Macroscopic rainwater harvesting

Measures in industrial premises in Mumbai

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Rainwater harvesting (RWH) is emerging as an important tool to generate fresh water resources as fresh water becomes scarce. For industries, it is twice as beneficial as it helps not only in generating fresh water resources for in-house industrial and other non-potable applications, but also in effecting substantial savings on water. This article presents a case study of an industrial premises in Mumbai, which has implemented RWH measures at a macroscopic scale. With advantages of a vast expanse, high rainfall and availability of technical expertise, the premises has been able to generate a storage capacity of more than 400 million litres. It is implementing measures which will utilize more than 225 million litres of harvested water through direct means. The case provides a very good example of macroscopic rainwater harvesting which can be emulated by industries and small communities.

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Introduction

The growing fresh water scarcity is considered one of the biggest challenges faced by humanity in the 21st century. Massive population growths, rapid urbanization and increasing industrial demand are some major factors that have put enormous constraints on fresh water inventories. India and China, being the most populous countries, with rapidly growing economies and high rates of industrialization, are likely to face severe constraints of water availability. Most Indian cities face varying degrees of water shortage and, water being an essential commodity, authorities are compelled to either restrict or ration water usage by industries. It has therefore become imperative for everybody, and even more for industries, to adopt water conservation measures and explore alternative sources of water. Rainwater harvesting (RWH) is one such measure that can act as a supplementary and/or distributed water source.

RWH has been practised by humankind in various forms through all ages of civilization, as civilizations have always flourished near water sources, especially surface water. However, the modern system of piped supply by municipal or water supply authorities has resulted in gross dependence on that single source; which, in turn, has led to societies forgetting or neglecting RWH practices at the individual and industrial levels. Now, however, regulations have been promulgated by many municipal authorities, including those of Mumbai and Chennai, which make RWH practices mandatory for industry as well as for all construction. But even prior to these regulations, many of the forward looking industries had already adopted RWH measures, either to meet their water demand or to get economic advantages. This article is an appraisal of a large scale (macroscopic) adoption of RWH measures by an industrial premises in Mumbai.

The concept of RWH

The philosophy of rainwater harvesting is "catch it while it rains". It requires arresting rainwater during the monsoon, storing it in artificial or man-made reservoirs (lakes, tanks, etc.) or in natural reservoirs (aquifers) and, with suitable treatment, using it later whenever required. It is also defined as the process of augmenting the natural infiltration of rainwater or surface runoff into the ground by artificial methods, such as by recharging through pits, trenches and bore wells, or by directly diverting runoff water into existing or abandoned wells, or by conserving rainfall by artificially storing and using it for a different purpose.

The choice and effectiveness of any particular method depends on several local factors, including the end use of the water. Design parameters for an RWH scheme include rainfall intensity, rainfall profile, number of rainy days in a year, hydro-geographical characteristics of the catchment area, distribution, treatment and end-usage of harvested water.

The implementation of an RWH scheme not only results in the generation of fresh water resources to meet an ever-increasing demand for water and to reduce dependency on municipal supply, but also provides numerous advantages, such as augmentation of the ground water reserve, reduction in ground water pollution and reduction in runoffs.

RWH measures can be implemented either at microscopic level or at macroscopic level. Rooftop rainwater harvesting or RWH at housing complex or society level can be classified as microscopic rainwater harvesting. For large catchment areas, RWH measures can be implemented in the form of *bunds*, check dams, holding ponds and so on, which can be classified as macroscopic rainwater harvesting measures. In fact, most municipal or water supply authorities, including that of Mumbai, adopt macroscopic RWH measures by storing rainwater in dams and lakes. The basic design concept remains the same for both types of RWH measures, but, implementation and end usage change.

Site characteristics and water demand of premises

The said industrial premises is located in Mumbai, which falls amongst the highest rainfall areas of India. The total water demand of the premises is nearly 11 million litres per day (mld), which consists of industrial requirements, public health requirements and gardening and horticulture requirements. This demand is met partly with 9.5 mld from the Municipal Corporation of Greater Mumbai (BMC) and partly from bore wells, open wells and recycled water. Municipal water charges have risen sharply in recent times, and at present BMC supplies at the rate of Rs 25 per cubic metre.

The area of the premises is around 845 hectares (2,089 acres) and it receives more than 2,000 mm of rainfall annually. There is an in-house facility for monitoring major meteorological parameters, including rainfall. The plot is surrounded by the Trombay hills on the northern and south-western side. The eastern and south-eastern sides lie along the shores of the Thane creek. There is a level difference averaging 80 m from the foot of the hills to the lowest level of the premises. The runoff on the Trombay hills drains off into a residential colony towards the northern slope, in the adjoining industrial area towards the western slope, and into the premise area towards the eastern and south-eastern slope. There are various stormwater drains originating from the foot of the hills in different directions, which finally drain off into the sea (the Thane creek). The soil structure in the planar zone consists mostly of marine clay and moderately and highly disintegrated rock. The rock bed is found at a depth of 6-19 m. There are more than 25 bore wells and 10 open wells, some of which go dry in the lean season.

Implementation of macro-level rainwater-harvesting

Thanks to several advantages, such as the vast expanse, the nearly unidirectional runoff pattern, the high rainfall intensity, the availability of technical-economical capabilities and an enlightened management, the premises provides a classic case study of macroscopic planning and designing of RWH measures. Adequate storage capacities in the form of lakes and artificial reservoirs have been developed at a number of places. As the storm drains run off hill and the built-up areas at the foothill, macroscopic RWH measures provide dual advantages: one, having water available for gardening and other non-potable purposes, thereby saving on the water bill; and two, saving the downstream structures from flooding. In such cases, a check dam with an artificial reservoir is the most common RWH measure, and this has been adopted. A total of eight check dams have been built in the premises with different reservoir capacities. Some of the check dams have been built in the same drainage basin (micro-catchment area) at different elevations and some cater singularly to a specific drainage basin. All these check dams, except one, are earthen gravity dams. The most recent check dam, completed in 2007, is built of "colcrete" masonry.

Construction details of earthen check dams

As described earlier, these check dams have been designed and constructed as earthen dams with an inner impermeable core. The lengths of the dams vary from 107 to 270 m. The dams are located at different elevations. The heights of the dams at the deepest bed level vary from nearly 4 m to 20 m. The top width of all dams has been kept at 2.74 m. The slope at the upstream side is 2.5:1 H:V, whereas it is 2:1 H:V on the downstream side. All the dams have been provided with a spillway in the form of a waste weir and sluice.

Table 1: Storage capacities of artificial reservoirs (existing)

Artificial reservoir number	Storage capacity (million litres)
1	2.5
2	1.7
4	70
6	75
9	48.8
10	125
13	48
14*	50
Total	**421 ml**

*collaborative reservoir

Table 2: Potential capacity of proposed reservoirs

Artificial reservoir number	Storage capacity (million litres)
3	12.5
5	31.5
7	26.2
8	25
12	10

Out of these seven reservoirs, Nos. 9 and 11 retain water throughout the year. The other five go dry during the lean season. So far the water from these reservoirs has been used largely for irrigation and horticulture. Recent proposals have been developed to utilize them for industrial applications (described in a later section). In addition, the reservoirs also feed the bore wells and open wells and help in maintaining the ground water table. The greenery and rich eco-diversity of the premises have been greatly supported by these reservoirs. Only non-municipal water is being used for irrigation and landscaping in keeping with an in-house policy decision in this regard.

Construction details of "colcrete" check dam

A refinery belonging to the public sector is located at the western side of the foot of the Trombay hill, and shares a fence with these premises. A major storm drain, serving nearly 20 hectares of catchment area of the premises, flows through the refinery and drains into the Arabian Sea.

With a view to implementing RWH measures, a Memorandum of Understanding (MOU) has been signed between the two establishments, under which a check dam and reservoir have been developed in the industrial premises, with the refinery being the beneficiary of the harvested water. The entire cost of construction has been borne by the refinery and consultancy has been provided by the industrial premises. The length of the constructed dam is nearly 200 m, and the estimated reservoir capacity is nearly 50 million litres. A holding pond of nearly 4 million litres has been constructed in the refinery area and a distribution mechanism has been worked out.

The constructed dam is of "colcrete" masonry with a maximum height of nearly 12 m. "Colcrete" is also known as "pre-packed concrete" and is obtained by forcing a viscous mixture of cement, sand and water, called "colgrout", through the voids in pre-packed rubble stones or aggregate. The work was completed in 2007 and the harvested water is being used primarily for the cooling towers of the refinery. Earlier, the refinery used to draw seawater through its jetty nearly three kilometres away to meet the cooling water requirement and this implied substantial operation and maintenance costs. Now, the refinery uses harvested water for its cooling towers for nearly 5 months, which has brought down these costs considerably.

Storage capacities of existing reservoirs

By constructing the eight check dams, a substantial storage capacity has been generated by the premises. The capacities of the artificial reservoirs created by these check dams are listed in Table 1. Thus, a storage capacity of 421 million litres has been created in the refinery.

Proposed check dams and artificial reservoirs

Apart from the existing check dams and reservoirs, a number of new locations have been identified where new check dams can be constructed. It is estimated that an additional storage capacity of nearly 105 million litres can be created through these new check dams. The details, including cost aspects of proposed reservoirs, are being worked out. Table 2 describes the estimated capacities of the proposed reservoirs.

Additional proposals for end usage of harvested water

With greater emphasis being laid on water conservation measures and in order to generate fresh water sources, additional proposals are under implementation for the industrial use of the reservoir water. The usage so far, namely gardening and horticulture, has been expanded into non-potable and industrial requirements of the premises. Four specific proposals have been worked out and they are under implementation now.

Proposal No. 1

This has been developed for the greater use of Reservoirs 9 and 10. The reservoirs serve a common drainage basin and are located in series at different elevations. The proposals for their desilting and capacity augmentation are under implementation. Further downstream, two reinforced cement concrete underground (RCC UG) tanks, each of half a million litre capacity, have been planned, under which one will function as a raw-water tank and the other as a clean water distribution tank.

A proper interconnection is being developed among these reservoirs and a water body series consortium is being established. A distribution mechanism has been worked out through the lowest reservoir, that is, the RCC UG clean water tank.

During the monsoon, the surface runoff and reservoir overflow will be collected in RCC tanks for harvesting. After the monsoon, the feed will be taken from Reservoir 10, the capacity of which is being augmented from 16 million litres to 40 million litres. When exhausted, Reservoir 10 will be fed from Reservoir 9, located upstream, thereby establishing a water body series consortium.

Proposal No. 2

This proposal has been developed for Reservoirs 1 and 2 to avoid losses due to infiltration. The capacities are being augmented by 35 per cent and the bed of the reservoir will be lined with a polymer membrane to prevent infiltration losses. A distribution mechanism for the non-potable requirements of the nearby area is being implemented.

Proposal No. 3

This proposal seeks to use the harvested water of Reservoir 4 through the existing infrastructure. The reservoir is located at the top of the Trombay hill and a pipeline connection is being laid to bring the water down by gravity. Existing RCC tanks are going to serve as holding tanks and water, duly treated, is proposed to be fed to nearby structures for non-potable requirements.

Proposal No. 4

This proposal is being implemented to utilize the water of reservoir No. 11, which is the largest capacity reservoir of the premises. A 150 mm diameter pipe is being laid to bring the water to the central airconditioning plant (CAP) of the premises to meet its makeup water requirement. After completion of the project, the CAP will be functioning with the harvested water for nearly eight months.

These proposals are estimated to cost nearly Rs. 25 million, and will harvest nearly 228 million litres of water through direct means.

Cost analysis of fresh proposals

This analysis concerns only the additional proposals and does not include the cost of check dams already constructed during the earlier development of the refinery. The cost of BMC water, as stated earlier, is Rs 25 per cubic metre. With the volume of 228 million litres of harvested water, the savings on the water bill amount to Rs. 5.7 million per annum. The cost recovery period, calculated by an annuity method, which assumes a standard interest rate on reducing balances, comes out to be less than five years. However, the most important savings are a precious 228 million litres of fresh water, enabling BMC to feed a population of nearly 7,800 additional people through the year.

Conclusion

Water conservation measures have assumed enormous importance owing to a heightened water demand and an increasing water scarcity; and rainwater harvesting has been established as the most economical and feasible option for water conservation and freshwater source generation. Since its inception, the industrial premises has demonstrated great farsightedness in water conservation measures, and the existing check dams are a great example of this. The premises has been able to develop a storage capacity of more than 400 million litres and plans to increase it by another 100 million litres. With different utilization schemes of harvested water, it is able to utilize more than 225 million litres of water annually, for its industrial and non-potable applications. This is not only helping to save the water bill, but also helping the municipal authorities to divert supply to more scarce sectors. It can be said that with all the RWH measures that the industrial premises has implemented, it may serve as a very good role model of macroscopic rainwater harvesting measures. ❒

Water and development information for arid lands – A global network (G-WADI)

G-WADI strengthens the global capacity to manage the water resources of arid and semi-arid areas. Its primary goal is to build an effective global community through integration of selected existing materials from networks, centres, organizations, and individuals who become members of G-WADI. The network promotes international and regional cooperation in the arid and semi-arid areas.

G-WADI's specific objectives include:

- Improved understanding of the special characteristics of hydrological systems and water management needs in arid areas;
- Capacity building of individuals and institutions, matching supply with need;
- Broad dissemination of understanding of water in arid zones to the user community and the public;
- Sharing data and exchanging experience to support research and sound water management;
- Raising awareness of advanced technologies for data provision, data assimilation, and system analysis; and
- Promoting integrated basin management and the use of appropriate decision support tools.

For more information, contact:
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