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A framework for sustainable ground water reserves in Ahmedabad

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Abstract:

Since urbanization, the demand for water is increasing day by day and the sources of fresh water are depleting rapidly. Population expansion, industrialization and irrigation for agriculture are the major reasons. In order to reduce the overuse and depletion of fresh water sources many approaches are there namely aquifer recharging, rain water harvesting, cutting down the water supply and water pressure, reuse of grey water, using sea water for flushing, etc. The aquifer recharging and rain water harvesting methods help conserve and replenish the fresh water sources. This study aims to find out appropriate techniques that help conserve and sustain fresh water sources with respect to the city area; along with case studies and their application in water scarce cities of India.

Ahmedabad, a city in the Gujarat state of India is facing the issue of depleting ground water levels and its quality. The study, tries to form a framework of sustainable ground water reserves in Ahmedabad with implementation of water harvesting methods, aquifer recharging methods, stopping the leakages and waste water treatment. These methods can be implemented by confirming them in the new building and city planning regulations. The framework will be supported by examples of the cities in India that have been able to increase their ground water level like Chennai, Hyderabad and Bangalore.

Key words: ground water, rain water harvesting, artificial water recharge.

1. Introduction

Since urbanization, the demand for water is increasing day by day and the sources of fresh water are depleting rapidly. Population expansion, industrialization and irrigation for agriculture are the major reasons.

A survey from NASA in 2011 shows the countries around the world with fastest depleting ground reserves of water. In the survey India faces the depletion of north-western aquifer at the rate of 17.7 cubic kilometers per year, which is the highest amongst the other countries. Also according to the Central Ground Water Board (CGWB) of India, around 56% of the wells, which are analyzed to keep a tab on ground water level, showed decline in its level in 2013 as compared to the average of preceding 10 years (2003-12) period. India also faces the issue of over-population and is urbanizing at a rapid pace. This would mean more and more extraction of ground water.

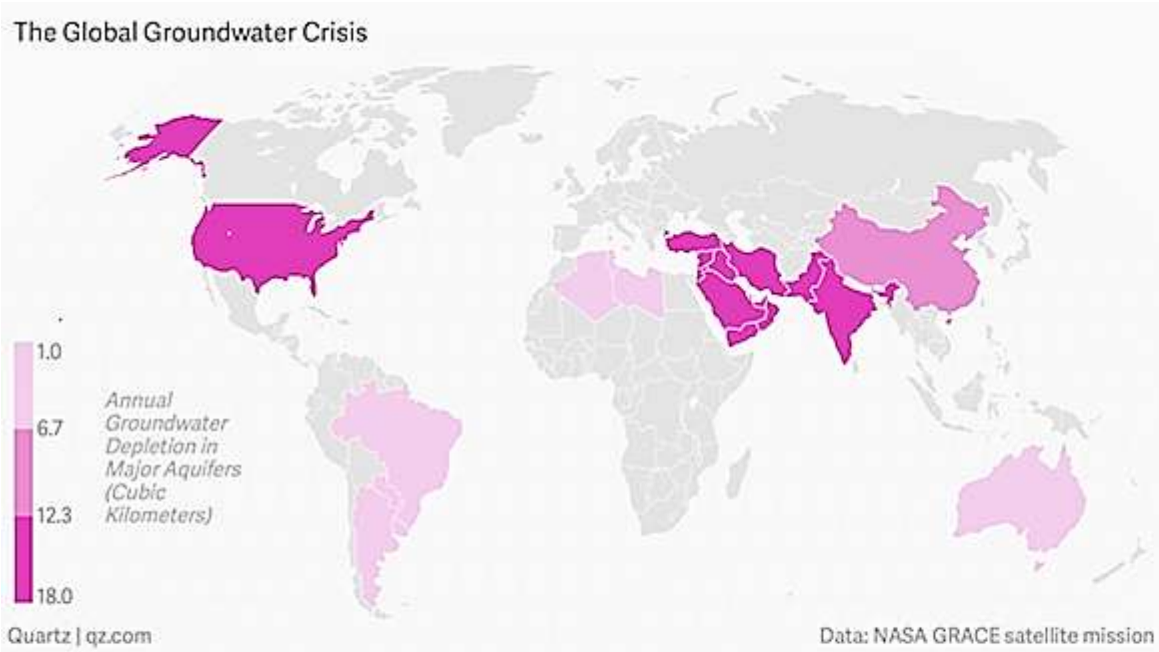


Fig. 1 Annual Groundwater depletion in major Aquifers around the world

Water scarcity is a characteristic of north-western states of India, such as Gujarat. Over time, the continuous increase of the population as well as the financial, administrative and technical deficiencies of the new supply system have led to the deterioration of the water service in the city. In the meantime, the water demand has considerably increased due to the improvement of standards of living. This has resulted in an increasing pressure on underground water resources, which has led to an alarming depletion of aquifers.

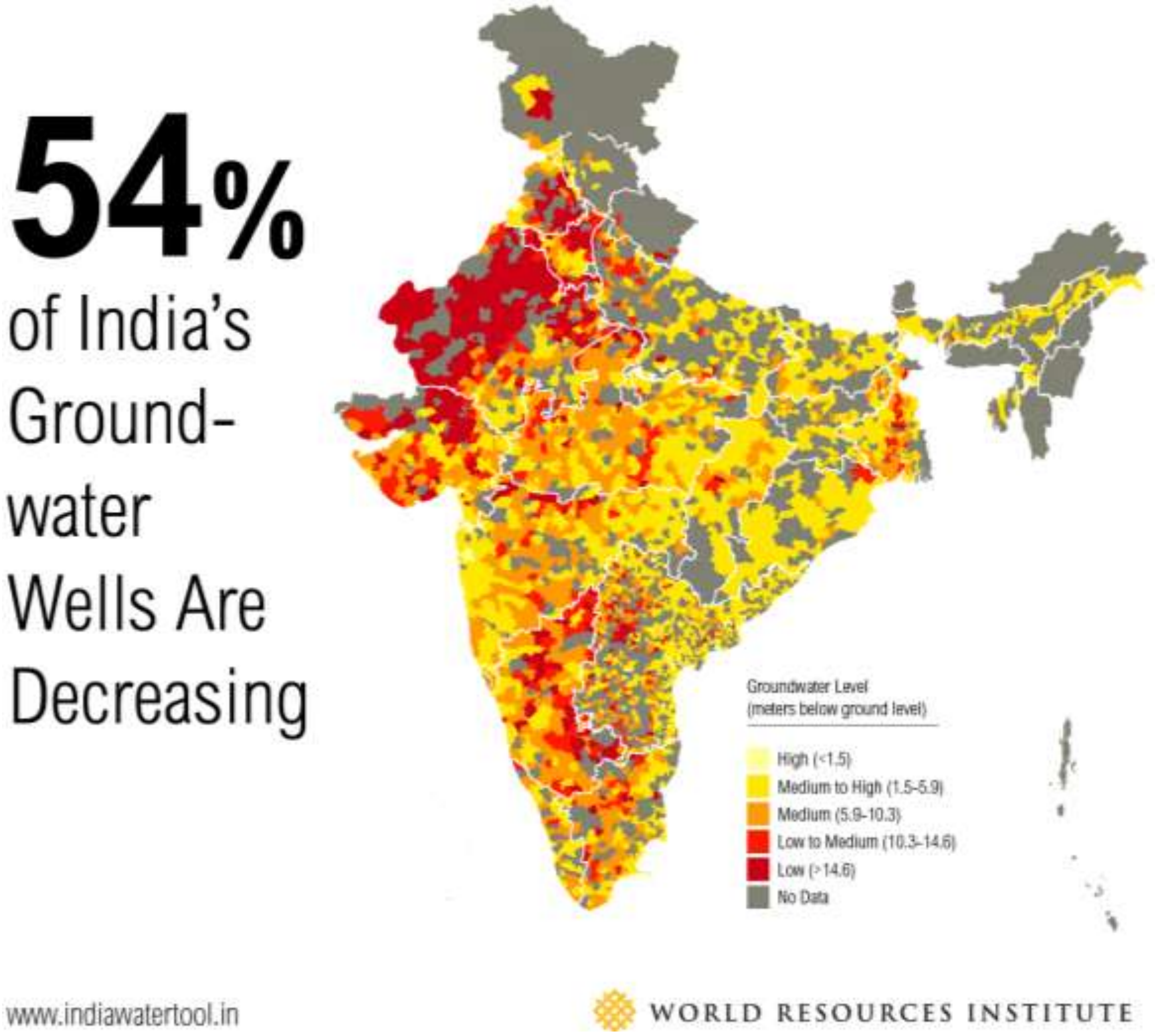


Fig. 2 Decreasing groundwater in India

An authoritative report by the Central Ground Water Board (CGWB), "Groundwater Scenario in Major Cities in India", has raised alarm that groundwater development in and around Ahmedabad–Gandhinagar urban area has reached "a critical stage" and "not much scope exists for further development." The report further states that "groundwater level has gone down too much to extract groundwater economically even for domestic use". According to the study, "Increasing urban population and industrial requirement create more stress, making situation more critical". The situation has been such that the successive governments of Gujarat had to bring water from far away which is economically, socially and environmentally unsustainable on the long run.

This indicates the need of a systematic way of water harvesting to prevent the depletion and raise the ground water level.

2. Ground Water Scenario of Ahmedabad City

According to the report of Central Ground Water Board (CGWB), the present ground water table lies below 90 m. below ground level. In late sixties, it was in the range of 33.5 to 44.19 m below ground level. The water table in user confined aquifers ranges from 20 m. to 50 m. below the main sea level. The groundwater tables have been falling at the rate of 2-3 meters per year because 70-80% of the city's water supply has come from bore wells. This has resulted in exploitation of deep aquifers which, has led to sharp decline in piezo metric level below 60 to 80m.

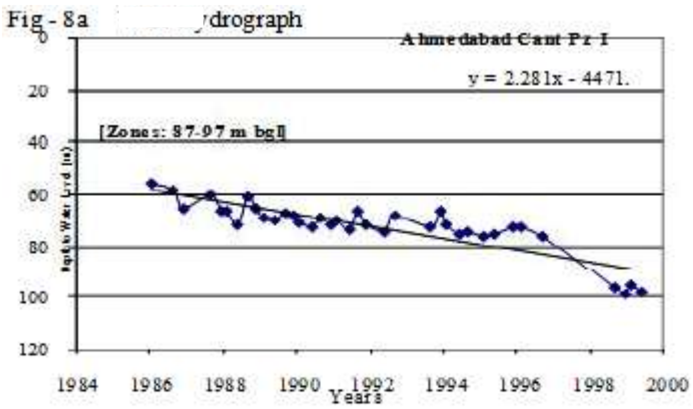


Fig. 3 Graph showing Depleting ground water levels in Ahmedabad

The data indicates that in rural areas, the overexploitation of groundwater continues relentless. In Ahmedabad district, particularly areas around Daskroi, the utilisable groundwater resources are 142.56 MCM/yr. With a draft of 215.06 MCM/yr, there is a (negative) balance of -95.75.20 MCM/yr. The stage of development is 150.86 % and both Daskroi and Ahmedabad talukas have been classified as "over exploited". It is the result of the uninterrupted large scale development of groundwater from deep aquifers that the water levels have progressively declined.

Data suggest that the pressure on groundwater is likely to rise continuously. Recent history of water supply suggests that in decades of 1970-80, water requirement of Ahmedabad urban area was totally met through series of deep tube wells spread in entire city areas, but now it is not so. Before 1986, out of total 400 million litres per day (mld) of water supplied, contribution from groundwater resources was 350 mld (88%). With the implementation of various surface water sources projects at present, out of total 760 million litres per day (mld) water supply, only 30 mld (4%) is from ground water resources today. Yet, the fact is, the water demand is increasing with the rise in population. It has been projected that by year 2031 projected population of 1,01,44,000 persons would require around 1,623 mld from present 760 mld.

Due to the urbanization process, the ground water pollution has made some shallow aquifers unsuitable for the domestic needs. The groundwater at shallow depths in the area show wide variation in the chemical quality. The Multilayered aquifer system, down to 300-400m depth in Ahmedabad area has brackish to saline or high fluoride / nitrite zones at various depths. In the area close to the Sabarmati river, in the central and northern parts, the groundwater quality is better where as it is brackish to saline in rest of the area. High nitrate concentration (more than 100 ppm), indicating probable pollution of this aquifer, has been observed at a number of sampling points. High fluoride concentration (more than 1.5 ppm) has also been observed in localized areas. Unrestricted and inefficient construction of deep tube wells through such multilayered aquifer, tapping the entire available granular horizon mixes inferior quality groundwater with good quality at many places. Some time, through old and damaged tube wells casing, brackish or polluted water mixes with good quality aquifer zones.

Over the years, consistent fall in water levels has affected the well yields and pumping costs. Lowering of aquifer potential heads seems to have created a regional groundwater trough in the central part.

The situation has gone grim because presently only one third of the sewage of the city is being partially treated. The report observes that a part of the treated water is recycled and used for irrigation and industrial purposes and the excess quantity is discharged in the Sabarmati River. Remaining two thirds of untreated sewage is directly discharged in the Sabarmati which make downstream most vulnerable to groundwater pollution. Industrial effluent of eastern part of Ahmedabad urban area are either discharged in to the Kharicut canal, small nallas or spread over the topographic depressions. This has caused degradation of land in these areas and probably also effected the shallow groundwater."

The above mentioned issues of depleting levels and quality of ground water need to be addressed as rapidly as possible.

3. 2. Steps taken to raise the depleting water levels in Ahmedabad

From the policy side, the city has adopted some new water regulations after a major drought hit the state of Gujarat in 1999. It now mandates that all new developments above a certain size to either capture rainwater for direct use, or to collect it in a percolation pond for filtration and much-needed recharge of the ground water. The Development Plan, 2021 of Ahmedabad dictates all the new development of having a rain water harvesting system in place, only then Building-use permission will be given.

During decades of 1980-90, to supplement groundwater resources, surface water supply from Dharoi reservoir was planned with construction of riverbed intake wells. However, with increasing agriculture demand in upstream reach of Sabarmati River and also due to diminishing base flow in Sabarmati River, the project could not be succeeded to lessen stress on groundwater resources. This forced the authorities to depend on Narmada canal based water, some 200 km away, as the source of water supply to the urban areas of Ahmedabad and Gandhinagar. In spite of this, the daily water supply per capita today is a mere 140 liters (as opposed to 180 liters envisioned by the city's water plan).

But there have been no steps taken to propagate the use of ground water recharge techniques, to include the local people to apply water harvesting.

4. Traditional practices of Artificial Ground Water Recharge

The history of rain water harvesting dates back to 3000 B. C. during the early Bronze Age in Egypt, Mesopotamia and Indus Valley Civilization. The Egyptians and Mesopotamians made canals and dams (of soil) for irrigation. In Greek and Roman civilizations, aqueducts, tanks, public fountains were built. During Indus Valley Civilization presence of water supply channels, wells, tanks (for baths) and dams (called bunds) has been found. The traditional water harvesting methods of India have developed since centuries namely talab/ bandhis, johads, baoris/ bers, jhaleras, step-wells, kunds, tanks and kuls. All of these were for the public at community or city/ settlement level and were associated with religion and places of cultural significance. These, were the highly developed engineering marvels -for rain water harvesting in our history of mankind.

In Western India, particularly in Gujarat, there are age old traditions of water harvesting that include the balancing of the underground aquifers. The strategic location of small ponds and lakes near a village served the villages well over the years in helping the people manage their water resources for a year round availability. Great examples of traditional water harvesting systems exist all over Gujarat. The best known and celebrated examples are the Step Wells of Gujarat in Patan and Adalaj near Ahmedabad. In Ahmedabad city, houses in the traditional Polls had used the underground tanks to hold clean rainwater for use through the year. Mahatma Gandhi's house in Porbunder is a specific example of this kind of rainwater harvesting that was practiced in the Gujarat region.

Ahmedabad also has a long history of rainwater harvesting. The oldest example for this are the famous vavs or vavdis, the monumental step wells that used to provide rainwater, collected during monsoon season, to the community year-round. They consist of a vertical shaft in the middle from which water is drawn. This shaft is surrounded by corridors, chambers and steps which provide access to the well. They were profusely carved and served as a cool resting place in summer. These structures are multi-storey underground water tanks shaped such that a series of stairs, on one side, would allow for comfortable access to the water level as it is slowly falling over the course of the dry season, while there is also a direct connection to the lowest point of the well from where water can be pulled up to the surface in a vessel. The step wells are adorned with artfully carved pillars and arches, and the climate inside is cool and pleasant. Examples of step wells that still exist today in Ahmedabad include Dada Hari Vav and Adalaj Vav, both built in the 16th century, as well as Mata Bhavani Vav, which is even older. What is interesting is that places of worship (both Hindu and Muslim) are either integrated in each of the vavs or can be found directly adjacent. Those, today, are still in use while the wells themselves have dried up.

Fig. 4 Images of Adalaj Vav, Dada Hari Vav and Mata Bhavani Vav respectively

The traditional wooden residential structures as well as many of the places of worship of the Old City incorporate a smaller scale version of rainwater harvesting. Water used to be captured from the second rainfall of the monsoon onwards, from the pitched roofs, then carried down through copper gutters and chains to be stored in limestone-lined deep tubewells (between 30 and 50 ft deep at 2-3 ft in diameter). The relatively small scale (25.000 – 30.000 litres per family and year) of the wells implies that this water was used mainly for drinking and cooking. The use of copper and limestone as materials ensures the high quality of the water to last for months; it is in fact far superior to the quality of water from other sources, including today’s municipal water supply. Maintenance and operation efforts, given the simplicity of the historic structures and durability of materials, are relatively low.

Fig. 5 Images of the tanks in Pol Houses of Ahmedabad

4. Modern practices of Artificial Ground Water Recharge

In todays' time with the advancement in technology, there are many kinds of water recharging and harvesting methods. For water recharging artificially, percolation tanks, underground dam, infiltration pond, soil aquifer treatment, sand infiltration, recharge releases, bank filtration, dune filtration, etc. These methods of artificial water recharging is usually done at a community level. For rain water harvesting, there are two methods, roof-top and surface-runoff water harvesting. Rain water harvesting is usually done at individual level. As it seems to demand much of maintenance, it is not much preferred method. But now it is high time we recharge and harvest our rain and waste water.

Basic requirement of artificial recharge are availability of non-committed runoff in space and time and identification of suitable hydrogeological environment and sites for augmenting subsurface reservoir through cost effective artificial recharge techniques. Apart from the requirements, the criteria listed by CGWB are identification of the areas with declining water levels and quality, hydrometerological studies, hydrological studies, soil infiltration studies, hydrogeological studies, aquifer geometry and chemical quality of source water are considered.

But methods of artificial recharge are helpful in areas that have huge tracts of open-vacant land i.e. in rural area. As Ahmedabad City is highly urbanized, the roof-top and surface run-off rain water harvesting method would be more helpful. But again, the surface run-off method has a problem of bad quality water due to solid waste on the ground. The roof-top rain water harvesting has a share of its problems, but they can be tackled.

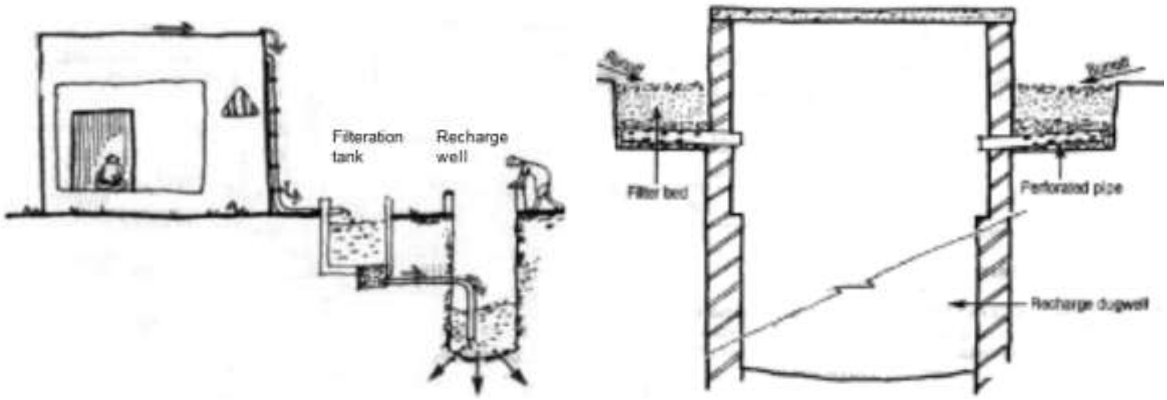


Fig. 6 Simple diagrams showing roof-top rainwater harvesting and surface run-off harvesting

4.1 Case Studies for rain water harvesting in India

(i) Bangalore: It is a city located at 920 m above sea level. The two major sources or water are River Cauvery and River Arkavathy. River Cauvery is 95 km away and 500 m below, incurring huge transportation and pumping costs for the city. The characteristic of the city is that the rain water flows out of the city in three different directions and does not get infiltrated. In 1972, there were over 272 lakes and tanks, which have reduced to 80.

The Chemical Engineering Dept., Indian Inst. Of Science. A roof area of about 511 sq m was tapped and water redirected by altering and linking the down pipes appropriately to an existing sump of capacity 30,000 litres, A first rain separator and a filter was introduced. 377 kilo-litres of water is being harvested every year at Rs. 60/- a kilo-litre. The expenditure was of Rs. 11,000/- and savings made are Rs. 22,650/- per year.

Fig. 7 Images of the rainwater harvesting in Chemical Engineering Dept.

A neighbourhood colony of about 4 sq. km. had put in place a decentralized water management system incorporating rain water harvesting more by serendipity than by design. Two small tanks in Narsipura area were designed to collect rainwater and act as percolation tanks to recharge the aquifer. About 15 bore-wells on an average sunk 80 m deep, and then supply water to the colony of about 3000 houses. Sewage discharged from each house is collected and treated both physically and biologically through an artificial wetland system and led into one of the tank. The loop of water supply and sewage treatment is completed within a small area, in an ecologycally and economically appropriate manner.

Fig. 8 Images of the rainwater harvesting in Narsipura.

(ii) Chennai: Chennai, the capital city of Tamil Nadu, has ground water as the main source of water supply, as it is not situated near a river. So it becomes crucial to harvest rainwater. Padmavathi Nagar an area in Chennai, has an area of 16,556 m2 and buildings with roof area of 8,584 m2. It has 69 plots, out of which 59 were constructed. In that, 10 are apartments containing an average of 10 flats in each unit. The soil condition of this area is clayey in nature up to 9 m depth followed by sandy soils. The average depth of water table from ground level is 8.5 m. The rain water harvesting method was surveyed here where it was found that recharge per unit area was found to increase after the implementation of RWH and even the quality of water improved.

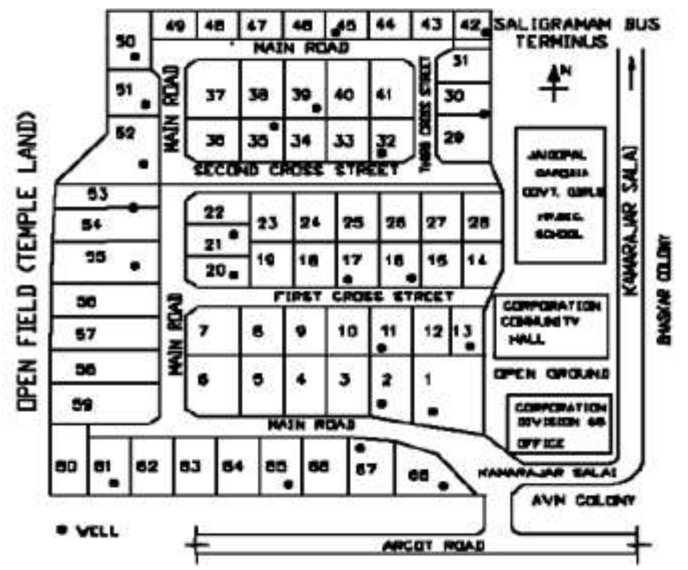


Fig. 8 Images of the rainwater harvesting in Padmavati.

(iii) Hyderabad: Hyderabad city has a hilly and rocky terrain. The case study is of Cygnus Microsystems Ltd. In Cherapally Industrial Area, Hyderabad. The total rainwater storage capaciy created is of 1,37,500 litres. Rest of the rainwater falling on the plot is channelled into two recharging pits located at the lower part of the plot. Arrangements have made to maximise the chances of this water percolating into the ground through these pits. The cost of investment per litre is Rs. 3.80 and the pay back period of the project is 3-4 years. The stored water quality tested periodically, has not found to be of any deterioration in its quality. Maintenance requirements include chlorination of drinking water and cleaning of the sumps and filters (once in a year).

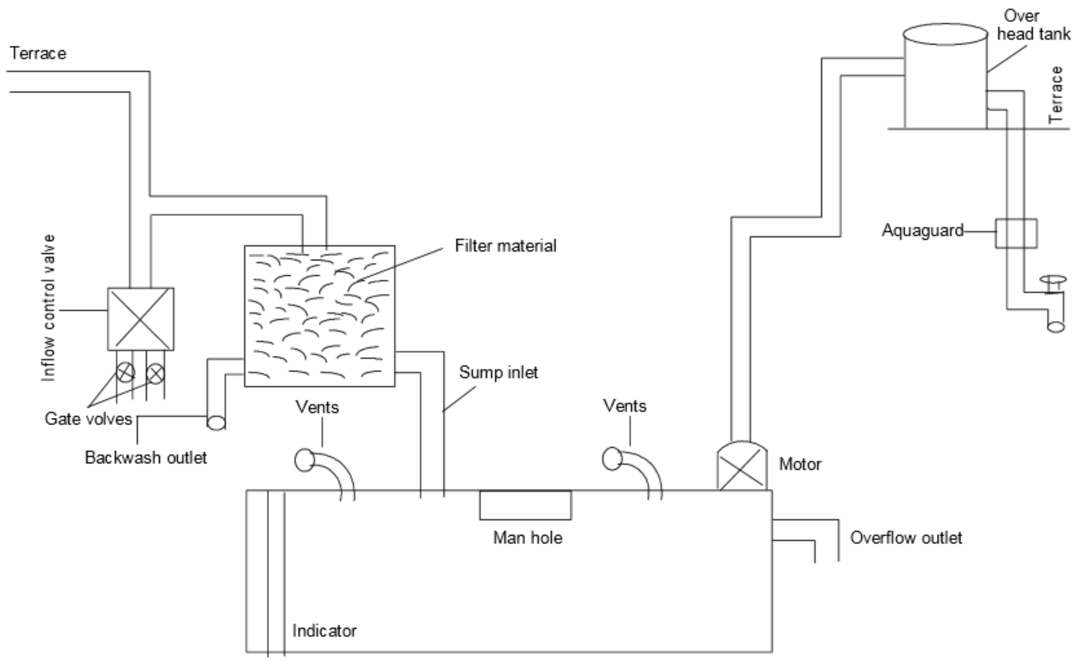


Fig. 9 Rainwater harvesting system in Cygnus Micro-systems limited.

(iv) Saijpur Lake, Ahmedabad: The Case study is about reviving a shrinking lake. The focus here is the involvement of people and the Municipal Corporation, and not the techniques of redeveloping the water body. The project was initiated by United Nations Environment Programmes under Ecosystem Services Approaches to Poverty Alleviation (ESPA). The project is a part of “Supporting Urban Sustainability”- a collaborative programme supported by Swiss International Development Agency (SIDA) and Swedish International Centre of Education for Sustainable Development (SWEDESD).

Fig. 9 Saijpur Lake: Google Image May 2011 & 2005 respectively.

The ESPA proposes to addresses the comprehensive needs of the communities with reference to their dependence on waterbodies. ESPA seeks to tie together various requirements with reference to social and environmental issues in a holistic manner, recognizing the interdependence between human beings and nature. This waterbody is rain fed, with an approximate area of 41000 sqm. Saijpur Bogha ward is predominated by low income households, working in the industrial units in the vicinity.Through the detailed study at Saijpur waterbody; a number of issues were identified which needs to be addressed during the redevelopment of the waterbody. These issues can be broadly classified into Environmental Degradation, lack of Social Amenities and livelihood issues.

Many groups had a stake in the redevelopment of the waterbody. The community living around the waterbody, the Ahmedabad Municipal Corporation (AMC), the local urban body responsible for providing civic needs and amenities to the population living within its jurisdiction, the architecture agency hired by the local body for preparing the design for development of the waterbody, the NGOs (like SEWA) who are working in the area for economic development of the women in the area, the SUS team who wanted to build ESPA component in the waterbody redevelopment plan. For developing the lake physically, the lake was first desilted, soil removed was used for landscaping. The garden was made around the lake. The settlements around the lake were rehabilitated with proper facility of toilet, bathroom and sewage network so that the lake is further not polluted. A weekly market is also proposed there. For ecological development of the lake, native species of plants are planted along with grass to bind the soil and prevent soil erosion. Aquatic life has also been introduced in the water body. For social development, a library cum reading room, playground for children with play equipment and integrated community areas.

The local residents residing in hutments and slums are having low incomes. The operation and maintenance of the waterbody and the garden areas, maintenance of the fruit bearing trees, maintenance of social amenities, maintenance of the waterbody and the surroundings, all can be taken up by the resident community through Community Based Organizations (CBO's). This is likely to yield better results and increase the ownership of waterbody by the surrounding communities. Lot of economic activities in the neighborhood is informal in nature taking place on roadsides in the form of vegetable vendors, handcarts selling different products etc. A dedicated space in the redevelopment plan where the informal activities can be located, small Kiosk and vending spaces are to be developed and provided to the members from surrounding community. The rents from these Kiosks can be used for the maintenance of the waterbody and surroundings.

Thus, this kind of ESPA approach can help improving our environment as well as improve the lives of the people.

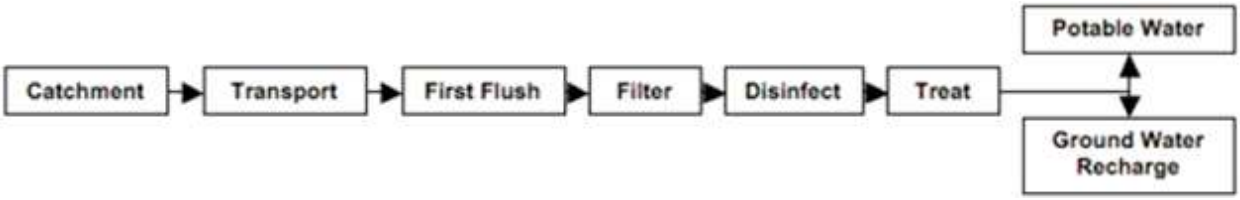
6. 5. Rainwater Harvesting in Ahmedabad

The average rainfall in Ahmedabad is around 800 mm. If the rainwater is harvested, it would be more than sufficient for the residents of Ahmedabad. As we have seen earlier that water from Narmada Dam is brought to Ahmedabad through Canals and supplied for fulfilling the water needs of the city. Due to this, the regular flow of Narmada River has been reducing by time. Had it been not done, may be rainwater harvesting would be looked at as a solution to declining water levels and supply. Below are the steps to a framework for harvesting rainwater in Ahmedabad.

5.1 Rainwater Harvesting at individual household and community level:

Rainwater harvesting at individual household level is being practiced in Ahmedabad, but is not a prevalent method. People have thought the harvesting to be a costly business and maintenance demanding.

A roof-top rainwater harvesting is the simplest method that can be applied to achieve sustainable ground water levels. It is the technique through which rain water is captured from the roof catchments, water is filtered and stored in reservoirs. Harvested rain water can be stored in sub-surface ground water reservoir by adopting artificial recharge techniques to meet the household needs through storage in tanks.



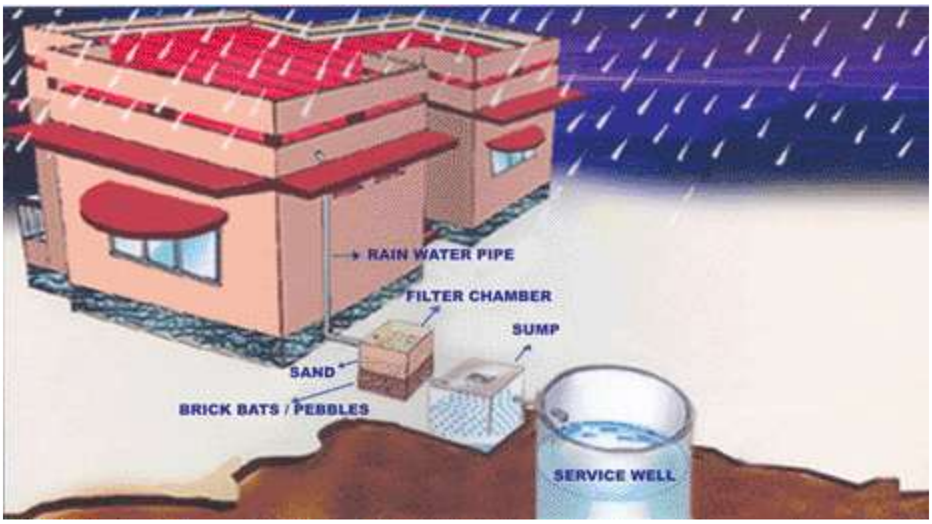


Fig. 10 Rainwater Harvesting at individual level

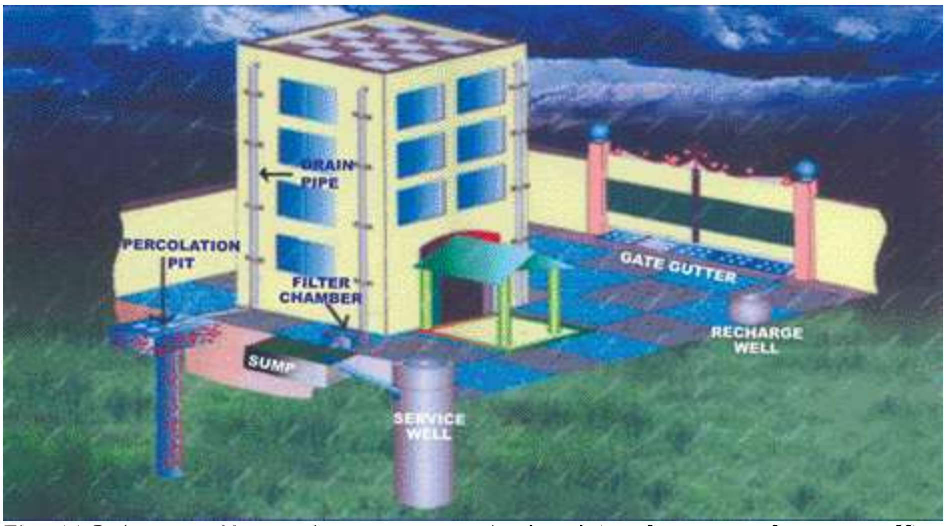


Fig. 11 Rainwater Harvesting at community level (roof-top + surface run-off)

Presently, every new upcoming project in Ahmedabad is expected to have a rainwater harvesting system, only then the Building-use permission will be given. But then there is no authoritarian body to inspect whether the rainwater harvesting system is still in use or not. There are no available statistics to see how much rainwater harvesting is being practiced in the city.

In order to propagate this method, the government of Gujarat and Municipal Authorities should co-operate with people for installing rainwater harvesting system at subsidized rates. The other thing that can be done is installing rainwater harvesting system at community or neighborhood level. In this case 4 to 5 societies or community level residences can collectively install rainwater harvesting system. The water harvested can be stored in a collective tank and can be sent further to recharge bore wells of individual community. This way, the cost, maintenance responsibility and the benefits of rainwater harvesting can be shared and taken care of.

5.2 Rainwater harvesting system at public spaces:

Rainwater harvesting can be done at public places like public gardens and parks, lakes, community halls, schools, colleges, libraries, other institutions, municipal offices, etc. as well. The catchment area may consist of both roof-top and surface run-off. The water collected from the catchment areas is collected in a planted bed where there are layers of sand and gravel beds for filtering the water. The filtered water directly gets recharged in the aquifer. The extra water that cannot be absorbed, is directed to drain.

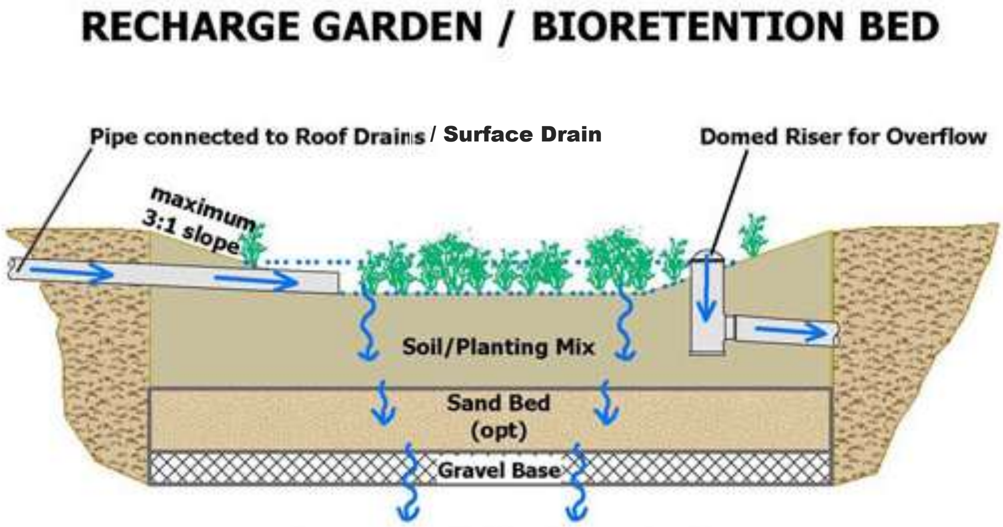


Fig. 12 Rainwater Harvesting at public places (roof-top + surface run-off)

For maintenance of the rainwater harvesting system at public places, the ESPA approach as discussed above in the case study of Saijpur Lake at Ahmedabad can be applied. In an urban area, ther is a considerably high population of poor and unemployed/ temporarily employed people. Most of them are in informal sector and their business is affected due to rainy weather for example idol makers, construction laborers, etc. Such people and their communities can be trained to maintain the system like, cleaning the pits, inspecting the tank and the filters, etc. This would provide them temporary employment.

5.3 Other measures:

There is much wastage of water due to faults like transmission wastage, leakages, illegal connections, leaking taps and tanks in buildings, etc. According to a study conducted by Cept University and the Sabarmati River Front Development Corporation Limited (SRFDCL), there is a wastage of 38.34 crore litres of water which can meet needs of 39.5% people across the city. If this wastage is plugged, Rs 4.17 lakh could be saved every day.

The solution to check these leakages is Water meters. They record the volume of water that has passed through the pipelines. This would reduce the problem of water leakages to a great extent. Moreover, since people would be paying for the water as per their usage, there would be reduction in house level leakages and maintenance costs.

The other problem faced during monsoons is water logging on roads, flooding and lack of appropriate water level in the ground. This is because of absence of storm water drains at many areas in Ahmedabad. If there is a proper network of Storm water drainage connected to lakes and other water bodies like canals, with appropriate waste and water filtering technologies, much water can be recharged to the ground and the problem of flooding along with water logging can also be solved.

6. Conclusions

The inclusion of rainwater harvesting is necessary not only because water is not availabe, but because it is a precious resource that is declining at a rapid pace. It is a renewable resource, only if enough efforts are put into making it renewable. The onus is on the architects, engineers and planners to initiate the large-scale integration of rainwater harvesting systems in building designs, landscapes, neighborhood and the city. Right from small houses to the city itself, rainwater harvesting can be adopted, provised there is an institutional framework and thus, professional involvement is created. There is a need of people specializing in rain-water harvesting at both stages, installation and maintenance. For this, engineers and laborers are all required. There is a scope for the unemployed to get employment in this sector, if it is promoted.

In the high water demand scenario, the rainwater harvesting and recharging are the solutions for a sustainable water supply along with combating many other issues of flooding, over-use and wastage of water and unemployment. Along with the increased ground water levels, rainwater harvesting systems also provide good quality water. This results in overall improved health of the citizens as water-borne diseases are prevented. A natural increase in ground water levels with the help of these rainwater harvesting systems also help maintain an ecological balance, as the amount of water consumed from the rivers, lakes, wells, etc. is balanced by rainwater recharge.

Thus, a comprehensive framework of rainwater harvesting may provide the sustainable groundwater reserves in Ahmedabad.

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