Qualitative Assessment of Rain Water Harvested from Roof Top Catchments: Case Study of Embakasi, Nairobi County

Joanne N. Gakungu

Abstract- Rain Water Harvesting (RWH), in its broadest sense, is a technology used for collecting and storing rainwater for human use from rooftops, land surfaces or rock catchments using simple techniques such as jars and pots as well as engineered techniques [6]. This paper aims to assess the quality of harvested roof-top rainwater from three different roofing materials in Embakasi area in Nairobi County. The roofing materials are corrugated iron sheets, clay tiles and concrete tiles. Chemical analysis included testing for iron, copper, zinc, fluoride, aluminium, lead, zinc, manganese, sodium and potassium. Physical analysis of pH and turbidity was carried out as well as bacteriological analysis for Escherichia coli (E. Coli) and total coliform. All the rainwater samples results for the samples taken after first run-off, were within the guidelines for both chemical and microbiological parameters established by the World Health Organization [10]. On the contrary, turbidity levels were higher than the maximum allowable concentration for drinking purposes hence the need to allow the first run –off during any rainfall event. As revealed from the analysis, all the samples require some level of treatment e.g. chlorination in order to ensure they meet regulatory standards for drinking water. However all water samples are quite safe for all other domestic uses including laundry, toilet flushing, bathing and other general cleaning. The integrated management must consist of regular cleaning of the catchment areas and the storage tanks and the employment of automated mechanical systems for discarding the first portion of each rainfall. The use of clay roofing tiles is preferable but due to cost, corrugated iron sheets maybe adopted.

Key words: *Rain Water Harvesting, Roofing Materials, Water Quality*

I. INTRODUCTION

Water quality degradation, soil erosion, deforestation and urbanization greatly compromise the quality and availability of surface and groundwater resources [2] hence threatening sources of potable water supply .The problem of water scarcity is strongly connected to the problem of water quality. Surface and ground water resources in Kenya are increasingly becoming polluted from sources caused by the activities of agriculture, urbanization, industry, leachate from mining and garbage dumps, sediments, salts, eutrophication of lakes, infiltration of fertilizer and pesticide residues, all of which increase catchment degradation. Lack of effective pollution control compromises the quality of water, posing potential health hazards, increasing treatment and maintenance costs, and affecting inland, estuarine and coastal aquatic ecosystems.

Rainwater harvesting, in its broadest sense, is a technology used for collecting and storing rainwater for human use from rooftops, land surfaces or rock catchments using simple techniques such as jars and pots as well as engineered techniques [6]. A typical rainwater harvesting model comprises of components for transporting rainwater through pipes or drains, filtration, and tanks for storage of harvested water.

Even though such a solution seems to be so attractive from an ecological point of view, potential health risks from ingestion of harvested rainwater related to microbiological and chemical contaminants should be taken into account. Contamination by chemical pollutants may arise from a variety of materials with which the rain water comes into contact starting from the atmosphere. Rain water could dissolve gases and wash off chemicals from contacting dust particles and roof materials. It could dissolve the metals or derived chemicals. Elution of chemicals from the walls is also possible from the storage tank.Heavy metals such as iron, aluminium and zinc have been detected in rooftop-harvested rainwater [8], [7], [11]. Although several additional studies in other countries have examined the effect of roofing material on harvested rainwater quality, domestic studies of the effect of roofing material on harvested rainwater quality might be more useful because roofing materials, coatings, and building practices vary globally.

There is a general community perception that rainwater is safe to drink without having to undergo prior treatment. This is partially supported by limited epidemiological studies [5]. Additionally, a previous research study has reported that RWH quality is generally acceptable for drinking and household use [4] and poses no increased risk of gastrointestinal illnesses when compared with mains water [5]. In contrast, a number of studies have reported the presence of specific pathogens, including opportunistic pathogens in RWH [1], [3], [9]. Waterborne diseases remain a cause for concern in developing countries.

The main objective of the study was to examine the effect of roofing materials on the chemical and bacteriological quality of rainwater harvested for domestic use. This paper also provides guidelines for the selection of roofing materials that will aid in the harvesting of clean rainwater.

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II. MATERIALS & METHODS

A. Description of the Study Area

Embakasi is considered part of Nairobi's Eastlands area, lying 15km to the south-east of Nairobi province. Jomo Kenyatta International Airport, the main airport of Nairobi is located in Embakasi. Embakasi Division is divided into following locations: Dandora, Embakasi, Kariobangi South, Kayole, Mukuru kwa Njenga, Njiru, Ruai and Umoja. As a residential estate it houses mostly middle to lower income citizens. Most of the residential houses are four to eight-storey flats. A map of the study area is shown below

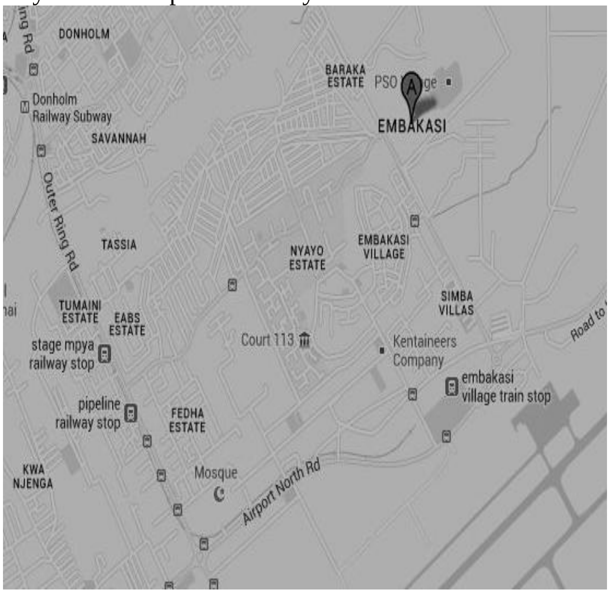

Figure 1 Map of Embakasi
Source: Google maps

B. Sampling

To compare rainwater contamination in different locations, rain water samples were collected in four sampling sites (see Figure 1) namely Fedha Estate, Tassia Estate, Nyayo Estate and Baraka Estate. These locations were chosen as they represent a sample of high density residential areas within Embakasi area. Harvested rain water samples were collected via roof-top run made of three selected roofing sheet materials namely corrugated iron sheets, clay tiles and concrete tiles. The samples were analyzed for physical, chemical and bacteriological content using standard methods for water examination at the NCWSC Kabete Laboratories. Samples were collected during the months of April and May, 2013 during the long season of rains.

C. Questionnaire Survey

A questionnaire survey was carried out in Embakasi area to understand the current water supply situation, the problems the residents face as well as their attitude towards rain water harvesting. Questions were asked in the two national languages, Kiswahili and English. The survey comprised of both open ended and closed ended questions, and the interview conduction was an interactive process. Daily activities of the study population and timing of different activities were also keenly observed so as to know the time at which respondents can be approached for data collection with minimum possibility of disturbing their routine activities. A total of three hundred correspondents were interviewed. As shown in the table below, 70% of the correspondents live in houses whose roofing material is corrugated iron sheets.

Table I Comparison of roofing materials in a survey

Roof Material	No. of correspondents participating in survey
Corrugated iron sheets	210
Clay Tiles	40
Concrete Tiles	50

III. RESULTS AND DISCUSSION

A. Chemical Analysis

Chemical analysis was conducted by the NCWSC according to the standard methods for the examination of water by the Kenya Standards for Drinking Water – KS459-2007, American Public Association, American Water Works Association and the Water Pollution Federation. The corrugated iron sheets samples had higher average total iron and zinc concentrations than the other two roofing materials.

The source of this iron and zinc may be the corrugated iron sheets itself and atmospheric deposition. The corrugated iron sheets samples also had higher average total aluminium concentrations than the other two roofing materials. Given that corrugated iron sheets are composed of zinc and iron, it may be that the aluminium levels found in this study originated in atmospheric dust and dry deposition. None of the roofing materials were significantly different from each other when analysis of the fluoride and manganese levels was done. This suggests that roofing materials were unlikely to be the source of fluoride and manganese deposition. Potassium and sodium levels were lowest in clay tiles possibly as result of its porous nature, these metals were trapped in the clay tiles. Lead and copper were not detected in any of the roofing materials. The results of the chemical analysis are shown below.

Table II Sample Chemical Results after First Draw
Source: NCWSC

Parameters	**RESULTS (mg/l)**				**WHO GUIDELINE (mg/l)**
	Baraka Estate (Concrete tiles)	**Fedha Estate** (Corrugated iron sheets)	**Nyayo Estate** (Corrugated iron sheets)	**Tumaini Estate** (Clay tiles)	
FLOURIDE (F-)	0.81	0.82	0.85	0.81	1.5
LEAD (Pb)	N/D	N/D	N/D	N/D	0.01
ZINC (Zn)	0.1052	0.3049	0.3059	0.1032	5.0
IRON (Fe)	0.0329	0.0527	0.0530	0.0324	0.3
MANGANESE (Mn)	0.0603	0.0604	0.0605	0.0603	0.1
SODIUM	8.1	8.3	7.8	4.1	200
POTASSIUM (K)	4.7	4.8	4.7	1.8	12
ALUMINIUM (Al)	0.006	0.014	0.014	0.006	0.1
COPPER (CU)	N/D	N/D	N/D	N/D	0.1

B. Bacteriological and Physical Analysis

Bacteriological and physical analysis was conducted by the NCWSC according to the same standard methods for the examination of water highlighted above. The samples were examined for the two widely used bacterial indicators, namely total coliforms and Escherichia coli (E coli). The average pH of the harvested rainwater from all of the three roof types was in the near-neutral range (pH 7.0 to 7.4). The pH of the samples taken from the concrete tile and clay tile roofs was higher than that from the corrugated iron sheets. The rainwater harvested from the concrete tile roof had the highest Ph level, with an average pH of 7.4, probably due to the reaction of pure rainwater (pH 4.8 to 5.9) to the alkaline components of the tiles. The WHO guideline for non-potable urban water reuse is that the turbidity should not exceed 5 mg/L and for drinking water, the turbidity should not exceed 1mg/L. The levels found in the harvested rainwater from all the three roofs in this study exceeded 1 mg/L. This shows that all harvested rain water needs some form of disinfection by chlorine before use. However, all water samples are quite safe for all other domestic uses including laundry, toilet flushing, bathing and other general cleaning. The results of the physical and bacteriological analysis are shown in tables 2

Table III Sample Bacteriological and Physical Results after First Draw
Source: NCWSC

Parameters	**RESULTS (mg/l)**				**WHO GUIDELINE**
	Baraka Estate (Concrete tiles)	**Fedha Estate** (Corrugated iron sheets)	**Nyayo Estate** (Corrugated iron sheets)	**Tumaini Estate** (Clay tiles)	
MPN of EColi	Nil	Nil	Nil	Nil	Nil (counts / 100 ml)
MPN of Coliform	Nil	Nil	Nil	Nil	Nil (counts / 100 ml)
pH	7.4	7.02	7.05	7.3	6.5-8.5
Colour	4.73	2.23	2.25	4.68	<15 TCU
Turbidity	3.0	3.0	2.9	2.9	5 NTU for non-potable water and 1 NTU for potable

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IV. CONCLUSION

Kenya needs to make a major paradigm shift – from focus on the extraction and distribution of water to conservation and development of the water resources. This means that the institutions/departments dealing with water resources development need to be resourced accordingly, and policies that conserve water such as rain water harvesting, water re-use and catchments protection need to be put on the forefront of national development efforts. Furthermore, the local government should launch awareness campaigns highlighting the importance of rain water harvesting.

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