Evaluation of the Quality and Quantity of Harvested Rainfall from Different Catchments Systems Case Study: North West of Libya

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Abstract

This study was conducted in north west of Libya which received an average annual rainfall of 200-250 mm. Due to the limitation of water resources in the study area for domestic use, the study aims to evaluate the quality and quantity of harvested rainwater from different catchments including cisterns near asphalt roadway, open surface from mountain and hills aspect, dams lakes, houses roofs and direct precipitation. With emphasis to harvested rainwater quantity, statistical analysis based on historical data of rainfall in the study area was conducted to detect the probability of rainfall occurrence with suitable return period. The results of analysis highlight the availability of rainfall for harvesting purpose. Harvested rainwater characteristics from different catchments have been investigated on the basis of samples collection and determination of physical parameters, chemical composition and microbiological analysis. Common anions and major cations as well as the metals Pb, Cd, and nitrate were tested .with emphasis on rainwater quality affected by the different catchments, it was found that the measured compounds in the harvested rainwater from different catchments were generally matched the WHO guideline and Libyan Stander Specification of Drinking Water. Cd concentrations in the collected samples near the roadway appeared to be higher than the guideline values. A Faecal Coli form, which is an important bacteriological parameter for the different catchment systems, was investigated. The results show that no Faecal Coli forms were detected in water samples except in the samples collected from cisterns near the asphalts roadway and the dams lakes. The finding results revealed that microbiological parameters were affected mainly by the cleanness level of catchment areas, while chemical parameters were influenced by the human activates and the natural of the catchments areas.

Keywords: Harvested Rainwater, Rainwater quality and quantity, catchments systems.

Introduction

Harvested rainwater may be the only source of water supply for many rural and remote households where no other water supply is available Rainwater harvesting for domestic use and as drinking water source, is becoming increasingly popular as the availability of good quality water declines. In urban and suburban environments, rainwater harvesting could help public water systems reduce peak demands and help delay the need for expanding water treatment plants. Rainwater harvesting can reduce storm water runoff, non-point source pollution, and erosion in urban environments. Rainwater is valued for its purity and softness and is generally superior for landscape purposes to most conventional public water supplies. Rainwater harvesting can be used for both indoor and outdoor purposes in residential, commercial, and industrial applications.

In the study area, rainfall is sufficient to make rainwater harvesting reliable and economical source of water even during short-term droughts. Homes in remote areas with no access to other sources of water supply depend on rainwater for all their needs. In addition to residential use, there are many examples of rainwater harvesting systems being used in commercial and industrial applications. Public facilities, such as schools and community centers have started harvesting rainwater to conserve water supplies (Heijnen 2001). Rainfall is the most unpredictable variable in determine the potential rainwater harvesting for a given catchment. Developing rainfall probability or frequency curves based on past rainfall data is valuable tool for decision makers to make a rapid preliminary assessment about the like hood of success of a rainwater harvesting project (Anush et al 2003). According to the probability or frequency analysis of annual rainfall totals subjected to an area, the rainfall harvesting potential sites and the return period of each event can be calculated (Wifag, Hassan 2007). Among the several factors that influence the rainwater harvesting potential of a site, the catchment characteristics are considered to be the most important. The harvested runoff depended upon the area and the type of the catchment over which it falls as well as surface features.

Rainwater harvesting can be categorized according to the type of catchments surface used, and by implication the scale of activity. Rainwater collecting and storage systems need to be monitored in a similar fashion as any other piece of important infrastructure around the house or the institution. The practice of collecting rainwater harvesting can be classified into to broad categories: land-based rainwater harvesting occurs when runoff from land surfaces is collected in furrow dikes, ponds, tanks and reservoirs. Roof-based rainwater harvesting refers to collecting rainwater from roof surfaces. Roof-based rainwater harvesting results in much cleaner source of water and provides water that can be used for potable indoor purposes. The quality of rainwater harvested is one reason to use rainwater as primary drinking water source. The need for quality water has been well documented and is crucial for human and ecosystem health (Mintz, bartram, lechery 2001).For the quality reasons harvested rainwater for human consumption is preferably collected from roof catchments. The livelihood approach promotes the use of runoff water also for productive purposes, such as small scale irrigation for domestic food production, watering small stock, watering tree nurseries etc. such as slope , does not create a problem. The quality of harvested rainwater depends upon many factors such as air quality, system design and maintenance, materials used, rainfall intensity, length of time between rainfall events, social context as well as water handling. In addition to the harvesting and handling of rainwater, the environmental surroundings of the catchments system play an important role in water quality .Rainwater catchment systems are open to environmental hazards because of the nature of the catchment area .

There are several ways contaminants can enter the rainwater system and compromise the water quality such as atmospheric pollutants and urban and industrial locations (Gould and Nissen_petersen 1999). In industrialized urban areas atmosphere pollution has made rainwater unsafe to drinking (Thomas and Green1993). Especially in areas with high traffic intensity and heavy industries where heavy metals such as lead are found in the atmosphere.(Gould, 1999). The bacteriological quality of rainwater collected from land surface or ground catchments are generally poor. From properly managed rooftop catchments, equipped with storage tanks with good covers and taps, water with relatively high quality can be collected though. This water is typically suitable for drinking and commonly meets the drinking water standers of WHO (Yaziz et al 1989). In study developed by (E. Sazakli 2007) show that the principle component analysis reveled that microbiological parameters were affected mainly by the cleanness level of catchment areas, while chemical parameters were influenced by the sea proximity and human activities.

The purpose of this research is to assessment the quality of water storage from rainwater harvesting collected from various land surface catchments near asphalt roadway in rural areas. Absolute quality of rainwater collected depend on the cleanliness of the atmosphere, material used for the catchments surface ,gutters and down pipe the storage tank and the water extraction device as well as level of maintenance of the catchments system . In rural areas atmospheric pollution is not generally thought to be a problem. The purpose of this research is to assessment the quality of water storage from rainwater harvesting collected from various land surfaces Catchments near in rural areas.

Material and Methods

The study catchments area in figure (1) was selected in North West part of Libya to investigate the quantity and the quality of rainwater harvesting. The macroclimate of the study area gives a regime of one rainy season per year appears during the period of October to May.

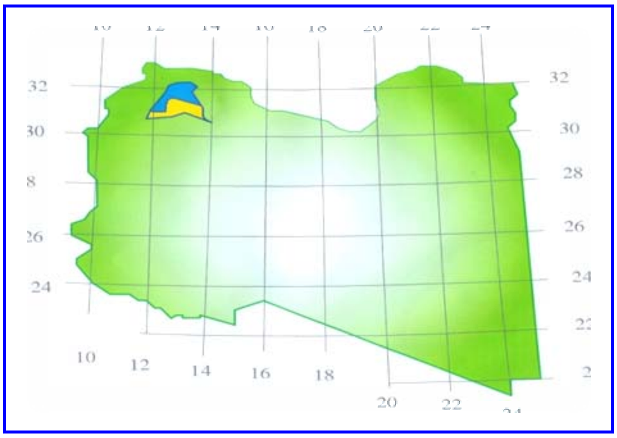

Figure (1) Location of the study area

For quantity issue, rainfall data was collected from several metrological stations in the study area. Rainfall data for the study area were available for a period of 36 years from 1970 to 2006 expressed in mm. Statistical analysis based on historical data of rainfall in the study area was carried out to detect the probability of rainfall occurrence with suitable return period and to assess the availability of rainfall for harvesting. The rainfall data was ranked and plotted on probability paper according to Weibull formula equation (1).

$$P= m /n + 1 \qquad (1)$$

where:

P is the probability of an event being equaled or exceeded.
m is the order of rainfall event.
n is the number of sample.

The return period is the average period of time expected to elapse between occurrences of events at certain site. The return period can be derived once the exceedance probability P (%) is known (1/probabalility of equaling or exceeding).

For the quality issue, harvested rainwater from different catchments including cisterns near asphalt roadway, open surface from mountain and hills aspect, dams lakes, house roof and direct precipitation, was investigated for there quality. Seventy samples of rainwater were collected from different catchments during the rain season 2006-2007. Figure 2 show the location of the samples collected from the study area. The collected samples were analysis on various physical-chemical and biological parameters.

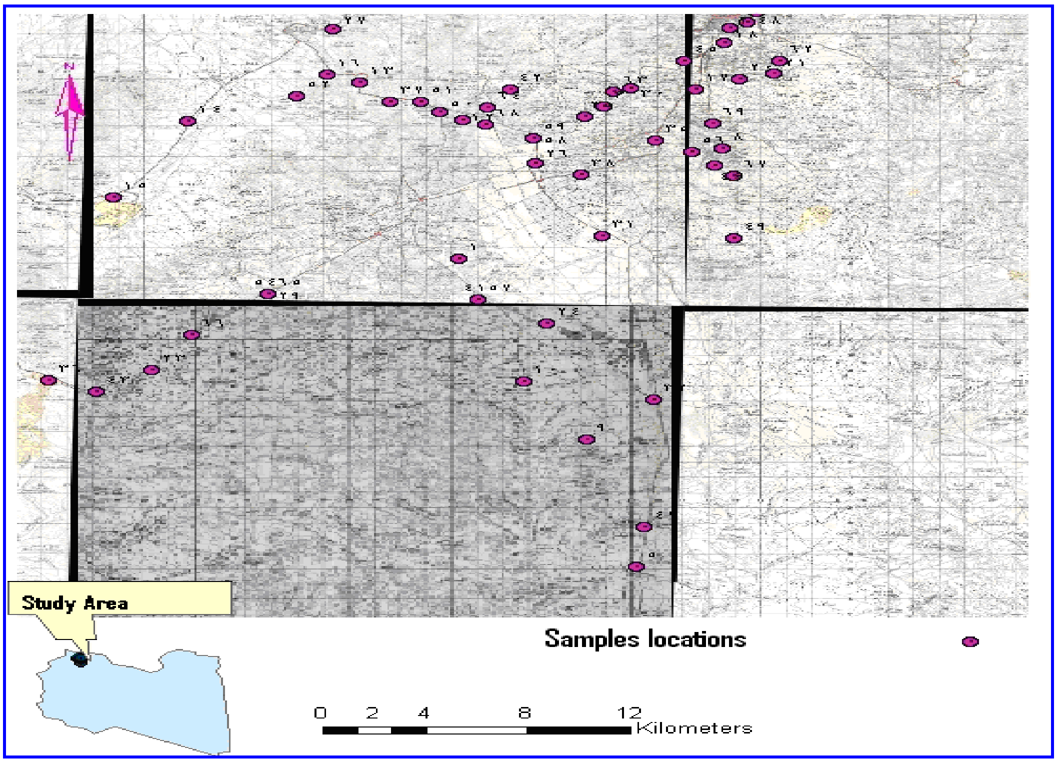

Figure (2) Location of the samples in the study area by GPS

Results and Discussion

Rainwater availability

Rainwater availability is very important indicator for any sound rainwater harvesting project. According to the annual rainfall totals subjected to study area, the study area received an average rainfall from 250 to 300 mm per year. Rainfall pattern based on the annual rainfall for the period from 1970-2007 is shown in Figure (3) .It appears that the average yearly rainfall amount received in the study area is favorable for rainwater harvesting systems.

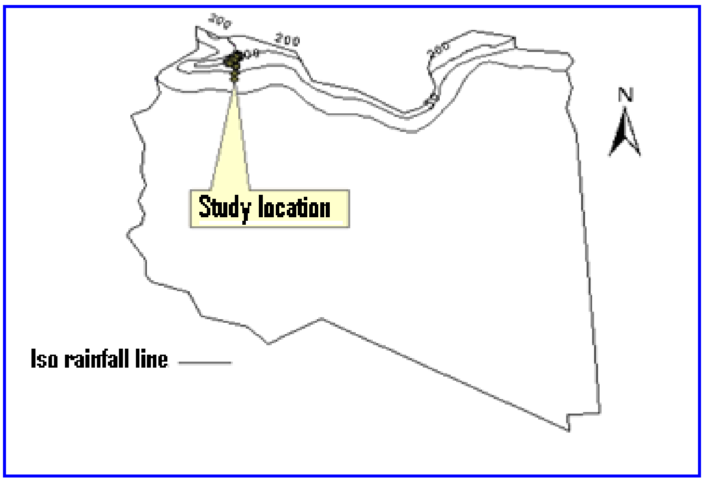

Figure (3) annual rainfall in the study area

Rainfall probabilities and return period calculations

To estimate the probability or frequency of events of a given magnitude of rainfall will occur or be exceeded, the probability analysis were conducted for the annual rainfall data records of the years 1970 to 2007. The plotted curve of the probability analysis (rainfall data from one metrological station) is shown in Figure 4.

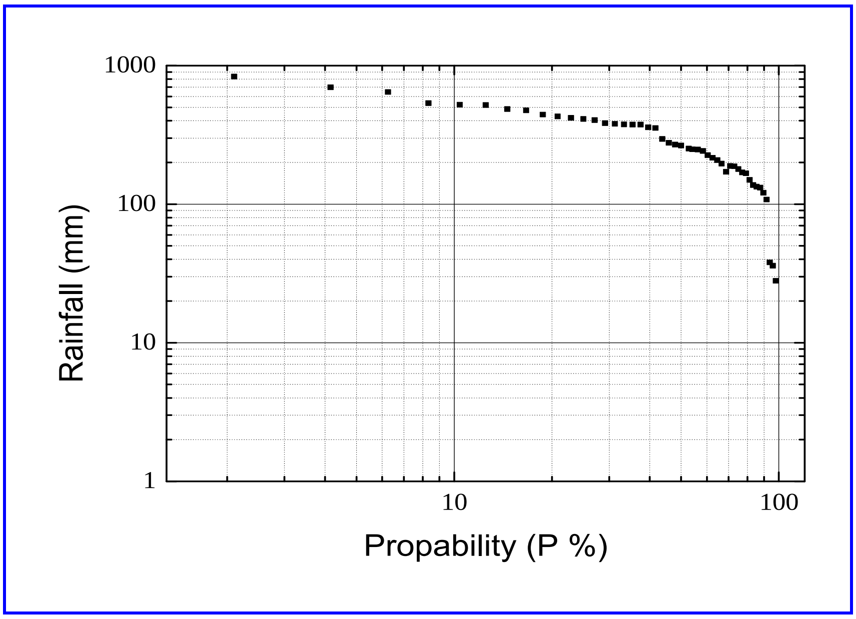

Figure (4) Probability analysis for the annual rainfall

From the figure it is possible to obtain the probability of occurrence of specific magnitude of rainfall. Inversely, it is also possible to obtain the magnitude of the rain corresponding to a given probability. The return period can easily be derived once the probability P (%) is known (1 /probability).

Figure 5 shows the return period curve of the rainfall for the study area. According to the probability of annual rainfall totals subjected to the study area, the analysis show that the probability of occurrence of annual rainfall 200-250 mm or more is around 60-70 %. This means such rainfall magnitude will occur once every year. The results of analysis indicate that there is suitable amount of rainfall for harvesting purpose in the study area.

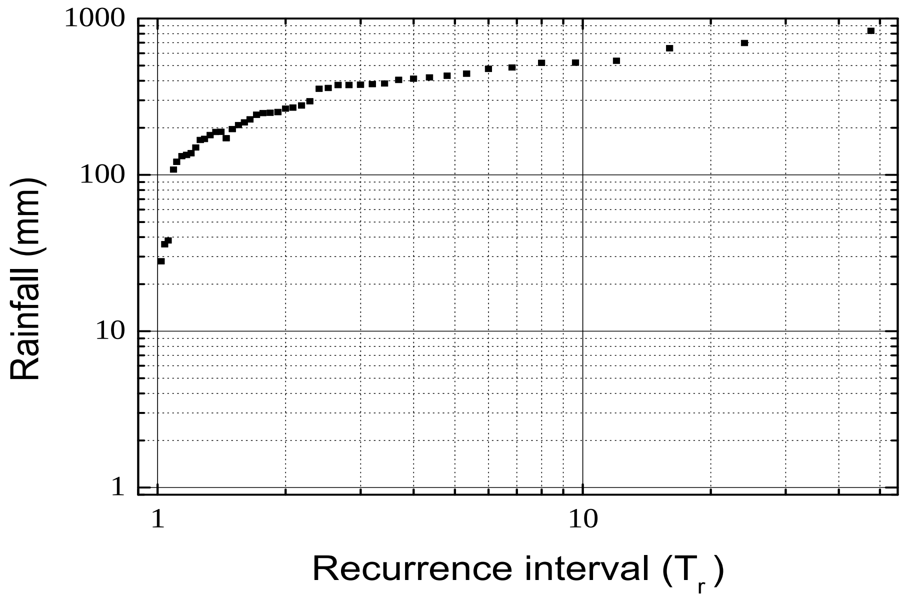

Figure (5) Return period for the rainfall events

Quality of Rainwater Harvesting

The main constrain on using harvested rainwater for different use have been the water quality aspects. The rainwater collected depends on the cleanliness of atmospheres, materials used for the catchments surface, methods of storage and the water extraction device. For the quality issue, harvested rainwater from different catchments including cisterns near asphalt roadway, open surface from mountain and hills aspect, dams lakes, house roof and direct precipitation, was investigated for there quality Table(1) . Collected samples from different sites were analyzed for chemical and bacteriological quality. The observations are summarized in the Table (2) shown below, the results are also analyzed graphically (Figure 6-10). Based on the above tabulated values and the figures, the following observation is made. It is observed that the electrical conductivity (EC) of water sample remained consistently low in all the samples collected. It is range from (30 - 977) µs/cm. It is in the limits approved by the WHO guideline, the results also indicating the absence of any salinity problems Table 2, Figure 6).

Table 1: different sites in the study area for collected samples

Sample No	Sample site	Sample site description	Sample source
1-8	Site # 1	direct precipitation	Direct rainfall
9-30	Site # 2	open surface(mountain and hills aspect)	Runoff
31- 40	Site # 3	cisterns near asphalt roadway	Runoff
41- 45	Site # 4	dams lakes	Runoff
46 -70	Site # 5	houses roofs	runoff

Table 2: Mean results of chemical and bacteriological analysis for waters samples

Parameter	Site# 1	Site # 2	Site# 3	Site# 4	Site # 5
EC µs/cm	30	320	977	230	270
TDS mg/l	19.9	206.7	593.2	162.6	175
pH	6.37	7.37	7.66	7.94	7.7
Ca^{2+} mg/l	*	48,8	61.32	32.0	28.6
Mg^{2+} mg/l	*	11.29	35.6	7.96	8.2
Na mg/l	*	8.7	33.9	7.2	10.4
K^{+} mg/l	*	7.1	16.6	5.8	7.7
HCO_3 mg/l	*	139	188	117.3	95.6
SO_4 mg/l	*	30.1	176.3	16.6	13.13
Cl mg/l	*	22.1	83,4	18.5	28.5
NO_3 mg/l	0.75	1.83	0.87	9.4	1.94
Pb mg/l	*	*	0.0204	0.026	*
Cd mg/l	*	0.0176	0.0162	0.00218	*
Fecal Coliforms	Non detected	detected	detected	detected	Non detected

Site#1direct precipitation,
Site#2 open surface (mountain and hills aspect),
Site#3 cisterns near asphalt roadway,
Site#4 dams lakes,
Site#5 houses roofs.
* Not detected

The WHO has suggested a limiting value of 500 mg/l of TDS for potable water. In the present investigation this limit is not crossed on either side by any of the samples under study. However in the samples collected from site # 3 (cisterns near asphalt roadway), the TDS value is about to reach the minimum permissible limit. The waters samples have registered handsome values of TDS (19.9 mg/l – 593.5 mg/l) (Table 2, Figure 6). These values are acceptable for domestic use and agricultural purpose. From the tabulated values and the figures (Table 2, Figure 7), it is observed that the pH of the waters samples is on normal range and only minor fluctuation in pH was recorded. The pH levels were within the limits set for domestic use as prescribed by WHOM. The average pH levels of the waters samples were about 7.4, which suggested that there were no serious acid rain problems in the study area. Major cations, Ca^{2+}, Mg^{2+}, Na, and K^{+} , in waters samples collected from different sites was investigated. The results of the analysis shows range values, between (48.8-71.32 mg/l), (8.2-35.5 mg/l), (7.8- 33.9 mg/l), (5.8-16.6 mg/l) respectively (Table 2 and Figure 8). The major anions HCO_3, SO_4, and Cl show concentration ranges, between (95.6- 188 mg/l), (13.13-176.3 mg/l), (18.5-83.1mg/l) respectively (Table 2and Figure 9). It is observed that the greater amounts of both cations and anions are measured in collected waters samples from cisterns near asphalt roadway. The collected samples from direct precipitation registered very low values for both cations and anions. In general the concentration of cations and anions in collected samples from different catchment areas fall well within approved limit by WHO. Nitrate is the other principal inorganic nitrogen form readily available for plant uptake. There are several processes affecting the quantity of NO_3 in the harvested rainwater. The data presented in (Table 2 Figure 10) show acceptable values of NO_3 concentration in the waters samples from different catchment areas. The values ranges from (0.75 -9.4 mg/l).Very low concentration was observed in the waters samples collected from direct precipitation, where the highest concentration were measured in waters samples collected from dams lakes.

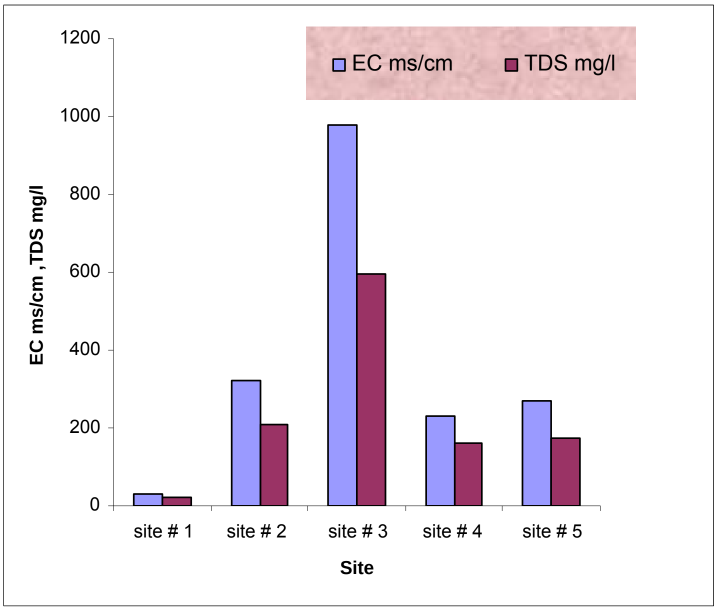

Figure (6) TDS and Electric Conductivity in the study area

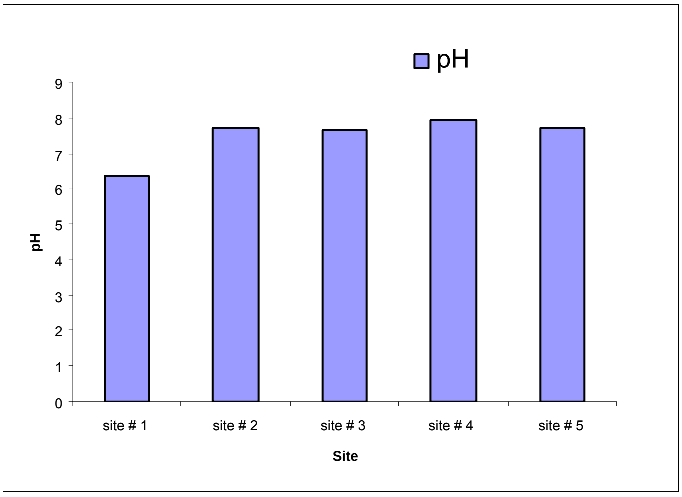

Figure (7) pH in the study area

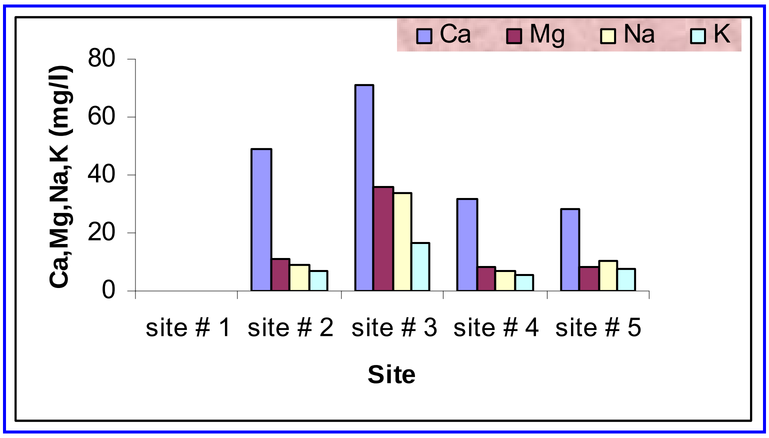

Figure (8) Calcium, Magnesium, Sodium and Potassium in the study area

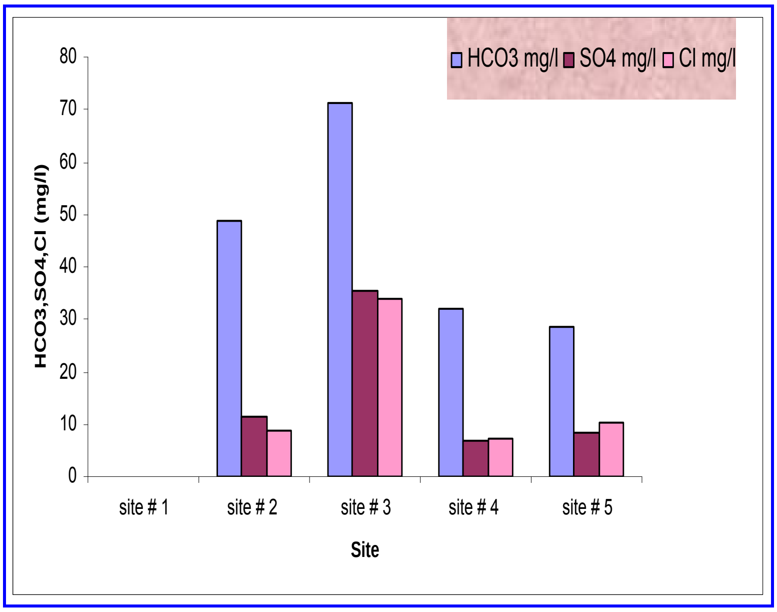

Figure (9) Bicarbonate, Sulfate and Chloride in the study area

The relatively low levels of NO_3 concentration in waters samples collected from direct precipitation can be attributed to no any industrialized sources in the study area, while the approximately high concentration can be attributed to non point source of municipal wastes from septic tanks, landfill and agricultural activities in the study area which can be transported by runoff processes. In the all waters samples, nitrate concentrations remained consistently low and in the limits approved by WHO. The results of analysis indicated that the heavy metal concentration for Lead (Pb) and Cadmium (Cd), were mostly below the limits sit by WHO (Table 2, Figure 10). The maximum allowed value of Pb, Cd is 0.05 mg/l and 0.005 mg/l respectively. It is observed that there was no detected Pb and Cd in the waters samples collected from direct precipitation and houses roofs catchments. This can be attributed to no possible sources of lead and cadmium in the study area. Very low concentrations where observed in the waters samples collected from cisterns near asphalt roadway and dams lakes which can be attributed to car and other vehicles products which carried by runoff to the cisterns. The other source may be due to place of cisterns near the roadway and landfill. In this study Fecal

Coli form bacteria, which are an important bacteriological parameter for the different catchment systems, were investigated. The results (Table 2) show that no Fecal Coli forms were detected from the first and fifth waters samples for both direct precipitation and houses roofs. Fecal Coli forms were detected in the samples collected from cisterns asphalts roadway, the dams lakes and open surface (mountain and hills aspect) catchment systems. The finding results revealed that microbiological parameters were affected mainly by the cleanness level of catchment areas and also influenced by the human activates.

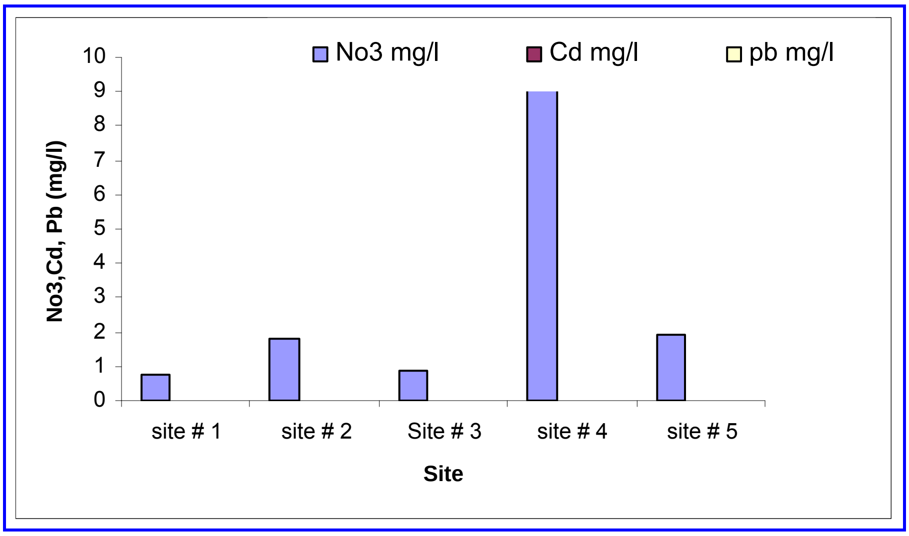

Figure (10) Nitrate, Cadmium and lead in the study area

Conclusion and Recommendations

The present investigations appear that the average yearly rainfall amount received in the study area is favorable for rainwater harvesting systems. According to the annual rainfall totals subjected to study area, large amounts of rainwater can be harvested in the study area and can be used for difference purpose. The quality of harvested rainwater depends upon many factors such as air quality, harvesting system design and maintenance; materials used rainfall intensity, length of time between rainfall events, social context as well as water handling. The principal component analysis revealed that chemicals and microbiological parameters were mainly affected by the cleanness level of catchments and human activities. The results of this study showed the application of an appropriate rainwater harvesting technology can make possible the utilization rainwater as valuable and in many cause necessary water resource. Based on the data presented earlier, the following recommendation is made:

-Building rainwater harvesting systems far away from existing cesspits.
-Building sediment trap basins and cleaning frequently.
-Keeping the catchments areas clean during the rainy season .

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