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Research Article

Quality Valuation of Direct Harvested Rainwater Near Nekede Landfill in Owerri West Local Government Area, Imo State, Nigeria

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ABSTRACT

Quality assessment of direct harvested rainwater at Nekede landfill in Owerri west Local Government, Imo State, Nigeria was examined. Some physicochemical and bacteriological parameters were analyzed. The WHO (2006) domestic, irrigation and rules for consumption standards was used to assess if the harvested rainwater is impure or infected. The water samples were collected from four sampling locations at a distance of 20 m away from each other. EP samples (March-April 2019) shows, turbidity ranged 5.0-5.20 NTU, Cl (3.40-3.90), Mn (0.05-0.09), NO_3-N (8.40-9.90), $PO4^{3-}$ (0.03-0.05) mg l^{-1} falls within the limit, Cu 1.0-1.10 mg l^{-1}, Zn 3.00-3.10 mg l^{-1} falls within WHO standards only. Cd, Al and Co_2 were above the standards, SAR and Na was Not detected (ND). PP (June - July 2019) shows turbidity, Cu, Cl, Mn, Ca, NO_3-N, Na, and $PO4^{3-}$ falls within the recommended standards. Cd (0.02), Al (0.02-0.06), CO_2 (5.00-5.10) mg l^{-1} was above the standards, while SAR and Zn has (4.63-47.27) (3.00-3.20) mg l^{-1} falls within WHO standard and Mg (0.43-0.60) mg l^{-1} falls within FAO. E-Coli results on EP 20-32, PP 10-35 and Coliform count EP (ND), peak precipitation (1-10) falls within FAO standards, Salmonella EP and PP was above WHO and FAO standards. The bacteriological parameters indicates that the water is not fit for drinking, thus the water has been seriously contaminated with dangerous pollutants.

RESEARCH ARTICLE

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INTRODUCTION

Rainwater is the core source of water to feed the demands that is either for ground recharge or satisfying the surface water bodies. Where surface water is not readily sufficient, rainwater becomes the alternative source for domestic uses. According to Adriano *et al*., (2011) It has become the key water source in most regions with significant rainfall but lacks modern and unified supply system. It is a good choice in regions where quality fresh surface water or groundwater is deficient. The application of appropriate rainwater harvesting technology becomes important for the utilization of rainwater as a water source. Rainwater categorized as distilled water, collects impurities such as dust particles, gases, bacteria etc., during its passage through the atmosphere. The portion of rainwater which flows over the surface near landfill known as runoff picks up organic matter, whereas the portion percolating through the ground has got mineralogical composition with organic and inorganic matter which gathers while making movement through the subsurface strata before it reaches the water table. The accumulated quality of water in rainwater harvesting (RWH) systems are affected by several issues, these includes:

a. Ecological circumstances which is closeness to massive industries, major roads and the existence of birds (Fo¨rster, 1998; Taylor *et al*., 2000).

b. Weather-related conditions for instance temperature, drought hours and precipitation patterns (Evans *et al*., 2006).

c. Connection with catchment materials and the dirt and debris that are dumped upon it amid rainfall events (Simmons *et al*., 2001; Van Metre and Mahler, 2003).

d. Management by pre-cistern treatment devices such as filtration or first-flush alteration (Yaziz *et al*., 1989; Martinson and Thomas, 2005).

e. Natural management processes which take place within the rainwater cistern (Scott and Waller, 1987; Spinks *et al*., 2003).

f. Handling by post-cistern treatment instrument such as particle filtration, ultraviolet disinfection, chlorination, slow sand filtration or hot water systems (Coombes *et al*., 2000).

According to Abdul *et al*. (2009), freshwater harvesting is a simple-low-cost water supply method, that includes to collect and store rainwater directly from roof surfaces, open field and ground catchments for rural, agricultural, industrial and environmental purpose. Harvested freshwater maybe the only source of water supply for rural and remote households where no other water supply is available. Rainwater harvesting for domestic usage is becoming increasingly popular as the availability of good quality water is declining. This is further exacerbated by the adverse impacts of climate change on water supply sources. The most noteworthy issue in relation to using unprocessed harvested rainwater for drinking or other potable uses, however, is the potential public health risk associated with microbial pathogens.

Harvested rainwater (HRW) has been considered an efficient choice water source for drinking and diverse non-potable uses in a number of nations throughout the world, the most important issue in relation to using untreated HRW for drinking or varying potable uses, nevertheless, is the potential public health risks related with microbial pathogens (Muhammad and Mooyoung, 2008). In the past, the provision of piped water directly to the household has been related with better hygiene and reduction in disease (Christine, 2006).

The basis of water quality investigation is to generate information which will become useful in the management of water resources in any nation or community. It would prove useful in administration, control and investigation of pollution challenges, classification of water resources, baseline data collection, water quality surveillance and water quality prediction (Ekiye and Luo, 2010). According to Igwo-Ezikpe and Awodele (2010) some physico-chemical and microbiological parameters of rainwater collected from Industrial areas of Lagos State Nigeria, showed that the anthropogenic activities, the rainwater samples were to a great extent contaminated and would be hazardous to human consumption without proper treatment.

Consumption of this water sources by human beings has proved dangerous because of the associated health hazards. The determination of degree of pollution of rainwater harvested from catchment near dumpsite requires painstaking investigation, careful application of expert knowledge and huge financial resources, frequent monitoring of water quality. A research of rainwater quality found that there is correlation between water quality and rainfall intensity. Values of pollutants (COD, BOD, N, and P) were found to be higher in case of moderate rain, whereas; samples taken during a heavy rainstorm; the components have low concentrated, as the rain washed the contaminants (Teemusk *et al.*, 2007).

There is no landfill regulation and standard that provides a basic for compliance and monitoring. Burning of waste introduces harmful substances into the air which raindrops pick up as they fall through the atmosphere. In most cases, rainwater near dumpsite becomes contaminated and poses health risk to humans who depend on it as a drinking water source. The physio-chemical, biological levels of pureness define the exact quality valuated with respect to the demand for the supposed usage (Chapman, 1997). Some of the natural factors which affect the water quality regularly include, rocks, soils and the earth surface of which it flows, activities from Industries, agriculturist and mining effluent which emanates from organic evolution (WHO, 1996). The major focus of this article is to analyse the physio-chemical and bacteriological quantity of direct harvested rainwater with respect to WHO (2006) domestic, irrigation and rules for consumption standards and to assess if the harvested rainwater is impure or infected, make suggestions on the improvement of the quality of harvested freshwater near landfill.

MATERIALS AND METHODS

The study was conducted near a landfill located along the old Nekede road in Owerri West L.G.A of Imo State. It lies between longitude 5° 25' 3" N and latitude 6° 55' 06" E. The study area was about 3 km from Owerri main town. It was characterized by a main annual precipitation ranging from 2000 mm-25000 mm, a mean temperature ranging from 26°C-28°C and humidity ranging from 70%-80% (Google Earth, 2016).

Four samples of rainwater were harvested from old Nekede landfill in Owerri West L.G.A Imo State. Two samples were harvested during the early precipitation (first rainfall of the year) of the year, one sample per month in March and April 2019 respectively. From these two samples, one sample was harvested at the landfill and the other sample was harvested at a distance of 20 m away from the landfill which serves as a control point. The remaining two samples were harvested during the peak precipitation (when precipation is intense) of the same year one sample each in June and July 2019; one sample was harvested at the landfill and the other sample was harvested at a distance of 20 m away from the landfill which also serves as the control point.

The early precipitation samples was carried out between 10:00 am and 1.00 pm in March and April 2019 whereas the peak precipitation samples collection was done between 8.00 and 10.00 am in the morning of June and July 2019, using sterilized sampling Can installed at a fixed point. The sampling Cans were affixed 1 m above the earth surface to prevent rain splash. The sampling Cans labeled were immediately transported after collection to the "De Apples" laboratory Egbaeda in Imo State for examination and analysis.

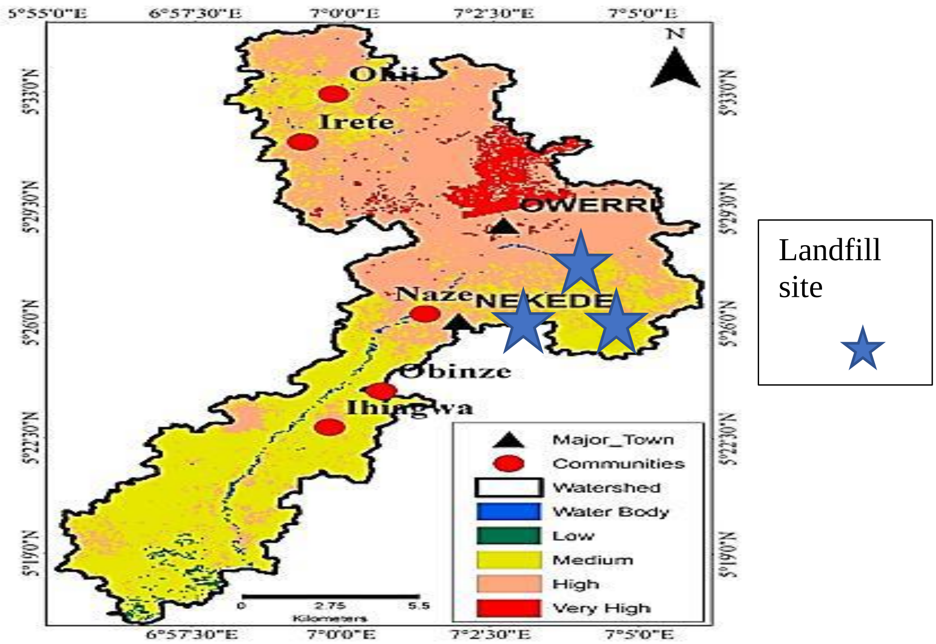

Figure 1. Map location of the study area Obineche *et al.* (2020).

Laboratory Analysis of Water Parameters

Twenty one (21) freshwater constituent was determined in each sample. Standard techniques were used to analyse the other parameters. The physic-chemical and bacteriological properties of the harvested water was analyzed. The visual aspect was carried out using a portable automated calorimeter. Other properties like colour, turbidity and odour were obtained through organoleptic process.

Temperature: The fluctuation in water temperature usually depends on the season, geographical locations, Sampling time and temperature of effluence entering the source of water. The temperature was determined at the point of sampling using a mercury-in glass thermometer with calibration 0-100°C.

pH: This is defined as the measurement of the hydrogen ions content and also the composition of the acidity and alkalinity levels. The pH was determined using standardized digital JENNY 3540 pH meter in the laboratory.

Total Dissolved Solids: A given volume of samples were filtered and weighed into a known, mass of evaporating dish. It was then evaporated to dryness and then weighed again. The difference in weight between the first and the final reading gives the total dissolves solid in mg l^{-1}.

The phenolphthalein alkalinity, methyl orange alkalinity gives the total alkalinity, traced elements were analyzed using the spectrophotometer.The amount of SAR was determined using the formulas

$$SAR = \frac{NA^{+}}{\frac{\sqrt{Ca^{2+} + Mg^{2+}}}{2}} \quad (1)$$

The determination of heavy metals, like zinc (Zn) cadmium (Cd), copper (Cu), aluminium (Al), manganese (Mg), sodium (Na) was carried out using atomic absorption spectrometer, while calcium (Ca), carbon (iv) oxide (CO_2), chloride (Cl^-), was determined using the titration method and titration with EDTA was used to determine the hardness. Colorimetric after distillation was used to obtain fluoride (F^-). The odour and pH was by dilution factor and pH electrode.

The media for bacteriology investigation includes: Plate count agar for aerobic mesophilic bacteria, while for Coliform count lactose broth media incubation at 35±0.5°C was used (APHA, 1985); the total heterotrophic bacteria and fungi count was by surface spreading method (Okafor, 1985). The reagents used were graded with instruments pre- calibrated preceding the analyses. Membrane filtration technique were used for E- coli and salmonella determination.

Turbidity: This illustrates how particles suspended in water affects its limpidity. It serves as a crucial indicator of suspended sediments level. This was measured in the laboratory using turbidimeter model 2100 A.

After the data have been collected, the raw data compiled from field observations and measurements were summarized using the IBM SPSS version 2012 statistical software package was used in the determination of the mean and standard deviation, while the graphical plots was generated using microsoft excel version 2010 The result of the laboratory analysis was represented with tables and graphs to obtain clear means of comparison and conclusions.

RESULTS and DISCUSSION

The result in Table 1 and 2 shows all the physiochemical and bacteriological values analyzed. The two tables shows the variation in the four different sample locations with their physiochemical and bacteriological parameters investigated in the rainwater samples and the comparison between the early and peak rainfall of the year at old Nekede landfill. The result of the physiochemical and bacteriology analysis of direct rainwater sampled with summary of individual description during the research study is as presented in the tables. The comparison of values of the different parameters with the World Health Organization and Food and Agriculture Organization.

Table 1. Physiochemical parameters of direct harvested rainwater at Old Nekede landfill.

Parameters	EP Samples		PP Samples		SR	MV	SD	WHO Limit	FAO Limit
	1	2	1	2					
Odour	Odourless	Odourless	Odourless	Odourless	-	-	-		
Turbidity NTU	5.20	5.00	5.00	4.80	4.8-5.20	5.00	0.100	5.00	35.0
pH	6.90	6.30	6.50	5.90	5.9-6.90	6.40	0.360	6.5-8.5	6.5-8.5
Cu (mg l^{-1})	1.00	1.10	1.20	0.09	0.09-1.2	0.84	0.442	2.00	0.20
Cl^- (mg l^{-1})	3.90	3.40	3.98	3.90	3.40-3.98	3.79	0.228	250	1065
Cd (mg l^{-1})	0.02	0.01	0.02	0.02	0.01-0.02	0.02	0.000	-	-
Al (mg l^{-1})	0.04	0.02	0.06	0.02	0.02-0.06	0.03	0.000	-	-
CO_2 (mg l^{-1})	5.60	5.50	5.40	5.00	5.0-5.60	5.37	0.236	-	-
F^- (mg l^{-1})	2.10	2.50	1.06	1.03	1.03-2.5	1.67	0.667	1.00	1.00
Mg (mg l^{-1})	0.50	0.60	0.60	0.43	0.43-0.6	0.53	0.089	0.30	5.00
Mn (mg l^{-1})	0.09	0.05	0.09	0.06	0.05-0.09	0.07	0.000	0.10	0.20
NO_3-N (mg l^{-1})	9.90	8.40	10.0	8.90	8.4-10.0	9.30	0.674	50.0	30.0
P (mg l^{-1})	0.02	0.01	0.01	0.01	0.011-0.02	0.012	0.000	-	-
Zn (mg l^{-1})	3.10	3.00	3.20	3.00	3.0-3.20	2.325	0.779	3.00	2.0
Hardness (mg l^{-1})	29.0	27.0	34.0	32.0	27-34.0	30.50	2.692	2.00	No limit
Ca (mg l^{-1})	14.0	13.4	14.5	13.0	13.0-14.5	13.725	0.572	75.0	800.0
PO_4^{3-} (mg l^{-1})	0.05	0.03	0.05	0.03	0.03-0.05	0.04	0.000	200	480
SAR	-	-	47.27	4.63	4.63-47.27	25.95	21.32	No limit	15.0
Na (mg l^{-1})	ND	ND	13.00	12.0	12-13.0	12.50	1.375	200	480

NTU: Nephelometric Turbidity Unit, ND: Not Dectected, ppm: Part per million mg^{-1} l^{-1}, Cu: Copper, Cl: Chloride, Cd: Cadmium, Al: Aluminium, CO_2: Carbon dioxide, F^-: Fluoride, Mg: Magnesium, Mn: Manganese, NO_3-N: Nitrate Nitrogen, P: Phosphorus, Zn: Zinc, Ca: Calcium, PO_4^{3-}: phosphate, SAR: Sodium Absorption Ratio, Na: Sodium, ER: Early precipitation sample, PR: Peak precipitation, SR: Sample range, MV: Mean value, SD: Standard deviation

Table 2. Bacteriological parameters of direct harvested rainwater at Old Nekede landfill.

Parameters	EP samples		PP samples		SR	MV	SD	WHO	FAO
	1	2	1	2				Limit	Limit
E-coli	25-30	20-25	30-35	10-20	-	-	-	0.00	500.0
Salmonella	40-44	30-35	25-35	25-30	-	-	-	-	-
Coliform	ND	ND	0-10	1-5	-	-	-	0.00	1000.0

ND: Not Detected. All bacteriological parameters have this unit cfu: Colonie forming unit.

Turbidity: Turbidity (cloudiness) which is measured in Nephelometric Turbidity Unit (NTU), measures the extent to which suspended substance in the water is absorbed or scattered when beaming light energy incident on it. It is easier to detect the turbidity of a glass of water when it is greater than 5 NTU. Obviously, water at point of supply with turbidity above 5 NTU is likely objectionable for the health reasons and most importantly aesthetic reasons. The above rain water turbidity was 5.2, 5.0, 5.0 and 4.8 NTU respectively. The sample 1 under early rainfall has higher turbidity unit of 5 NTU other samples have maximum unit of 5 NTU (Nigeria) as shown in table 1. Thus, in terms of turbidity, the rain water passed the test.

The pH of water measures the taste property of the water. The pH values of the four samples of the direct rainwater were measured and found to be 6.9, 6.3, 6.5 and 5.9 respectively. The range shows 5.9-6.9 which is slightly above the WHO and FAO limits, while the mean values of 6.40 falls within WHO and FAO recommended standards.

Odour: Odour is said to be perceptual experience recorded by the sensory system mental state. Odour is highly objectionable and is highly unacceptable in any water meant for drinking especially at the point of use. The production of volatile substances by algae, hydrogen sulphide and other substances contribute to odour in water. Thus, in terms of odour, the rainfall has no odour.

Chloride: Highly salinity content is inarguable an inherent characteristic of Streams, rivers, wells and other small water bodies which often have little salt content. In this research, both the mean value and range of chloride 3.79 mg l^{-1} and 3.40 – 3.98 mg l^{-1} falls within WHO and FAO acceptable limit.

Calcium: The values of calcium obtained in sample 1 under the early and peak precipitation has the highest value of 14.0-14.5 mg l^{-1} followed by sample 2 under early and peak precipitation which has 13.4 and 13.0 mg l^{-1} which was to be the lowest obtained. It was observed that the mean values of calcium concentrations falls within the WHO and FAO standards of 75.00 and 800 mg l^{-1}, this show that the water is fit for irrigation and possibly drinking purposes.

Manganese: Manganese contents shows range 0.05-0.09 mg l^{-1} and mean values of 0.07 mg l^{-1} which indicates that it falls within the WHO and FAO recommended standards. Although iron found in freshwater has not been said to be the cause of any known health problem, however, manganese in drinking water is reported to cause neurological disorder (Nigerian Industrial Standard for Drinking Water, 2007).

Nitrate: Nitrate is not desirable in drinking water because it occurrences in water, has been medically proven to cause various kinds of health problems including methemoglobinemia (infant cyanosis or blue babies). The maximum contaminant level for Nitrate in various water quality standards around the world is 50 mg l^{-1} (NIS, 2007). Therefore, from the table1 it will be observed that the harvested rainwater range 8.40- 10.0 mg l^{-1} and mean values 9.30 mg l^{-1} falls within WHO and FAO limits.

Sodium Adsorption Ratio (SAR): Table salt which is often used to add flavour to food to desired taste contains sodium, a highly electropositive substance, as its only positive element. Intake of too much salt into the body is associated to increase in heart pressure of susceptible individuals, worsening of cases of people suffering from heart, kidney or circulatory problems. The direct rain water value in this research for early rainfall was not detected but varies for peak rainfalls were found to be 47.27 and 4.63 mg l^{-1}. The range and mean values are 4.63-47.27 mg l^{-1} and 25.95 mg l^{-1} which falls within WHO recommended limits,

Sodium: The mean value of sodium falls within the acceptable limits 12 500 mg l^{-1} of the WHO and FAO. their range are 13.0-14.5 mg l^{-1}. Therefore, the rainwater is free from sodium contaimations.

Magnesium: The mean value as obtained in the table 1, shows that magnesium 0.53 mg l^{-1} falls within the FAO limit only, and ranges between 0.43-0.6 mg l^{-1} respectively. This indicates that the water is not 100% fit for drinking.

Cadmium: The result of the range and mean value of cadium obtained shows 0.01-0.02 mg l^{-1} and 0.02 mg l^{-1} respectively, which is above WHO and FAO the recomended limits for drinking and domestic uses.

Hardness: The hardness values for samples 1 and 2 under early precipitation were 34 mg l^{-1} and 32 mg l^{-1} respectively, hence the values obtained were not up to the WHO 200 mg l^{-1} and FAO standards when compared. This shows that the water obtained would lather easily and is safe.

Phosphate: The mean values and the range of phosphate obtained 0.04 mgl^{-1}, 0.03 – 0.05 mg l^{-1} shows that the sample falls within the recommended limit by WHO and FAO. Hence drinking water is not supposed to contain phosphate.

Zinc and Copper: The mean value results of Zn and Cu, 2.325 and 0.84 mg l^{-1} shows that it falls within WHO limits only. While their ranges are 3.0-3.20 mg l^{-1} and 0.09-1.20 mg l^{-1}.

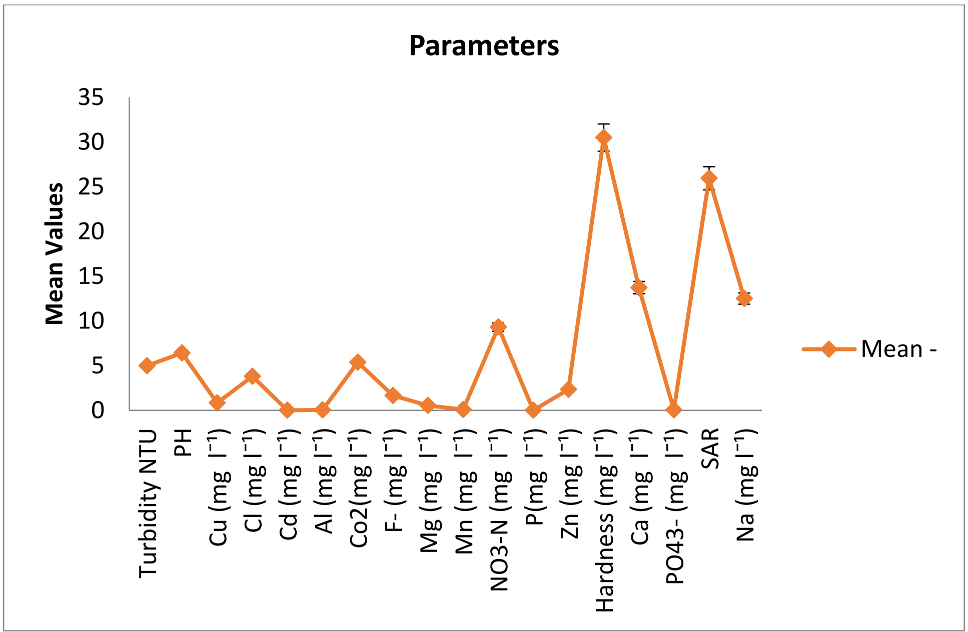

Figure 2. Graphical representation of mean values against parameters.

Bacteriological: E-coli and other harmful bacteria were seen. The E-coli of the water samples collected have slight differences. The results from table 2 shows that, E-coli early and peak precipitations samples falls within FAO limit, while the salmonella composition in the rainwater for early and peak precipitation was above the WHO and FAO recommended limits. Coliform count was not detected in the early precipitation (EP) but was detected in the peak precipiation (PP) which falls within the FAO recommended limit.

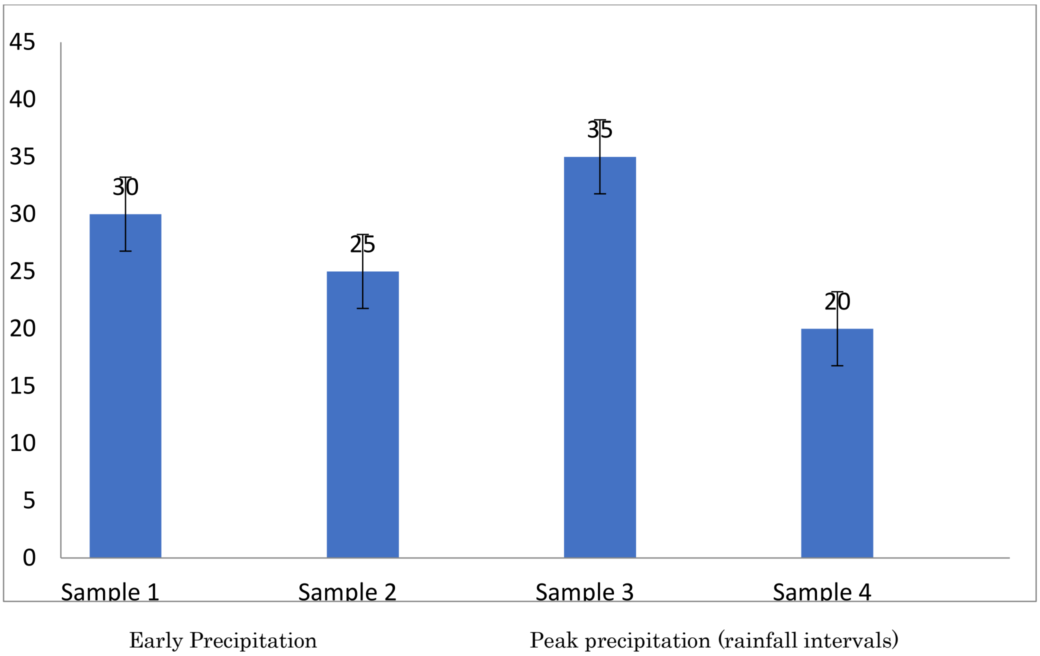

Figure 3. Graphical representation of E-coli in all the samples analyzed.

CONCLUSION

The results of the water quality analysis indicate that direct harvested rainwater near dumpsite is not fit for consumption due to domestic and industrial effluents discharged into the surroundings. The various human activities and the emission of CO_2 gas into the atmosphere which help to build up water contaminants is very dangerous and hazardous to health. The results of the physiochemical and bacteriological parameters of the direct rainwater samples from four sampling locations on the direct rainwater based on the FAO and WHO standards, leads to the following conclusions; the total coliform and salmonella thyphi contents were very high and thus the water is not fit for drinking. The acceptable pH limit for drinking water ranges between 6.5-8.5; any water with pH which is not within the recommended limits causes instability in diet and hence it hold in toxic ion. In these samples, the pH values vary from 5.9-6.9 which is in line with the permissive range for drinking water. Finally, the quality assessment of direct harvested rainwater near Nekede landfill in Owerri West L.G.A Imo State, Nigeria was evaluated and result shows moderate variations among some samples of the parameters. Some of the water samples could be said to be appropriate for domestic uses, but not for human consumption due to contamination especially by gaseous emission of CO_2 into the atmosphere.

There is need of a conservation and management plan to reduce the sewage impact on water. It was quite evident from the findings that the site is receiving lots of domestic and industrial waste effluents. The solution of this problem lies in the treatment of sewage and disposable of fully treated sewage disposal. We should go for alternative methods for the sewage disposal like the dry sanitation.

Public participation is needed for waste bin awareness, water pollution caused by sewage, agricultural and industrial impacts can be controlled by considering the following;

1. A natural focus on water sector reform should be encouraged and water-related institutions should be reorganized, water conservation should be accelerated and system efficiency should be increased.
2. A sewage system should be provided for the collection and treatment of the sewage system.
3. Illegal incineration of waste in landfills should be prevented so that the careless and illegal dumping of solid waste should be minimized, as the introduction of harmful substances that predispose people who live nearby to a high risk of cancer will lead to the problem of polluting the air and soil as well as nearby water bodies.
4. To determine the degree of pollution of rainwater harvested directly near the very large dumpsite, careful research should be carried out, practice based on expert knowledge, and water quality should be frequently monitored.
5. Villagers should be informed about the dangers of using untreated water as a source of drinking water.

DECLARATION OF COMPETING INTEREST

The authors declare that there are no conflict of interest

CREDIT AUTHORSHIP CONTRIBUTION STATEMENT

Christopher Ikechi Obineche: Writing original draft, methodology and investigation.
Cordella Chika Emekachris: Analysis of figures.
Donatus Okwudiri Igbojionu: Validation and review.
Chinedu Obani: Compilation and statistical review.

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