The influence of different storage tank types on the quality of harvested rainwater In Zliten city, Libya

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Abstract

Rainwater is usually considered a safe and suitable source of potable water; little is done for monitoring the quality of stored rainwater tanks. For this reason, it is very important to evaluate the quality of rainwater collected and, stored in different storage tanks types. In this study, samples of harvested rainwater were collected from three different storage tanks types which are, metal tanks, plastic (PVC), and concrete tanks. The storage tanks types showed statistically significant differences ($p<0.05$) in some quality parameters such as pH, total dissolved solids (TDS), trace and heavy metals. The results of the analyses were compared with valid quality guidelines to evaluate its suitability for domestic uses. The stored rainwater samples tested positive for faecal coliform and the bacteria count were above the permissible limits of World Health Organization (WHO). The trace and heavy metals in the water samples were within the permissible limits of the (WHO) except for copper (Cu) and iron (Fe) concentrations in metal tanks. In this study found well-constructed concrete tanks and Plastic (PVC) tanks are the most suitable storage tanks types. It was concluded that collected rainwater may not be suitable for direct drinking, without treatment, but could be used for other domestic purposes.

Keywords: Rainwater harvesting, storage-tanks, physiochemical, Microbiological.

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1. Introduction

Rainwater is usually considered a safe and suitable source of potable water. Rainwater harvesting is a technology used for collecting and storing rainwater from rooftops, the land surfaces, steep slopes, or rock catchments using simple techniques such as pots, tanks and cisterns (Prinz, 1999, pp151). There are many factors affected on quality of water collected in a rainwater harvesting system, which include, the nature of the catchment system and the roof materials, environmental pollution from industries, automobiles and anthropogenic activities, the presence of birds, dirt, and debris dropping on roofs and rainwater catchments (Taylor et al., 2000, p 336-340) and the type of storage materials for harvested rainwater (Baguma et al.2010, p 3333-3348).

Many studies have contributions of storage tank materials to the microbiological and physicochemical quality of harvested rainwater. Roof surfaces are often as source of contamination for rainwater, storage tanks also have their roles in the harvested rainwater quality, especially for rainwater intended for later use and there by stored for long period of time (Adeniyi and Olabanji, 2005, pp149-166). The leaching of metals from metal tanks was found to be significant in a study carried out, but concrete or plastic tanks did not have any notable impact on the concentration of copper (Cu), lead (Pb) or zinc (Zn) (Hart and White, 2006, pp19-25). The leaching of organic compounds is a concern with plastic tanks (EPA, 2002). Quality of water in storage tanks depends on the source and handling of the storage tanks (Sule et al., 2011,pp3-5). Many studies have concluded that, the chemical contaminants may dissolve during precipitation and leach due to the characteristics of the rainwater system components and storage design. While in other study (Chang et al., 2004, pp307-315) revealed that storage tanks can be a factor in quality improvement of rainwater. (Thomas et al.,2003, pp109-115) indicated to the risk of microbiological contamination of rainwater during collection and storage in the home, and also impact the quality of water. Microorganisms found to be carried by birds and animal vectors include, Cryptosporidium, Giardia, Campylobacter and Salmonella, these microorganisms is known to cause gastroenteritis and other illnesses (Gerba and Smith, 2005, pp42–48). Depending on the tank material, the water is affected differently. This research is justified due to the significant roles played by storage tanks in rainwater harvesting in many areas in Libya, so as to bridge the gap of intermittent water supply.

This study was conducted to the influence of storage tanks types such as metal, plastic (PVC) and concrete on the quality of harvested rainwater. For this reason, harvested rainwater from different storage tanks was analyzed. The samples were analysis for different physicochemical and microbiological water quality to determine the sanitary appraisal of stored rainwater, to arrive at conclusions and provide recommendations on quality management of stored rainwater.

2. Materials and Methods

1.1 Study area and collection of rain water samples

The study area is located in Zliten city, 150Km east of Tripoli Libya within the coordinate latitude of 32°27′50″ (N) and longitude of 14°34′21″ (E). The field research area lies at Afatir region near the coast of Libya. The average annual rainfall in region is 240 millimeters, and the temperature values were in the range of 19 to 29 ºC.

Four locations have been selected in the above named region, in which three predominant storage tanks were identified, namely: Metal, Plastic and Concrete. Four samples are collected of each tank types in March 2014. Sample containers were soaked in acid solution overnight prior to sample collection, followed by proper rinsing with distilled-deionized water and the stored rainwater, before the samples to be analyzed were collected from the storage tanks. Samples for microbial analysis were kept with a sterilized capped bottle to arrest the further growth of bacterial prior to analysis. They were then taking to the laboratory for microbial and physicochemical analysis.

2.2 Physicochemical, Heavy metals and Bacteriological analysis

The total dissolved solids was measured using a JENWAY 3540 Bench combined pH/TDS meter (UK). Turbidity was measured using a portable turbidity meter WAG-WE30210 (UK). Nitrate was determined by the Brucine method (Ademoroti, 1996, p420). Chloride measured using titrimetric method. The determination of heavy metals was carried out using the flame atomic absorption spectrophotometer Perkin-Elmer A Analyst 200 (USA) as described in standard methods (APHA, 1998).

Total and faecal coliform bacteria tests are used to assess bacteriological water quality. These tests are used to index hygienic quality because total and faecal coliform are usually associated with faecal contamination and thus, their numbers reflect the degree of pathogenic risks. Bacteriological parameters including total coliform (TC), total bacterial count (TBC) and Confirmatory Faecal Coliform test were conducted using the multiple tube fermentation technique (MPN method) using Lauryl tryptose broth for the Presumptive Phase of total and faecal coliforms and Brilliant green lactose bile broth and EC Medium for the Confirmation Phases of Total coliform and Faecal coliform. The water quality analysis was carried out in accordance with the Standard Methods (APHA, 1998).

2.3 Statistical Analysis

Results were processed and analyzed using the software (SPSS) statistical analysis package for Windows. Data is reported as mean ± standard deviation. The parameters were tested for any significant difference amongst the storage tanks types.

1.4 Results and Discussion

The results of trace and heavy metals concentrations are illustrated in (Table1). The mean concentration of Calcium (Ca) was 2.99 ±1.62, 3.17 ± 1.1 and 5.02 ± 0.53 mg/l in metal, plastic (PVC) and concrete tanks, respectively. Mean values of Magnesium (Mg) concentrations found in metal, plastic and concrete tanks were 1.83 ±0.44, 1.12 ±0.15 and 2.36 ± 0.64 mg/l, respectively. Aluminum (Al) only detected in samples which collected from metal tanks was 0.03 ±0.02 mg/l. The mean concentration of Iron (Fe) were 1.23 ±0.1 mg/l, in metal tanks, 0.74 ± 0.18 mg/l, in plastic tanks and 0.96 ± 0.57 mg/l, in concrete tanks. Copper (Cu) and Zinc (Zn) detected in metal tanks had mean values of 1.09 ±0.02 and 0.80 ± 0.15 mg/l. Plastic (PVC) tanks mean values of 0.68 ±0.33 and o.41 ±0.1 mg/l, respectively.

In concrete tanks showed mean values of 0.27±0.18 and 0.64±0.29 mg/l for Cu and Zn respectively. Concentrations of Lead (Pb) and Cadmium (Cd) were not detected in all samples analysis.

Table 1 (Mean ±SD) values of trace and heavy metals concentrations of rainwater in different tanks types.

Parameter in (mg/l)	Metal	Plastic (PVC)	Concrete	WHO limits*
Calcium	± 1.62 2.99	± 1.10 3.17	± 0.53 5.02	75
Magnesium	± 0.44 1.83	± 0.15 1.12	± 0.64 2.36	50
Iron	± 0.10 1.23	± 0.18 0.74	± 0.57 0.96	0.3
Aluminum	± 0.02 0.03	ND	ND	---
Copper	± 0.02 1.09	± 0.33 0.68	± 0.18 0.27	1.0
Zinc	± 0.15 0.80	± 0.10 41.	± 0.29 0.64	5.0
Lead	ND	ND	ND	0.05
Cadmium	ND	ND	ND	0.003

***Source: (WHO, 1989)**

Based on physiochemical analysis results, illustrated in(Table2), the mean values of temperature was 26.3° C for metal tanks. And In plastic (PVC) , concrete tanks were 24.6° and 22.5° C respectively.

For pH and total dissolved solids (TDS), mean value of metal tanks waters were within 6.73 and 276 mg/l, respectively. In plastic (PVC) tanks water were 7.17 and 321mg/l, and in concrete tanks water the mean values were 7.84 and 483 mg/l for pH and TDS, respectively. Turbidity mean values were 1.45, 1.18 and 1.88 NTU in metal, plastic and concrete tanks, respectively. The NO_3 and chloride mean values were 1.94 and 0.51 mg/l in metal tanks, respectively. Plastic (PVC) tanks mean values 1.51 and 0.32 mg/l for NO_3 and chloride, respectively. While in concrete tanks mean values for NO_3 was 2.21 mg/l, for chloride was 0.19 mg/l.

According to bacteriology analysis results (Table3) shows that in concrete tanks, total bacteria counts and total coliform were lowest mean values of 3.4 ±0.28 MPN/100ml and 2.6 ±0.41 CFU/100ml, respectively. While in metal tanks having mean total bacteria counts values of (6.3 ±1.0)MPN/100ml. Plastic (PVC) tanks mean values were highest in total bacteria counts and total coliform, (10.1±0.74) MPN/100ml and (5.2±1.25) CFU/100ml, respectively.

Table 2. (Mean ±SD) Values of Physicochemical parameters of stored rainwater samples in different tanks types

Parameter	Metal	Plastic (PVC)	Concrete	WHO limits*
Temperature (°C)	± 3.78 26.3	± 4.16 24.6	± 1.53 22.5	23
pH	± 0.15 6.13	± 0.65 7.17	± 0.62 7.81	8.5—6.5
TDS (mg/l)	276±106	± 63 321	± 67 483	500
Turbidity (NTU)	± 0.68 1.45	± 0.38 1.18	± 0.47 1.88	5
NO3 (mg/l)	± 0.74 1.94	± 0.50 1.51	± 0.50 1.51	10
Chloride (mg/l)	± 0.28 0.51	± 0.10 0.32	± 0.10 0.19	----

***Source: (WHO, 1989).**

The storage tanks types showed statistically significant differences ($P<0.05$) for quality parameters such as pH, TDS, trace and heavy metals determined in the stored rainwater samples. The difference in the values of parameters of different storage tanks types shows the effect of types of tanks on the stored rainwater.

Table3 .(Mean ±SD) values of Bacteria count in(MPN/100ml)

Parameter	Metal	Plastic (PVC)	Concrete	WHO limits*
Total Bacteria count (MPN/100ml)	± 1.0 6.3	± 0.74 10.1	± 0.28 3.4	0
Total Coliform (CFU/100ml)	± 0.93 3.1	± 1.25 5.2	± 0.41 2.6	0

PH in metal tanks was lowest with a mean value of (6.13±0.15), while was high with a mean value of (7.81±0.62) in the concrete tanks, this may be attributed to the leaching of calcium carbonate from the concrete tank walls (Sazakli et al., 2007, pp2039–2047). The pH of concrete and plastic (PVC) tanks was within the permissible limits of the World Health Organization (WHO) drinking water quality guidelines. Total dissolved solids (TDS) was different significantly ($P<0.05$) between metal and concrete tanks and also between plastic and concrete tanks. Turbidity mean values was no significant different ($P>0.05$) in storage tanks types, this may be due to the fact that suspended solids tend to settle at bottom of the tanks (Amin and Alazba, 2011, pp1054-1064). Low values of turbidity were determined in all samples from different tanks types. This conforms to the acceptable guidelines for potable water quality of (WHO).

The mean values of NO_3 and chlorides from all storage tanks types show no significant difference ($P>0.05$). This indicated no contribution to the parameters from the storage tanks types may be due to different sample locations (Radaideh et al., 2009, pp26-31). Ca and Mg concentrations values were highest in the concrete tanks; this may be attributed to the calcium carbonate as the constituent of cement used in concrete tanks. While Ca and Mg concentration were no significant difference in metal and plastic tanks. In metal tanks were copper, iron and zinc high levels. The mean values of Cu, Fe and Zn concentrations in metal tanks exceeded the recommended limits of (WHO). This can be attributed to the low pH of stored rainwater in metal tanks which increases the potentials for the leaching of metals from the metal tank. The different between the concentration of Cu, Fe and Zn were significant ($P<0.05$) between plastic (PVC) and metal tanks, also between concrete and metal tanks, this agree with the findings of (Despins et al., 2009, pp117 -134).

The concentration levels of Cu, Fe and Zn were no significant difference (P>0.05) in plastic and concrete tanks. Iron and copper exceeded the recommended limits of WHO in metal tanks, while in concrete and plastic tanks were within the permissible limits of WHO for Zn and Cu.

The concentration levels of TDS and turbidity are within the permissible limits of (WHO). The results which determined in stored rainwater from different storage tanks in this study were within the permissible limits of WHO, except for iron and copper in metal tanks, this consistent with the findings of (Ziadat 2005, pp634-638). Concrete and plastic tanks have no notable impact on the concentrations of heavy metals in stored rainwater.

The lowest concentration of microbial contamination in the stored rain water samples which collected from the concrete tanks. While high concentrations of microbial contamination were in samples from plastic (PVC) tanks. Concentrations of microbial contamination was different significantly (P<0.05) in the storage tanks types. The difference in the microbial concentration between storage tanks types, may be due to the pH variations and temperature of the stored rainwater (Zhu et al., 2004, pp487–505). There are many studies indicated to some correlation between pH and growth of coliforms in rainwater tanks (Bannister et al., 1997). In concrete tanks was concentration of total coliforms lowest which have the highest mean pH values in this study, not observed in metal tanks with pH values lower than that of plastic (PVC) tanks and lowest in all storage tanks types.

The effect of temperature was found to have a significant difference in concentrations of microorganisms in stored rainwater in different storage tanks types (Amin and Han, 2011a, pp1804-1813) . Metal tanks has higher temperature than the plastic (PVC) tanks and hence the varying microorganisms concentration. Observed the effect of pH on microbial concentration impacted more than the temperature for which no significant difference (P<0.05). This study agrees with other studies. Results analysis showed that the rainwater stored in the selected tanks was polluted and unsuitable for drinking. The total coliform of rainwater in these storage tanks types is an indication of faecal contamination. The microbiological and chemical quality of tank stored rainwater is impacted directly by various catchment systems and roofs (Zhu et al., 2004, pp487–505).

The presence of faecal coliform in rain water samples which collected from storage tanks. This possess great danger to human health (Namrata and Han, 2005, p65). Water is unfit for drinking if there are any coliform bacteria (Edema et al., 2001, pp57- 61). The incidence of water borne diseases can therefore be attributed to untreated or poorly treated stored rainwater that contains pathogens (WHO, 1989).

3. Conclusion and Recommendations

The physicochemical properties of harvesting rainwater were most influenced by the different types of storage tanks and their component materials. Significant differences were also observed in some physicochemical quality parameters between metal and concrete tanks. The microbiological quality of the stored rainwater depends on the handling the

various catchment systems and roofs and storage patterns by users of the rainwater. Influence was significantly different for the types of storage tanks on the microbial index of the stored rainwater and the concentration of the microorganisms differed significantly according to storage tank type. The results of this study are conformed to a previous studies, which reported the microbiological contamination of harvested rainwater. However microbiological quantities of the stored rainwater samples were above the permissible limit of the World Health Organization drinking water quality guidelines. Meanwhile the physicochemical parameters were within the permissible limit of (WHO) water quality guidelines, except for the levels of Cu and Fe in metal tanks that exceeded the permissible limits of (WHO).

In order to get good quality of harvested rainwater the current study highly recommend to wash the catchment roofs and runoff before starting the rain season.

Current investigation established that, the Plastic (PVC) tanks and well-constructed concrete tanks are the most suitable device to store the rainwater.. Adding some disinfecting agents such as chlorine might help in reducing the risk of biological contamination.

Finally, rainwater samples should be collected and analyzed on regular basis from the storage tanks before using the water for drinking purposes.

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