Sandstones is high and so is the rate of failure. Very few successful tubewells have been constructed in Vindhyan Sandstone terrain in Bhopal.



The density of tubewells tapping the second confined/semi-confined aquifer in Deccan Trap in the outskirts of the city is very high, leading to depletion of water levels. It is this second aquifer in the Deccan Trap that is best suited for groundwater recharge by roof top rainwater harvesting for augmenting water supply in Bhopal City.

4.0 WATER SUPPLY

The water supply to Bhopal City is mainly from surface water form Upper Lake, located in the heart of the city and Kolar Dam, located about 30 Km. South of the city in Narmada Basin (a case of inter-basin transfer of water). The Upper Lake of the 11^{th} century contributes 104 million litres per day while the Kolar Reservoir, completed in 1989 contributes 127 million litres per day to the Municipal water supply. The share of ground water in the Municipal water supply is only 10 percent, being about 23 mld from about 350 tubewells and a few large diameter dugwells of the Bhopal Municipal Corporation/ P.H.E.D.

A total of 254 million litres per day water is available from all the sources against the present demand of 300 mld. Thus, the present water supply falls short by 46 mld. The demand would further rise in coming years. The estimated demand of water for the year 2015 is estimated to be about 500-525 mld for the projected population of 35 lakhs of the city. There is a public demand to meet out this projected demand by the diverting Narmada river water to Kolar reservoir i.e. lifting the water against the gravity for the distance of about 50 Km. which is a difficult and expensive solution.

5.0 GROUND WATER DEVELOPMENT

In Bhopal City ground water development has been taken up on need basis without proper scientific investigations. A large number of boreholes were drilled by PHED without scientific selection of drilling sites. The municipal water supply in the city especially in the new colonies developing in the outskirts of the city is very much inadequate even for drinking water needs of the residents. The residents, in desperation to meet their water needs, have restored to drilling their own tubewells in their plots ranging in depths from 30-100 m bgl. The number of such domestic tubewells, although never been inventoried, is estimated to be around 30,000. The yield of these tubewells dwindles in the peak summer months i.e. April to June. This leaves the residents in dilemma and they turn to the water market, which flourishes during these months, paying more than two hundred rupees for 5000 litres (one tanker) of water.

6.0 DOMESTIC WATER SUPPLY PROBLEM

The rapid urbanisation and industrialization of Bhopal city has brought numerous problems. The most pressing problem is the deterioration of surface water bodies and the declining trend of water level. A declining trend has been observed in the pheratic as well as in semi-confined to confined aquifer in the city. To control the decline in water level and dwindling discharge of Tubewells there is an urgent need to conserve water and recharge the aquifers.

7.0 SOLUTION TO THE PROBLEM

Two basic factors involve in recharging the groundwater; first in availability of surplus surface water and another is dissipation rate of recharging water. Surplus water is available from roof top in the form of rainfall. The dissipation rate (a function of transmissivity value of the aquifer) of the recharge aquifer should be known before adopting 'Roof top harvesting' in the area. The dissipation rate can be known by the method known as "Slug Test". By this method transmissivity of the aquifer can also be known.

"Slug" Test Method.

In Slug Test, a known volume of 'slug' of water is quickly injected (under gravity) into the well and the decline of water level (i.e. H values) is measured at closely spaced intervals, during ensuing minute or two. The rise in water level because of injection of water, i.e. H_o value can be estimated using the equation

$$H_0 = v/\pi r^2 c$$

Where, V = Volumes of injected water.

R = Radius of casing pipe.

Compute the values of H/H_0 for various time intervals and plot on a semi-log paper against time in seconds. Field curve is to be matched with master curves for the value of t at T, $t/r_c^2 = 1.0$. T is to be calculated by the equation

$$T = 1.0\, r_c^2 / t.$$

If the tubewell is successful and yield more than 3 lps of water, the transmissivity is considerable enough for recharge of aquifer by roof top rainwater harvesting.

7.1 Rain Water Availability For Different Roof Top Area In Bhopal City

The normal annual rainfall of Bhopal city as per IMD is 1260 mm of which 1085 mm is the normal monsoon rainfall received from 15th June to 30th September. For rainwater harvesting purposes, only the normal monsoon rainfall is considered for easy management of the rooftop rainwater harvesting. Table 1. gives the rain water availability for different individual roof top areas for buildings in Bhopal city.

Table 1 : Assessment of rainwater for different individual roof tops for Bhopal city.

Average Annual Monsoon Rainfall =1085 mm.

S. No.	Roof Area Sq. Km.	Total Rainfall Volume (Cum.)	Volume available for Recharge (Cum.)
1	50	54.25	32.5
2	100	108.5	65.1
3	150	162.75	97.65
4	200	217	130.2
5	300	325.5	195.3
6	400	434	260.4
7	500	542.5	325.5
8	600	651	390.6
9	800	868	520.8
10	1000	1085	651
11	1500	1627.5	976.5
12	2000	2170	1302
13	2500	2712.5	1627.5
14	3000	3255	1953
15	4000	4340	2604
16	5000	5425	3255
17	6000	6510	3906
18	7000	7595	4557
19	8000	8680	5208
20	10000	10850	6510

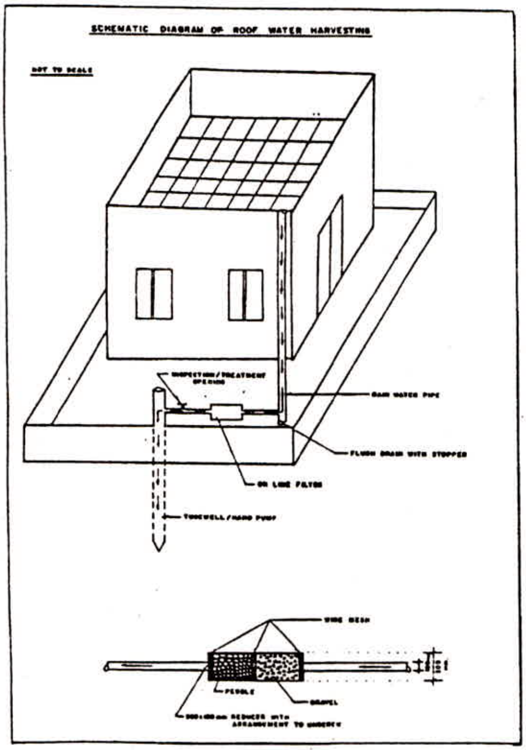
Considering 150 Sq.m as average roof top area of buildings in Bhopal, and 30,000 such roof tops contributing to recharge to groundwater through roof-top rainwater harvesting system, a total volume of 4.98mcm of rainfall water falls on the roof tops of the 30,000 buildings during the monsoon season. Thus, the volume of water available for recharge through tubewells, with 60% efficiency of recharge, is 2.93 m cum (2930 million litres). Of this 2930million litres, only 60 % will be available for utilisation through ground water structures throughout the year augmenting the water supply of the city by more than 5 mld giving a benefit of additional 167 liters per day to each household pumping water from tubewell.

7.2 Design of Rain Water Harvesting Structures

The house owner, who has tubewell(s)/abandoned tubewell(s)/dugwell(s) can divert the water from his roof to it through a suitable arrangement of pipes and filter, using the techniques described below.

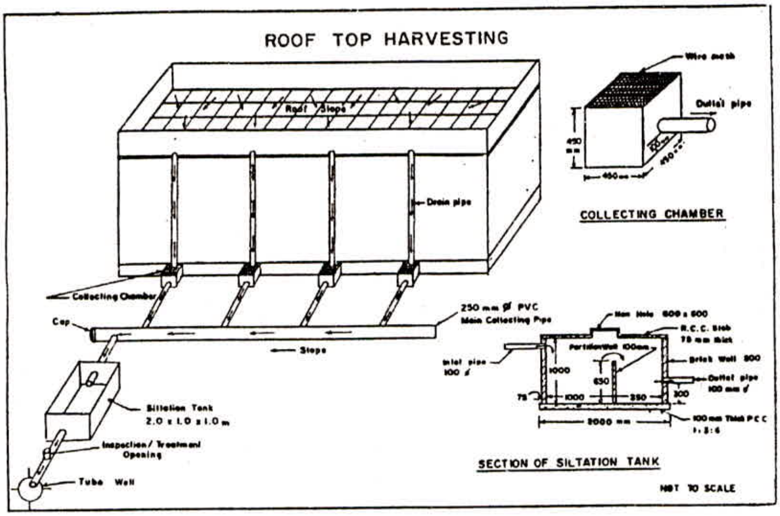
Gravity Head Recharge Well

This technique is suitable where borewells/tubewells are near to the Building and land availability is limited and also where aquifer is deep and overlain by impermeable strata. From the roof top of the building rainwater is channelised to the borewells/tubewells and recharge under gravity flow condition, ensuring that water is free from silt and any other impurities before letting the water enter the recharge well.



Recharging Abandoned Dugwell, Borewells & Hand Pumps

Due to severe depletion of ground water level, many dugwells, borewells and hand pumps are getting dried. These wells can be converted into useful recharge structures. Roof water and run-off water can be diverted into these wells through a pipe, and this water should be silt free. Abandoned dugwells are suitable for large building having the roof area more than 1000 Sq.m.



Groundwater recharge by roof top rainwater harvesting is an important aspect of water conservation and management, especially in context of urban areas, as it provides a cost effective means of collecting and storing water for use during the dry period. Not only for Bhopal city, but for all urban areas in the country, roof-top rain water harvesting structure should be included in the building bylaws. Groundwater recharge by roof top rainwater harvesting should be made mandatory for all buildings and no building structure should be passed without it.

ACKNOWLEDGEMENT

The authors express their gratitude to Dr. Saleem Romani, Regional Director, CGWB, NCR for his guidance, and encouragement in preparation of this paper. The authors are also thankful to him for granting permission for presenting this paper.

REFERENCES

Shri. Abrar Husain and Dr. Sanjay Gupta, (1999), "Hydrogeological Framework for Urban Development of Bhopal city", M.P.

Central Ground Water Board (2000), "Guideline for Artificial Recharge".

Department of Rural Development (1999), "Rain Water Harvesting".