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QUALITY DETERMINATIONS OF HARVESTED RAINWATER IN SELECTED STORAGE TANKS IN OWERRI , SOUTH-EASTERN NIGERIA

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ABSTRACT: *Despite the practice of domestic rainwater harvesting (DRWH)for domestic purposes , little or no effort has been made toward monitoring the quality of stored rainwater in storage tanks in Owerri, Imo tanks to ascertain their impacts on domestic harvested rainwater quality (DHRWQ). During the study, samples of harvested rainwater were collected from surface GP tank from FECOLART and underground concrete tank from private dwelling in Ubomiri for physiochemical and bacteriological compositions using standard methods . The results of the analyses were compared with water quality guidelines of World Health Organization (W.H.O) to evaluate its suitability for potable and domestic purposes. From the results, some of physical parameters like colour in surface tank without cover recorded 750 Pt/co, odour and taste objectionable, appearance greenish and turbidity 177 NTU all above the World Health Organization (WHO) stipulated standards for drinking water , with underground tank with cover lower than WHO standard. . Results of the chemical compositions recorded that rainwater stored in both tanks were slightly acidic with the mean of pH6.0, surface tank recorded iron with the value of 2.45mg/l-^{1}, and manganese values in both tanks exceeded the 0.10mg/l-^{1} World Health Organization (WHO) stipulated for drinking water. For bacteriological analyses, except the underground tank the recorded zero total coliform (TC), surface and underground tanks recorded highest values of bacterial the exceeded the WHO standards stipulated for potable water. The results further explained that surface tank without cover was more polluted than underground tank with cover in terms of physiochemical and microbiological compositions. From the results, it is observed that stored rainwater may not be suitable for direct drinking, without treatment, but could be used for other domestic purposes, which therefore called for rainwater treatment, maintenance and operational strategies(O&M*).

KEYWORDS: Physical, chemical, Bacteriological Harvested Rainwater , Storage tanks.

INTRODUCTION

Background of the Study

Water, after air, is the most essential commodity to the survival of life. Human life depends to a large extent, on water. It is used for an array of activities; chief among these being for drinking, food preparation, as well as for sanitation purposes. Inasmuch as safe drinking water is essential to health, a community lacking a good quality of this commodity will be saddled with a lot of health problems which could otherwise be avoided (Miller, 1997; WHO 2002). Rainwater harvesting (RWH) is any human activity involving collection and storage of

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rainwater in some natural or artificial container either for immediate use or use before the onset of the next season for domestic, agricultural, industrial and environmental purposes (Kun et al., 2004; Mati et al., 2005). Rainwater is an important source of fresh water especially for those who live in rural areas (Jamal et al, 2009; Ubuoh, 2012). Abbas, et al (1993), Meera, et al., (2006), Vazquez, et al., (2003) and Zunckel et.al (2003), found that there is a strong correlation between the present of contaminants in the catchments area and rainwater quality. Concerning the physicochemical and microbiological determinants, a study which was conducted in New Zealand demonstrated that roof-collected rainwater systems provide potable supplies of relatively poor physicochemical and microbiological quality (Greg, et al., 2001). This was studied and confirmed by Achadu et al (2013) who opined that despite the high level of dependence on rainwater for drinking and domestic uses due to lack of public pipe borne water supplies, little is done for monitoring the quality of stored rainwater in cisterns, tanks and reservoirs receiving rainwater.

One of the primary areas of concern regarding the use of rainwater, for either non-potable or potable applications, is quality. The quality of water collected in a rainwater harvesting system is affected by many factors. which include: the nature of the catchment system and the roof materials, environmental pollution from industries, automobiles and anthropogenic activities, the presence of dirts, debris and birds or rodents dropping on roofs and rainwater catchments (Forster,1998, Taylor et al, 2000; Ubuoh, 2012) and the type of storage materials for harvested rainwater. Catchment material, storage material and treatment (Adeniyi and Olabanji (2005), are three design considerations that can be optimized to maximize rainwater quality. In recent times rainwater is stored both in surface and underground tanks with or without covers (UNEP,1991 Many studies have also raised the contributions of storage tank materials to the microbiological and physicochemical quality of harvested rainwater.

The risk of microbiological contamination of rainwater during collection and storage in the home has long been recognized (Lye,2002; Thomas et al,2003). The water storage system can also impact the quality of water (Lye,2002). Microorganisms found to be carried by birds and animal vectors include, Cryptosporidium, Giardia, Campylobacter and Salmonella spp (Gerba and Smith,2005). Each of these microorganisms is known to cause gastroenteritis and other illnesses (Gerba and Smith,2005).

In Mbaitoli Local Government Area of Imo State of Nigeria, the people use rainwater stored in tanks without considering its quality and the health implications. There is a possibility of water-borne diseases arising from physical , chemical and microbial contamination. Therefore, the focus of this study is to assess the quality of rainwater stored in both surface and groundwater tanks in the LGA for domestic use bearing in mind the physical, chemical and bacteriological characteristics as well as health considerations for human survival in the study locations in particular and the State in general.

Study Area:

Mbaitoli L. G.A. is Imo State of Nigeria. It has an area of 204 km² and a population of 237,555 at the 2006 census, although the state government claims 234 km² and a 2004 population of 255,000. The rainy season begins in April and lasts until October with annual rainfall varying from 1,500mm to 2,200mm (60 to 80 inches). An average annual temperature above 20 °C (68.0 °F) creates an annual relative humidity of 75%. With humidity reaching 90% in the rainy season. The dry season experiences two months of Harmattan from late December to late February. The hottest months are between January and March . It has population of 237,474,

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with 31 autonomous communities in which 10 were randomly picked for the study (Ubuoh et al2013),

Selection of the Rainwater Harvesting Sampling Location

The study area is made of two randomly selected study locations viz:

(i) Federal College of Land Resources Technology (FECOLART) at the temporary site at Egbeada near Akwakuma in Owerri where there are surface tanks (GP) without covers.

(ii) Ubomiri village which has the concrete underground tanks with cover.

Sampling Rainwater Technique in the study locations

These sampled sites were randomly selected based on where they were found in the study area. Stored rainwater was collected from surface and underground tanks in a well labelled 4-litre plastic containers. These containers were thoroughly washed and filled with 4% hydrochloric acid (HCL) and rinsed with the sampled rainwater and left to dry under a control condition to avoid recontamination of the container. Thereafter, each container was washed again with tank- stored rainwater to be sampled and filled with the harvested rainwater sample for physicochemical analyses. For bacteriological analysis, rainwater samples were collected from surface and underground tanks with 4-litres plastic containers that had been sterilized in an autoclave at 121^{o}C for 30 minutes. Rainwater samples collected for physiochemical and bacteriological analyses were transported under controlled temperature in a cooler and refrigerated at 4^{o}C in the chemistry laboratory till all the parameters were analyzed at Imo State Environmental Protection Agency (ISEPA) Owerri.

Analysis of the Sampled Rainwater for Physical Characteristics:

The physical parameters determined include temperature (^{o}C), electrical conductivity (μ/Scm), total dissolved solids(TDS) (mg/l), colour (Pt/co), odour, and taste, appearance and turbidity (NTU) The electrical conductivity, total dissolved solids was measured using a JENWAY 3540 Bench combined pH/conductivity/TDS meter (UK). Turbidity was measured using a potable turbidity meter WAG-WE30210 (UK).

Analysis of the Sampled Rainwater for chemical Characteristics:

Chemical parameters considered include pH. Nitrate (N_2) (mg/l), sulphate (SO_4) (mg/l), iron (Fe) (mg/l), chloride (Cl_2) (mg/l), copper (Cu) (mg/l) and manganese (Mn) (mg/l). Total acidity and chloride measured using titrimetric methods. Sulphate was determined by turbidimetric method and Nitrate was determined by the Brucine method [Ademoroti,1996]. The determination of heavy metals was carried out using the flame atomic absorption spectrophotometer Perkin-Elmer A Analyst 200 (USA) described by APHA's Standard Methods for the Examination of Water and Wastewater (1998) (APHA,1998).

Analysis of the Sampled Rainwater for bacteriological Characteristics:

All bacteriological parameters including total coliform (TC), total bacteria count (TBC) 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

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coliform. The water quality analysis was carried out in accordance with the APHA's Standard Methods for the Examination of Water and Wastewater (1998).

RESULTS AND DISCUSSION

The results of the physical, chemical and bacteriological parameters of the stored rainwater in surface and underground tanks are shown in Tables 1to3, respectively. The results of these parameters in the harvested rainwater in different were compared with World Health Organization Standards (WHO) for drinking water.

Table 1: Physical Characteristics of Rainwater Stored in Surface Tank in FECOLART and Underground Tank in Ubomiri and Comparison with the WHO Minimum Standards for Drinking Water (Laboratory Analysis 2015).

Physical Parameters	Unit	Tanks		Mean	WHO Standards
		Surface	Underground		
Temperature	**°C**	28.00	28.00	28.0	-
Conductivity	**µ/Scm**	29.6	72.00	50.8	100
TDS	**mg/l**	15.00	36.00	25.5	250.00
TSS	**mg/l**	99.00	2.00	50.5	250.00
Colour	**Pt/co**	750.00	13	381.5	15.0
Odour	**-**	Objectionable	Unobjectionable	-	Unobjectionable
Taste	**-**	Objectionable	Unobjectionable	-	Unobjectionable
Appearance	**-**	Greenish	Clear	-	Clear
Turbidity	**NTU**	177	5	91	50.00

Source : Author's

Table 1 indicate that temperature recorded in the two tanks was with the mean value of 28°C and conductivity ranged between 29.6 – 72.00 µ/Scm with the underground having the highest value of dissolved salt than surface tank. In the surface tank, all other physical parameters of rainwater stored conformed with the WHO minimum standards except colour with 750.00 Pt/co, odour and taste (objectionable),appearance (greenish), and turbidity recorded 177 NTU, which exceeded the limit stipulated by WHO STD for potable water. In the underground tank, all the physical parameters were lower than WHO limits for potable water while odour and taste were unobjectionable with a clear appearance**.** The results are consistent with the finding of Ubuoh (2011)who observed the objectionable rainwater quality in terms of physical compositions in southeastern parts of Akwa Ibom State of Nigeria due to incessant gas flaring and decayed organic matter from the rooftops.

Table 2: Chemical Characteristics of Rainwater Stored in Surface Tank in FECOLART and Underground Tank in Ubomiri and Comparison with the WHO Minimum Standards for Drinking Water (Laboratory Analysis , 2015).

Chemical Parameters	Unit	Tanks		Mean	WHO Standards
		Surface	Underground		
pH	**-**	5.8	7.	6.0	6.5-8.5
Nitrate	**mg/l**	2.4	0.82	1.61	4.00
Sulphate	**mg/l**	6.04	1.2	3.62	250.00
Iron	**mg/l**	2.45	0.15	1.3	0.3
Chloride	**mg/l**	8.2	2.4	5.3	250
Copper	**mg/l**	0.01	0.01	0.1	1.0
Manganese	**mg/l**	0.30	0.34	0.27	0.10

Accordingly, the results of the chemical characteristics in Table 2 show that rainwater in the two randomly sampled tanks recorded the mean value of pH 6.4 with underground tank showing neutral (pH7.0) within the limit, while surface tank below neutral (pH6.10)but all fall within WHO standard for drinking. Apart from the high concentrations of iron with the value of 2.45mg/l and manganese with 0.30mg/l in the surface tank, other parameters in the surface tank were below the WHO minimum standards for potable water. In the underground tank the concentrations of iron (0.15mg/l) and manganese (0.34mg/l) were above WHO minimum standards for potable water.

Table 3:Bacteriological Characteristics of Rainwater Stored in Surface Tank in FECOLART and Underground Tank in Ubomiri and Comparison with the WHO Minimum Standards for Drinking Water (Laboratory Analysis ,2015).

Bacteriological Parameters	Unit	Tanks		Mean	WHO Standards
		Surface	Underground		
Total Coliform (TC	**CFU/100 ml**	20	None	20	2
Total Variable Bacteria(TVB)	**UF C/100 ml**	46	20	33	10
Heterotrophic Plate Count (HPC)	**CFU/100 ml**	6	3	4.5	Not available

Nearly all studies used total coliforms, faecal coliforms or E. coli as an indicator of faecal contamination, reflecting available water testing technology in most developing countries. Of these indicator bacteria, E. coli are regarded as the most reliable measure of public health risks in drinking water (Edberg et al. 2000). Total coliforms can originate from decaying vegetation in tropical areas and so do not necessarily indicate the presence of pathogens in water. Similarly, faecal coliforms are now often referred to as ‘thermo-tolerant’ coliforms because many may be non- faecal in origin. In our analysis, the most useful indicator of faecal contamination in point-of-use water, E. coli, was thus the least predictable.

Regarding bacteriological constituents in the harvested rainwater stored in tanks as indicated in Table 3, the surface tank recorded a total coliform (TC) value of 20 CFU , above the WHO minimum standards . Also, in the surface tank, total variable bacteria (TVB) was 46 CFU and

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heterotrophic plate count (HPC) recorded 6 CFU. The underground tanks recorded zero TC, TVB 20 CFU, and HPC 3 CFU. In both tanks , the overall means were TC 20 CFU, TVB 33 CFU both above the stipulated WHO minimum standards for drinking water and HPC with the mean value of 4.5 CFU with no stipulated standard . Currently, the Canadian guidelines recommend that HPC levels should not exceed 500 CFU/ml (This observation is supported by intervention studies, which have found that covered vessels reduce faecal and total coliform counts in stored water by 50% (Chidavaenzi et al. 1998; Mazengia et al. 2002).

Discussion

Water for human consumption should be colourless, tasteless, odourless and free of turbidity and must be free of chemicals and should not contain any microorganisms known to be pathogenic capable of causing disease—or any bacteria indicative of faecal pollution(Ubuoh, 2011). Reverse is the case in this study where storage tanks especially surface tank is heavily polluted. The temperature, conductivity, TDS, and TSS in FECOLART campus and Ubomiri village water tanks are within the WHO acceptable standard for drinking water. In the surface tank, the colour and odour which were above the minimum WHO standards were suspected to be as a result of invasion of algea or other biotic compounds as the tank has no cover. The colour and taste were objectionable with greenish appearance. Colour is usually due to the presence of decaying organic material or inorganic contaminants such as iron, copper, or manganese **(**www.safewater.org). In the covered underground tank, odour and taste were not objectionable and sampled rainwater recorded a clear appearance.

Odour in water is often associated with the present of organic and chemical such as algar and chlorine (Airiatu, 2003). High concentration of turbidity in the surface tank is linked to the presence of clay, silt, organic matter, and microscopic organisms (Koplan et al, 1978). The turbidity in a surface tank with no cover was suspected to be mainly as a result of fallen leaves, slime and other organic matter from rooftops.

Rainwater sampled from the tanks were slightly acidic, possibly due to dissolution of carbondioxide in rainwater leading to the formation of carbonic acid (H2CO3) (equivalently $OC(OH)_2$) (Duggal, 2004). When carbon dioxide dissolves in water it exists in chemical equilibrium producing carbonic acid (Greenwood et al, 1997):

$$CO_2 + H_2O \rightleftharpoons H_2CO \text{.............................. (Equation 1)}$$

Iron causes reddish-brown stains on laundry, porcelain, dishes, utensils, glassware, sinks, fixtures and concrete. Manganese causes brownish-black stains on the same materials.(Greenwood et al, 1997). The presence of Fe and Mn could have promoted the growth of certain organisms causing an unpleasant taste, odour and colour and produced rusk on fabric and plumbing fixtures which could cause health risk to human beings. The presence of bacteria and some other microorganisms may result from the contamination of the water catch facilities and storage tanks by wild birds, domestic animals, or human beings in particular (Gumbo, 1985; NHMRC, 1996, Edwards and Keller, 1994), Such is a potential source of human illness (Simmons et al, 2001). The presence of organic matter in water and its ingestion can result in its accumulation in the human body which may ultimately cause nervous system problems and kidney disorder (NHMRC, 1996).

The most important source of manganese in the atmosphere results from the air erosion of dusts or soils. Recently the EPA has indicated that there is a health concern with high levels of manganese in drinking water. There is evidence to suggest that children exposed to high levels of manganese from environmental sources (airborne, drinking water, dietary) may develop a variety of adverse developmental effects, particularly neurological effects (as discussed above). Many studies suggest that children exposed to particularly high levels of manganese over a long period of time (months or years) will eventually develop one or more symptoms, including general cognitive impairment, diminished memory, attention deficit, motor impairments, aggressiveness, and/or hyperactivity (WHO,2011). Heterotrophic bacteria present in water poses no health risks to humans but a high HPC count is an indicator for ideal conditions for the growth of bacteria. This can be a breeding ground for more dangerous bacteria, such as Legionella or E. Coli, cause foul-tasting water, lead to corrosion or slime growth in pipes(WHO,2011).

CONCLUSION

From the results of the rainwater stored in both surface tanks without cover and underground tank with cover, it could be concluded that rainwater in surface tank is highly contaminated with colour, odour, taste, appearance , turbidity as physical parameters, pH, iron and manganese as chemical characteristics and bacterial above the WHO standards for potable water than underground water having the highest manganese above the WHO standard alongside TVB. These contaminants were observed to have emanated from the catchments where rainwater was harvested and stored for human consumption which leads to the human's health impairments.

Recommendations

Despite impurities in storage tanks and harvested rainwater could be used in augmenting water supply especially in dry seasons , the following recommendations are suggested to properly harnessed rainwater:

- **(i)** The early rainfall should be diverted away from the storage tanks since it is most likely to contain undesirable materials which have accumulated on the roof and other surfaces between rainfall events.
- **(ii)** The storage tanks should be checked and cleansed periodically with chlorine
- **(iii)** Care should be taken to keep rainfall collection covered to reduce invasion pests and organic matters
- **(iv)** If rainwater is to be used for drinking and other domestic purposes, chlorination is necessary in order to maintain its quality at the level where health risks are minimized.
- **(v)** Where rainwater is to be used without treatment, users are advised to boil water before drinking.

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