Libyan Agriculture Research Center Journal International 3 (4): 178-182, 2012
ISSN 2219-4304
© IDOSI Publications, 2012
DOI: 10.5829/idosi.larcji.2012.3.4.1216

# Rainwater Harvesting in Tobruk, Libya

*Abdelkader A. Abdulla*

Department of Civil Engineering, Vocational College of Comprehensive Careers, Tobruk, Libya

**Abstract:** Tobruk is a water-stressed region and it has an annual average rainfall of only 38 mm. When work on this study had started, this too little amount of rainfall has given a disappointing impression. However, knowing that there are many households in Tobruk's rural areas that are entirely rainwater-dependent and their average consumption of the harvested rainwater per capita per day is 60-80 litres, was a great incentive for the rainwater harvesting topic to be investigated. With a good planning and the utilisation of all available means, significant amounts of rainwater, either runoff or stormwater, can be detained, collected and stored. The adopted theoretical and engineering approaches such as the rational method, have demonstrated that about 15 % of Tobruk's water demand can be provided by rainwater harvesting and this quantity can be significantly increased by choosing wider catchment areas. In terms of quality, the physico-chemical analyses of one sample collected from a rural area has not shown any toxic compounds or excessive levels of heavy metals which their removal can be of a high cost. In the urban areas, besides providing a viable resource of water, rainwater harvesting systems can efficiently prevent floods and hence protecting the population and the engineered environment from their disastrous impacts. The point at issue is that samples from both rural and urban areas have shown high levels of turbidity especially from urban areas. This, with no doubt, is because of the prevailing clayey and the sandy-clayey soil in the region, lack of plantation and the less development in the urban areas as it can be readily seen from the photos. Large-scale rainwater harvesting is feasible; nevertheless, it requires diligent and continuous efforts of studies and research funded by the government in order to create efficient methods and techniques of rainwater collection, storing and developing the existing ones.

**Key words:** Rainwater harvesting · Water scarcity · Rainwater quality and quantity

## INTRODUCTION

Rainwater harvesting in Tobruk has been used since the middle of the 2nd century B.C. during the Roman Era [1]. To store rainwater, Romans built many underground reservoirs called Roman Cisterns in and around Tobruk. Some of these reservoirs are still exist and in use ever since. For many rural regions around Tobruk, the Ancient Roman cisterns and Roman-style cisterns are the main resource of water for drinkingand livestock-breeding as people in this part of Libya did not engaged much in agricultural activities and they used to migrate from place to another in pursuit of water. However, people who settled down had to (using the Roman Techniques) construct water reservoirs to store rain water.

In Tobruk's coastal areas, where there are some seasonal agricultural activities such as olives, figs, grapes, etc., another pattern of rainwater harvesting techniques has been used, that is dikes-Dikes are usually made of stones or earth, their main functions are the storage and conservation of soil water and preventing soil erosion.

Another pattern of rainwater harvesting systems (very popular in Libya) is roof runoff collection for domestic and drinking use: This technique is used almost in every house. However, bad practices associated with these systems, make them subject to pollution.

Because of its location, in the MENA region (The Middle East and North Africa), Tobruk is considered to be water-scarce region [2] and desalinated sea water remains the essential resource of water for all purposes. The encouragement of rainwater harvesting in large-scale would provide Tobruk with potable water which favour the sustainable development.

**Corresponding Author:** Abdelkader A. Abdulla, Department of Civil Engineering, Vocational College of Comprehensive Careers, Tobruk, Libya. Tel: +218 (91) 464 0818.


Fig. 1: Tobruk's location on globe (Source; Google earth)

The absence of surface water resources, such as rivers, lakes, etc., the abstraction conditions occur in coastal aquifers resulting in sea water intrusion and thus groundwater deficiency and the high cost of sea water desalination and its environmental impacts, all these conditions and circumstances together necessitate the utilization of the potentially available water resources of low cost and environmentally friendly.

The great challenge that faces the success or failure of rainwater harvesting is the quantity that can be harvested from an area under given climatic condition, i.e. rate of rainfall [3].

Rainwater harvesting in Tobruk has not been linked to any environmental impacts, thus it represents competitive alternative resource of water.

**Study Area:** Tobruk city is, the capital of Al Batnaan territory, locates in the northeast of Libya on the Mediterranean Sea, its centre locates on 32°4' N 23° 57' E. Urban area covers about 25 $km^2$ of the territory with a residential population of about 150,000. Fig. 1 shows Tobruk's location.

Because of its position in the north, Tobruk is subject to the effect of the Mediterranean that gives it a moderate climate, especially in its sea- facing versants. And since the surface on the whole region does not exceed 200 m above sea level, it has no effect to moderate the temperature. Also, due to its location behind the Green Mountain region, Al Batnaan plateau is a scarce rainfall zone [1]. Annual average rainfall on the area is showed in Fig. 2.

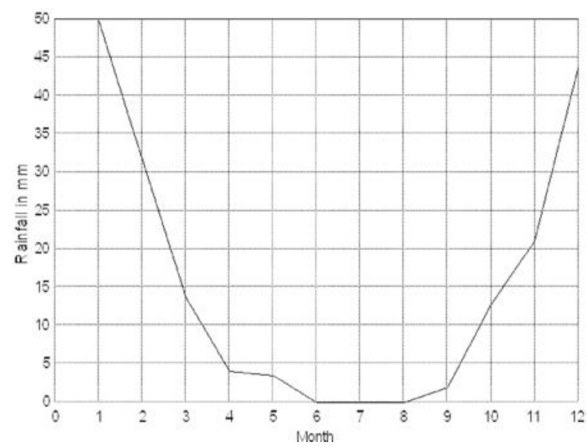


Fig. 2: Tobruk's annual average rainfall (Source: Tobruk's meteorological station)

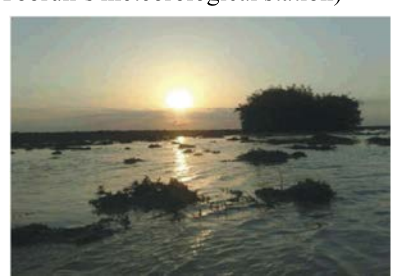

Fig. 3: Runoff over Sandy Clayey soil at western Tobruk (Source: Anon)

One of the Common types of soil that are widespread in Tobruk is the Sandy clay soil (Fig. 3); a predominant type of soil in the area. It is an arable soil good for vegetables and dates, found in the coastal plateau and valleys drainage.

From the data provided Tobruk's meteorological station, area's maximum rainfall per day between 1985 and 2006 is only (77.7 mm per year. Region of such amount of rainfall is classified as an arid area [4]. According to this rate of rainfall, lack of any other surface waters resources (e.g. rivers, lakes, etc.) and the shortage of groundwater, desalinated seawater is the main resource of water that serves a wide variety of purposes.

## MATERIALS AND METHODS

Rainfall measurements obtained by Tobruk's meteorological station over 20 years. Total average annual rainfall distributed over the year excluding (June, July and August, where rainfall is zero) is 38.0 mm/ year.

The annual rainfall runoff that can be harvested is calculated from:

$= \times \times$

where;

V is harvested water volume expressed in ($L^3$), *P* Rainfall in (L), A Catchment area in ($L^2$) and η Runoff coefficient (Dimensionless).

However, it is beneficial to include the rainfall intensity (i) in the design calculations. The purpose of this approach is to estimate the pipe size of catch (Detention) basins to hold the predicted volume of collected water and prevent overflow and thus flood from occurrence. For this purpose, Runoff flow should be calculated based on the Rational Method as follow:

$= i \times \times$

where Q is flow rate expressed in ($L^3$/ T), i rainfall intensity (L/ T), A is the catchment area ($L^2$) and η the runoff coefficient (Dimensionless).

Intensity (i) is obtained from intensity- Duration Frequency (IDF) curve. To determine the rainfall intensity from IDF curve, the corresponding duration of time is needed. Rainfall duration can be efficiently chosen to equal the time of concentration [5]. A time of concentration of 10 minutes from the available data of urban stormwater management at Tobruk, was chosen for the estimation of rainfall intensity (44 mm / hr).

Due to the variant topography of Tobruk, it is convenient to choose more than one catch basin, each of which locates at the lowest point in the catchment area.

Stormwater collection from rooftops in the urban areas at Tobruk has been practiced for many years as it is a simple process that requires only few affordable components; a rooftop, which is already exists, gutters and pipes and a storage canister or tank. But, due to lack of sufficient knowledge and the random selection of the storage tanks, overflow can occur causing loss of valuable quantities of collected water and damages to pavements and concrete surfaces. Hence, the size of storage tank is of high importance and should be defined in accordance with the catchment size as follow;

$_T =$

where $V_T$ is the tank storage volume expressed in ($L^3$) and V the quantity of harvested water.

Natural rainwater ponds are widely spread during winter in the rural areas southern Tobruk. They are left in their natural condition and only utilised for the livestock watering. Tobruk's rural areas are almost with no vegetation. Besides the enormous amounts of solar radiation that falls on Tobrukiii. the retained water in ponds are subject to a significant rate of evaporation. It is not feasible to cover those ponds as they are of very large areas and thus it is better to pump the accumulated water out of the ponds to storage reservoirs or directly to thetreatment works. This is necessarily to protect the harvested water from exposure to potentially contaminating resources as well as reducing deep percolation and evaporation losses. Due to the insignificant amount (38.0 mm/ year.) of rain that falls on Tobruk, the utilization of natural ponds instead of artificial ones concrete ponds, for instance would save great deal money.

Based on Eq. ( = i × × ), the wider the catchment area the greater the gained volume of the collected water. Nevertheless, a proper location of a pond should consider the contour lines of the catchment area which can naturally induce runoff and bring it into the pond (basin area). For this purpose, a watershed with a total area of about 4200 hectares is chosen. This choice is based on the following considerations:

- It has a distinctive topography that
- It is 15 km (9.30 miles) from the city, which makes it easily accessible by concerned bodies (e.g. governmental, environmentalists, engineers, etc.) and it is far enough from urban and industrial activities. Furthermore, this reasonable distance from the city would reduce the cost of pipelines and pumping processes.

Unlike the approach that has been used for the estimation of the collected volume of stormwater from urban areas, here the rainfall amount expressed in (L) will be used instead of rainfall intensity (L/ T). This is because no drainage systems or pipe networks are needed. Therefore, the simple formula ( = × × ) was adopted.

## RESULTS AND DISCUSSIONS

Table 1 summarises the results of the calculations for rainwater collection from urban areas. The results show that the total amount of runoff volume which can be collected from the urban area in Tobruk is 335,700 cubic meters per year. This amount is about 6.0 liters per capita per day. Obviously it is approximately equal to the per capita daily requirements for drinking and cooking which is 7 liters / day. On the other hand it is surprising that the Tobruk urban area yields only this amount of runoff volume. Indeed the average annual rainfall of 38.0 mm represents the major factor which determines how much water can be collected from a rainwater catchment.

However, the Runoff Coefficient ( ) has a tremendous influence as well since the more developed area; the greater volume of runoff can be induced and then stored. Figure 4 shows two urban areas within Tobruk city, one is very well developed and the other is of poor infrastructures which obstruct the runoff flow to collection basins and result in significant losses and also the forming of pools that can provide breeding sites for insects such as mosquitoes. This is referred to as 'the effect of urbanisation' on stormwater runoff. The figure indicates the significant effect of urbanisation on runoff rate because of the increased impervious cover provided by parking lots, streets and roofs, which reduce the amount of infiltration.

Rainwater collection yields from rooftops (residential and public buildings) presents more than 60 % of the total amount, the roofed area is less than that of other urban patterns though. This is not surprising since the prevailing material used for roofing is the reinforced concrete that has a runoff coefficient of 80-90 %. Also, a rainwater sample collected from a residential rooftop has demonstrated a value of 38.0 NTU of turbidity (Fig. 5). This is much less than those from streets or rural areas. By avoiding the use of rooftops for storage and petting domestic animal doves for instances much more clean water can be obtained.

(a)

(b)

Fig. 4: Urban areas within Tobruk (a) Developed residential area where the runoff can be induced and directed by gullies to collection basins or discharge points. (b) The effect of unimproved areas on runoff behavior


Fig. 5: Rainwater sample collected from a rooftop (Source: A Abdulla, 2010)

For rainwater harvesting from rural areas A watershed (catchment area) whose runoff coefficient factor is 0.3 with a total area of about 4200 hectares and an average annual rainfall of 38.0 mm, an amount of about 480,000 $m^3$/ year can be collected from the catchment area. Based on the rational method it can be seen that for given geographical- hydroclimatic conditions, the larger the water area the greater the harvested volume. Nevertheless, the chosen of a watershed (catchment area) ought to consider the topography of the ground surface which ensures the obtaining of the biggest pond of rainwater. This is from hydraulics point of view. However, the environmental health engineering dictates that the site of a catchment area entails the assurance against any potential contaminant either natural or man-made that might be brought, by the runoff, from higher elevations,

Table 1: Rainwater collection yields form urben areas

| Urban pattern | Total area $km^2$ | Roofed area $km^2$ | Runoff yield $m^3$/year | $m^3$//household per year |
|---|---|---|---|---|
| Residential areas and public buildings | 13.40* | 5.60 | 212,800 | 10.0 |
| Roads, parking spaces, pavements, | 6.64 | - | 122,900 | 5.7 |
| Total | 20.04 | 5.60 | 335,700 | 15.7 |

into the catchment area. The rainwater sample collected from a rural area has shown a high level of turbidity. This is inevitable since the prevailing soil type in Tobruk and its rural areas is the clayey or the sandy- clayey soil.

## CONCLUSIONS

Although Tobruk is located in a very arid area with an average rainfall of only 38 mm per year, nevertheless, significant amount of rainwater can be collected and stored. Rainwater harvesting techniques and methods are varied in accordance with the climatic and geographical conditions and therefore, developing or implementing of a specific method should firstly examine its reliability and profitability.

There is a regression in rainwater harvesting in Tobruk and it is not as much practiced as it had been. This is probably because the development that allows people access to the municipal water resources through pipelines and the construction of storage reservoirs in some rural areas and villages.

During the past two years Tobruk has been suffering from dry periods and much events of Ghibli storms* which results in a sever dry of the soil moisture and hence significant loss in water used for agriculture. This deficiency of water needs to compensate by other alternative resources of water.

Rainfall occurs episodically with inconstant magnitude and may not occur at all for extended periods of time and conventional major resource in Tobruk for all purposes is the desalted seawater. The latter is very expensive and it cannot be a sustainable resource once the government is of less means. Therefore, rainwater harvesting since it does not the total demand of water, it should be integrated with any other available resources. By obtaining the basic parameters of Tobruk Sewage Treatment Plant's effluent which are 7000 $m^3$/ day of only 3 mg/ l and 21 mg/ l for B.O.D and C.O.D respectively, this presents very attractive resource of water that can be incorporated with rainwater at least for irrigation. The physiochemical analyses of a rainwater sample did not show any toxic compounds or excessive levels of chemical elements that might pose serious health risks to consumers and therefore only basic treatment are required to deliver drinking water of acceptable quality. The only issue which is associated with rainwater quality in Tobruk's region is the high turbidity especially at urban areas. Tobruk has been suffering of floods because the poor infrastructures and therefore, stormwater drain systems should be well planned, engineered and integrated with infrastructures in future.

Rainwater harvesting favours the sustainable development as it can provide potable water at low cost with no known negative environmental impacts.

## REFERENCES

1. Sior, Ali, 1991. Tobruk 'the past and today' In Arabic, Benghazi: National Press.
2. Nasr, Mamdouh, 1999. Assessing Desertification and Water Harvesting in the Middle East and North Africa: Discussion Papers on Development Policy, Bonn: Zentrum für Entwicklungsforschung 'Universität Bonn'.
3. Boers, TH.M., 1994. Rainwater Harvesting in Arid and Semi-Arid Zones, the Netherlands: International Institute for Land Reclamation and Improvement/ ILRI.
4. Arrar, A., 1989. Current Issues and Trends in Irrigation with Special Reference to Developing Countries, In: "Resource Conservation and Desertification Control in the Near East, Report of the International Training Course, DSE, FAO, GTZ, UNESCWA, Germany and Kingdom of Jordan.
5. Larry, Mays W., 2004. Stormwater Collection Systems Design Handbook, e-book: McGraw-Hill.