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ORIGINAL ARTICLE

Quality assessment of non-roof harvested rainwater in industrial layouts of Enugu, South East Nigeria

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Abstract

Non-roof harvested rainwater was studied in Enugu industrial layouts of Emene and Iva Valley to determine the quality of the water. The determination was based on physicochemical parameters and concentration of 7 heavy metals, namely copper (Cu), chromium (Cr), nickel (Ni), manganese (Mn), zinc (Zn), lead (Pb) and cadmium (Cd). The physicochemical parameters of the rainwater: pH, colour, turbidity, total dissolved solids, conductivity were determined using Hanna water quality checker, and the anions nitrate, sulphate, chloride and phosphate were analysed in accordance to standard methods. The concentrations of Cu, Cr, Ni, Mn, Zn, Pb and Cd were determined using FS240 Agilent Atomic Absorption Spectrophotometer. The mean values (mg/l) of the metals: Cu, Cr, Ni, Mn, Zn, Pb and Cd in Emene sample are as follows: 0.12 ± 0.01, 0.10 ± 0.02, 0.37 ± 0.02, 0.03 ± 0.01, 0.15 ± 0.01, 0.58 ± 0.11 and 0.17 ± 0.07, while Iva Valley sample recorded 0.08 ± 0.01, 0.04 ± 0.01, 0.82 ± 0.06, 0.09 ± 0.02, 0.26 ± 0.01, 0.48 ± 0.04 and 0.31 ± 0.08, respectively. Some of these values are within or above the standard limit of World Health Organization (WHO) and Nigeria Standard for Drinking Water Quality (NSDWQ). It is important to note that these metals are toxic, persistence and have the potential to bioaccumulate. Therefore, non-roof harvested rainwater is not ready to consume water without some form of treatment. Monitoring, treatment and awareness on the harvesting and use of rainwater should be emphasized.

Keywords Water quality · Atmospheric pollutants · Health risks · Rainwater · Heavy metals

Introduction

Individuals and whole community health can be influenced by the quality of water at their disposal and when the water is of good quality, it is then an absolute requirement for healthy and productive life (Aryal et al. 2012). The drinking water quality is an indicator of water acceptance for human usage. Water quality is affected by natural processes and human activities (Akter et al. 2016). The human health may be at risk, if values of the physicochemical parameters exceed acceptable limits (Aryal et al. 2012) thereby posing a potential health risk to humans and other life forms (Okpoebo et al. 2014).

Currently, due to increasing awareness of water conservation, storm water runoff problems, rainwater harvesting is widely practiced and accepted as good source of water supply (Ahmed and Toze 2014). However, in some cases rainwater is not always clean water that should be readily consumed, because the area where the rain falls may affect the quality of the rainwater. In undeveloped settlements, rainwater may be contaminated by agricultural activities, while in developed settlements, rainwater may be contaminated by emissions from house-holds, offices and industries which readily dissolves in water without leaving any trace of change in colour, taste and may not be identified physically (Khayan et al. 2019). Continual population increase and growth in industrial activities impact greatly on the air quality (Marlier et al. 2018) and as such affect the quality of rainwater harvested, since the rainwater have the potential to dissolve atmospheric pollutants and various particulate matters.

Emene and Iva Valley areas are of great importance because they are the core industrial locations in Enugu Urban with resultant atmospheric pollution.

Emene Industrial layout is the location of most of the industries in Enugu, and some of the major industries in this areas are Anambra Motor Manufacturing Company Limited

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(ANAMMCO), Emenite Limited (Manufacturers of various roofing sheets/tiles, ceramic products), Innoson Technical & Ind. Co. Ltd (Manufacturers of various plastic products) and others. Due to poor power supply, all these companies rely on heavy duty power generators which combust fossil fuels and the presence of heavy duty vehicles with their exhaust fumes releasing pollutants and other toxic components into the atmosphere. Emene is the location of Akanu Ibiam International Airport, with other human activities.

Iva Valley which is another industrial layout is the location of Iva Valley Coal Mine (Colliery), Pottery and camp. The camp area is where the mechanic workshop for various kinds of vehicles and heavy duty equipment are located. The area experiences heavy presence of vehicles daily which are potential sources of pollution. The improper handling of spent lubricants which evaporates also constitutes a major source of pollutants. Other human activities also contribute to the air pollution in the area.

In previous studies of similar nature conducted in Wukari, Taraba State, North-Eastern, Nigeria, the rainwater was harvested and stored in various storage containers—metal tanks, plastic tanks and concrete tanks, to determine their effects on the quality of rainwater. Upon physicochemical and microbiological analysis of the samples, it was found that faecal coliform which is above World Health Organization (WHO) standard was present in all the samples, the physicochemical parameters showed significant differences of $P<0.05$ and iron and copper showed elevated concentrations while the other metals are relatively within permissible limit of WHO. The indication is that the receptacles for harvesting rainwater may be a source of contaminant (Achadu et al. 2013).

The study carried out by Moses et al. (2016), in Uyo, Nigeria, to determine the quality and acceptability of harvested rainwater for household purposes showed that the physicochemical parameters measured are below WHO limits for drinking water. The trace metals were shown to be within the WHO permissible limits except for Cu, Fe and Cd. Then, from the correlation analysis Fe was from natural sources, while Mn, Cu, Cr, Cd and Zn were from human activities. This indicates that consumption of the rainwater without treatment may pose adverse health effects.

Ebong et al. (2016), harvested rainwater from areas in the south-south of Nigeria that are exposed to continual gas flaring from the activities of multi-national oil companies. Analysis of physicochemical properties and some trace and heavy metals found that pH; Fe, Pb, Cd and Ni values were above the acceptable limits. The elevated values are as a result of human activities in the region.

The study by Igbinosa and Aighewi (2017) shows that the physicochemical parameters analysed in rainwater samples are within the limits acceptable by WHO in some communities, whereas in some communities the measured parameters are above the WHO acceptable limits, thereby suggesting proper rainwater harvesting system with periodic monitoring and assessment.

Furthermore, quality measurements of rainwater in Ontario, Canada, by Despins et al. (2009) show that parameters analysed are largely consistent with those reported by earlier researchers, but they noticed an improved microbiological quality during periods of cold weather. They are of the opinion that environmental conditions can affect the quality of rainwater harvested, but high quality can be maintained by the use of appropriate storage materials and post-harvested treatment. Most of the previous studies dwell so much on roof harvested rainwater and little or nothing is known of the quality of non-roof harvested rainwater.

Non-roof harvested rainwater studies have not been carried out in Enugu urban and this prompted this study with basic consideration of the physicochemical parameters of water and concentration of some metals in the rainwater. Heavy metals are very important because of its prevalence in recent times and potentials to dissolve in rainwater.

Therefore, with increase in population of Enugu Urban as a result of rural–urban migration, industrial development, the atmospheric pollution is equally increased. This study then serves as a baseline work on the standard of non-roof harvested rainwater in this area and to bring to the fore potential health risks of consuming untreated harvested rainwater.

Materials and methods

Study location

The location of the study is Enugu urban, Enugu State, Nigeria, which is between latitude $6^{\circ}00^{\prime}$N and $7^{\circ}00^{\prime}$N and longitude $7^{\circ}00^{\prime}$E and 7° $45^{\prime}$. It is in the tropical rainforest zone of south-eastern Nigeria with two distinct seasons, wet and dry (Ajah et al.2015). Residents of Enugu Urban, during the rainy seasons, depend solely on harvested rainwater for their various domestic and industrial purposes. This is because of the nature of the city's geological formation which limits ground water exploitation and also with the river bed being highly polluted (Ezenwayi et al. 2016).

The sampling was conducted on the two industrial layouts, Emene and Iva Valley using Ugwuogo Nike a rural area as control. There are 3 sampling points in each location and they are geo-referenced using Garmin Etrex Venture CX. The sampling points and the corresponding co-ordinates are shown in Table 1.

The study was conducted during the raining season of April–October, 2018. The rainwater samples were collected at 3 different times during the period April–May, June–July, August–September, and 9 samples were taken on each visit

Table 1 Sampling locations with areas and coordinates

Locations	Sampling area A	Sampling area B	Sampling area C
Emene	6.459957°N	6.460762°N	6.460255°N
	7.580428°E	7.580303°E	7.578955°E
Iva Valley	6.462684°N	6.464114°N	6.463198°N
	7.463925°E	7.465510°E	7.466503°E
Ugwuogo Nike (Control)	6.603046°N 7.463925°E	6.600125°N 7.559430°E	6.600690°N 7.552010°E

from the various locations for analysis. Figure 1 is the map of the area showing the sampling locations.

Sample collection and analysis

The rainwater samples are collected using 30 l cylindrical plastic containers on elevation of 3 m and located away from any source of pollution. The containers were covered with sieve of 0.45 micron in diameter with the rainwater falling directly into the containers without any interference. The sample containers were cleaned with dilute nitric acid solution to remove particles on the container and rinsed severally with distilled water. The physicochemical parameters of the rainwater collected: pH, colour, Turbidity, total dissolved solids (TDS), conductivity were determined using Hanna water quality checker. The anions nitrate, sulphate, chloride and phosphate were analysed in accordance to

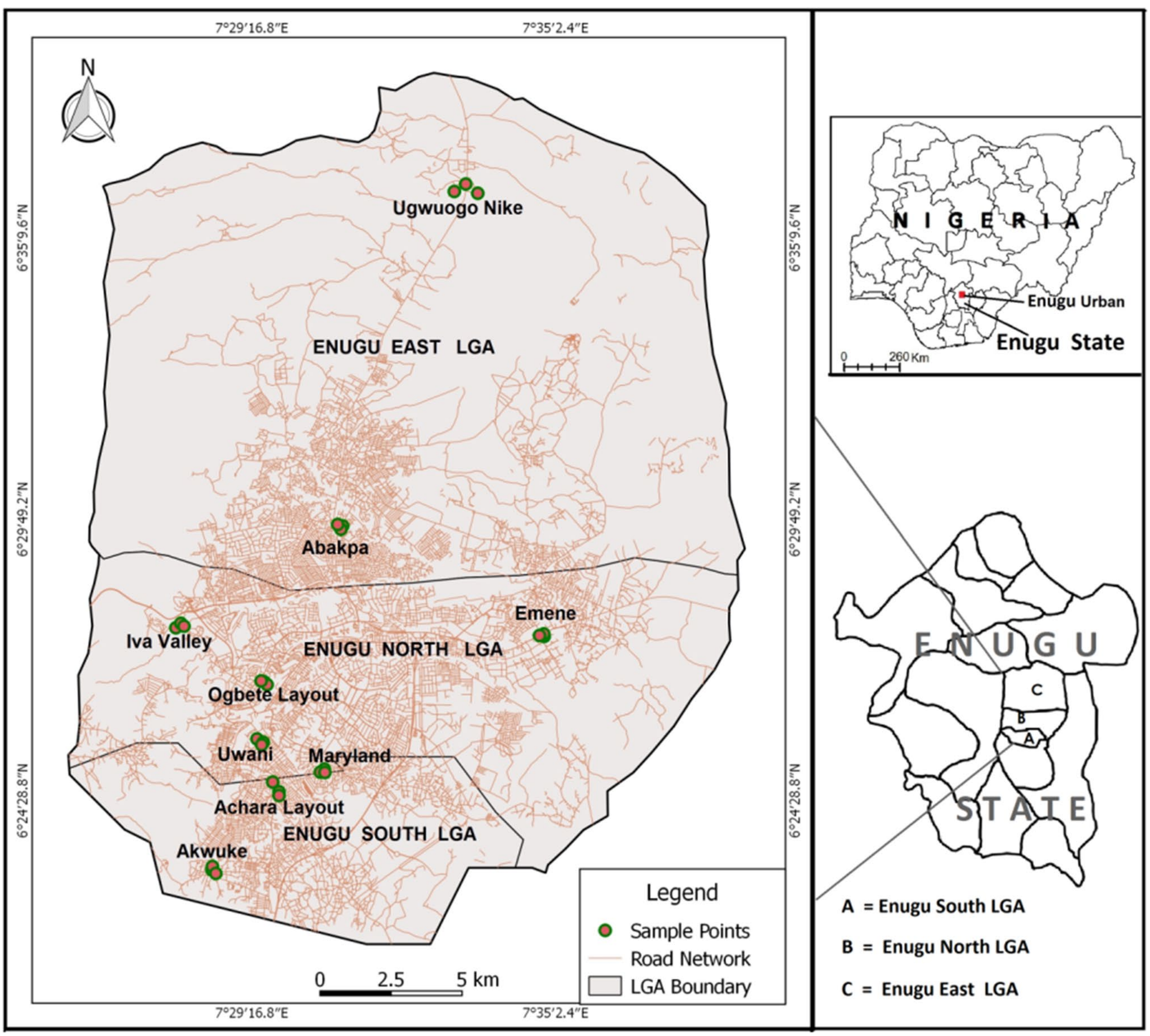

Fig. 1 Enugu city showing sampling locations of the study

standard methods (APHA 1998). Then, the rainwater sample was filtered using a microfiltration membrane of pore size 0.45 µm and 5 ml of 10% nitric acid was added, placed in an ice-chest and taken to the laboratory (Pobi et al. 2019). The samples were kept in the refrigerator preceding analysis for the heavy metals (Okpoebo et al. 2014). The collected water samples were digested with mixture of concentrated HNO_3 and $HClO_4$ in the ratio of 3:1 (v/v) (Pobi et al. 2019). The concentration of Cu, Cr, Ni, Mn, Zn, Pb and Cd was then determined using FS240 Agilent Atomic Absorption Spectrophotometer. Analytical blanks are used to standardize the instrument before the samples were analysed. The analysis was done in triplicates, and the average values were used to represent the data. All the laboratory containers and glass wares used for the analysis were washed thoroughly and rinsed with distilled water.

Statistical analysis was done using statistical package for social sciences (SPSS) version 20 at significance level $P < 0.05$.

Results and discussion

The results of the physiochemical parameters and concentration of the heavy metals of the non-roof harvested rainwater from Emene, Iva Valley and Ugwuogo Nike (Control) with the WHO, NSDWQ permissible limits are shown in Table 2.

The data are collated in line with WHO (2008) and NSDWQ (2007) permissible limits.

The mean values of pH during the period are 6.39 ± 0.04 in Emene, 6.81 ± 0.16 in Iva Valley. The NSDWQ limit is 6.5–8.5, the value in Emene is slightly lower, but it is negligible, while the value in Iva Valley is within the standard limit. The studies by Okpoebo et al. (2014) recorded a pH range of 5.1–7.6, and that by Moses et al. (2016) shows a pH range of 5.54–6.38. The values show that the rainwater is mildly acidic. The increased acidity of rainwater as a result of atmospheric pollution of sulphur and nitrogen compounds released by vehicular and industrial activities can expose the community that depends on this water for domestic purposes to some health effects, especially stomach ulcer and associated effects.

The conductivity of the harvested rainwater was high with mean values of 254.06 ± 1.71 µs/cm in Emene, while the mean values of 221.78 ± 1.56 µs/cm were recorded in Iva Valley as compared with a lower value as shown in the study (Moses et al. 2016). Although the values are below the NSDWQ limit of 1000 µs/cm, the high value shows presence of contaminants, especially electrolytes, which increases the conductivity of water (Adekunle et al.2007). Consumption of water with very high conductivity can become a health issue which may result to defective endocrine functions and may also cause damage to the brain (Hunter et al. 2009). Total dissolved solids (TDS) which is made up of a number of inorganic components and different salts, indicating the solid load of the water (Rai 2010). TDS mean values in the non-roof harvested rainwater are less than NSDWQ limit of 500 mg/l as shown in Emene 124.10 ± 1.15 mg/l and 117.72 ± 1.57 mg/l in Iva Valley. The values as shown are much higher when compared with values obtained in the studies in Uyo, Ile-Ife, Nigeria and Ayanfuri, Ghana as reported (Moses et al. 2016; Okoye et al. 2011; Amponsah et al. 2015). This indicates that the harvested rainwater is not fit for domestic use. Elevated TDS gives the water very poor taste that is not palatable. The water may cause laxative and constipation effects (Egereonu 2004). That

Table 2 Mean values of physicochemical parameters of the non-roof harvested rainwater with WHO, NSDWQ limits

Parameters	Emene	Iva valley	Ugwuogo Nike	WHO limit	NSDWQ limit
pH	6.39 ± 0.04	6.81 ± 0.16	6.71 ± 0.15	6.5–8.5	6.5–8.5
Conductivity (µs/cm)	254.06 ± 1.71	221.78 ± 1.56	287.26 ± 1.37	1000	1000
Total dissolved solids (mg/l)	124.10 ± 1.15	117.72 ± 1.57	125.86 ± 1.21	500	500
Colour (PCU)	33.42 ± 1.38	21.33 ± 1.41	20.56 ± 1.00	5.0	3.0
Turbidity (NTU)	1.83 ± 0.04	2.20 ± 0.46	1.46 ± 0.19	1.00	5.0
Sulphate (mg/l)	307.05 ± 1.32	420.50 ± 1.25	430.46 ± 1.30	500	100
Nitrates (mg/l)	0.45 ± 0.11	25.89 ± 0.51	2.31 ± 0.41	10.00	10.00
Phosphate (mg/l)	2.02 ± 0.25	0.77 ± 0.02	0.53 ± 0.15	5.50	5.50
Chloride (mg/l)	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	250	250
Copper (mg/l)	0.12 ± 0.01	0.08 ± 0.01	0.09 ± 0.01	2.0	1.0
Chromium (mg/l)	0.10 ± 0.02	0.04 ± 0.01	0.06 ± 0.01	0.05	0.05
Nickel (mg/l)	0.37 ± 0.02	0.82 ± 0.06	0.37 ± 0.10	0.02	0.02
Manganese (mg/l)	0.03 ± 0.01	0.09 ± 0.02	0.02 ± 0.00	0.05	0.2
Zinc (mg/l)	0.15 ± 0.01	0.26 ± 0.01	0.11 ± 0.02	3.0	3.0
Lead (mg/l)	0.58 ± 0.11	0.48 ± 0.04	0.15 ± 0.01	0.05	0.01
Cadmium (mg/l)	0.17 ± 0.07	0.31 ± 0.08	0.01 ± 0.00	0.003	0.003

is gastro-intestinal discomfort with associated pains and discomfort. The rainwater colour measured in the areas is above the NSDWQ limit of 3.0 (PCU) with Emene having a high mean value of 33.42 ± 1.38 PCU and Iva Valley showing 21.33 ± 1.41 PCU. This colour contrast may be due to presence of metals in the water, especially iron and manganese for they decolorize water (Egereonu 2004). Water de-colourization makes it unfit for drinking and for other domestic purposes, readily presenting it as bad or dirty water. Consumption of this kind of water may present a kind of psychological effect that can trigger of illness or a condition of feeling unwell.

The mean turbidity values are below the NSDWQ limit of 5 (NTU) with Emene 1.83 ± 0.04 (NTU) and Iva Valley 2.20 ± 0.46 (NTU). The turbidity level in water may be attributed to suspended particulate matter and the extent of the rainfall (Chapman 1996). The values are lower from the results obtained in the study (Moses et al. 2016). This may be acceptable but considering the areas being industrial with a lot of anthropogenic activities. This low turbidity may be as a result frequency of rainfall as observed in Emene and Iva Valley.

The mean value of sulphate is high in Emene and Iva Valley showing 307.05 ± 1.32 mg/l and 420.50 ± 1.25 mg/l which is below WHO standard limit of 500 mg/l. Sulphate occurs naturally in surface water and anthropogenic activities can also increase its atmospheric abundance (Yisa and Jimoh 2010). Water with high sulphate content gives unpleasant taste and laxative effects (Bashir 2012). This may present as diarrhoea, dehydration as well as stomach cramps. The mean values on nitrates in the rainwater harvested from the two industrial areas, Emene and Iva Valley are 0.45 ± 0.11 mg/l and 25.89 ± 0.51 mg/l. The value in Iva Valley is above the NSDWQ limit of 10 mg/l and this may be because of the abandoned coal mines in the area. Nitrate occurs naturally and it is part of the nitrogen cycle, undesirable in water because of its effect on infant less than 6 months old, causing methaemoglobinaemia (Egereonu and Nwachukwu 2005).

Mean values of phosphate are Emene 2.02 ± 0.25 mg/l and Iva Valley 0.77 ± 0.02 which are below the standard limit of 5.50 mg/l. Phosphate has no direct health effects on humans, but high concentrations indicate pollution and are mainly responsible for eutrophication (Yisa and Jimoh 2010). It can alter the ecosystem and may have adverse health impact on humans, in this case indirect effect. Chloride was not detected in the study areas indicating the absence of chloride ion in the air, but they may be present in levels below the detection limits of the measuring instrument.

The concentration of heavy metals in water is a major cause for concern since they are toxic, persistence and have a great tendency to bio-accumulate (Pobi et al. 2019; Igwe et al. 2003). The mean value of copper in Emene is 0.12 ± 0.01 mg/l and 0.08 ± 0.01 mg/l in Iva Valley. They are below the NSDWQ limit of 1.0 mg/l. Copper, although an important element in human nutrition, at high level can pose a danger, causing gastrointestinal tract irritation, anaemia, liver and kidney damage (Igwilo et al. 2006; Turnland 1988).

Chromium mean value in Emene is 0.10 ± 0.02 mg/l which is greater than NSDWQ limit of 0.05 mg/l, but in Iva Valley the mean value is 0.04 ± 0.01 mg/l which is below the limit accepted. Natural atmospheric sources of chromium are the weathering of the earth crust (Mortuza and Al-Misned 2017). Anthropogenic activities increase atmospheric chromium through emissions from municipal wastes incineration, chemical industries and other vehicular emissions (Dixit and Tiwari 2008). Industrially chromium is widely used in alloying, plating, tanning of animal hides, textile dyes and prevention of water corrosion, ceramic glazes, mordant dyes, pigments, refractory bricks and pressure treated lumber (Avudanayagam et al. 2003). Chromium is an important dietary element, and it is very essential in the metabolism of glucose, fat and protein (ATSDR 1998). High human exposure of chromium through drinking water and other routes has adverse effects which include respiratory tract infections, gastrointestinal system disorder, kidney and liver damage. Neurological cells and immune systems will also be affected and possibly damaged (ATSDR 1998; USEPA 1988; WHO 1988). Chromium must be as much as possible be removed from drinking water and waters for other domestic purposes because they are potential carcinogenic (Otukune and Biukwu 2005; Edet and Okereke 2001).

Nickel concentration is high in all the locations, and it is above the NSDWQ limit of 0.02 mg/l. In Emene, the mean value recorded is 0.37 ± 0.02 mg/l and in Iva Valley the mean is 0.82 ± 0.06 mg/l. Nickel is known to be abundant in the earth's crust and enters the atmosphere through weathering of rocks, soil, biological cycles, industrial activities, gaseous, liquid and solid waste disposal (Prego et al. 1999). Nickel is known to persist in the environment and have a longer settling time in the atmosphere and this may possibly be the explanation of high concentration recorded in these sample locations (Okpoebo et al. 2014). Nickel, however, has been classified as very toxic to life forms and relatively accessible and potential carcinogens (Forstner and Wittman 1983). The manganese concentration in all the sampled locations is below the NSDWQ limit of 0.2 mg/l. The values recorded at Emene and Iva Valley are 0.03 ± 0.01 mg/l and 0.09 ± 0.02 mg/l, respectively. Toxicity level of manganese is low with relative biological significance, and it is one of more biogeochemical and active transition metals in water (Mortuza and Al-Misned 2017). The mean values of zinc are below the NSDWQ limit of 3.0 mg/l in all the locations as shown for Emene and Iva Valley in Table 2, 0.15 ± 0.01 mg/l and 0.26 ± 0.01 mg/l, respectively. This low value of zinc may be attributed to the mode of harvesting the rainwater which is non-roof harvest. This also indicates that roof harvest of rainwater increases the concentrations of zinc in the water as recorded in some studies (Okpoebo et al. 2014; Ahmed and Toze 2014; Moses et al. 2016).

Zinc element occurs abundantly in nature, and also, it is present as a contaminant in food wastes, pesticides and agricultural run-off, as well as anti-fouling paints (Badr et al. 2009). Abdominal discomfort, nausea, electrolyte imbalance, dizziness and inability to co-ordinate the muscles in humans may result on exposure to high amount of zinc (Uba et al. 2013).

Lead mean values are very high in all the locations sampled and much higher than the NSDWQ limit and also higher than the safe standard by WHO. The values as recorded in the study are Emene 0.58 ± 0.11 mg/l and Iva Valley 0.48 ± 0.04 mg/l. This high value of lead is as a result of the use of leaded gasoline in the area, for vehicles, power generators, and industrial machines. Lead, a very toxic heavy metal, does not breakdown easily in the environment (Aremu et al. 2002). It has the potential to bio-accumulate and persist for a very long period (Aderionla et al. 2009). High exposure of lead affects every system in human body causing damage, cancer and even affecting the unborn foetus (Adedeji and Olayinka 2014).

The cadmium concentration is much higher than the NSDWQ limit of 0.003 mg/l in all the locations sampled. The mean value in Emene is 0.17 ± 0.07 mg/l and 0.31 ± 0.08 mg/l in Iva Valley. Being industrial locations, the activities emit cadmium abound in the areas and coupled with poor waste management practice of the inhabitants of these areas. This will possibly elevate the concentration of cadmium in the atmosphere. Cadmium is a transition element, and being present in any environmental matrix has the potential of poison (Mortuza and Al-Misned 2017). There are variations in the values of heavy metals in this study when compared with the results of other researchers (Achadu et al. 2013; Moses et al. 2016; Ebong et al. 2016; Igbinosa and Aighewi 2017; Adedeji and Olayinka 2014). The differences may be as a result of the mode of rainwater harvesting and storage. Then, the location of the study and the kind of activities that are obtainable in the area and environmental conditions is a factor that affects the values of the metal concentrations.

It is important to note that some of the physicochemical and heavy metals concentrations are shown to be high in Ugwuogo Nike, which is a rural area. Ugwuogo Nike is largely an agricultural settlement; the atmospheric pollution may be from the heavy use of fertilizers, pesticides, herbicides. There are pockets of stone and sand quarries in the area with daily presence of trucks which will as well contribute to the air pollution. Environmental conditions in terms of wind speed and direction can also bring about the pollution of the rural area.

Further statistical analysis using Pearson correlation (*r*) shows relationships between two parameters which have values of -1 and $+1$ (Saleem et al. 2012; Popoola et al. 2019). The values obtained are categorized as negligible, strong, moderate and poor correlation when r is equal to $0, \geq 0.7, \geq 0.5$ and ≤ 0.5, respectively (Popoola et al. 2019). Table 3 is the result of the correlation of the physicochemical parameters, and it shows that 8%, 16% and 76% of the parameters are strongly, moderately and poorly correlated, respectively. The pH significantly correlated positively with nitrate, manganese and zinc suggesting that these parameters influence the pH of the non-roof rain water evaluated.

The factor analysis which explained the variations observed in the physicochemical properties of non-roof harvested rainwater across the different locations evaluated shows that the two main principal components (PC) which explained the main variation had pH, Zn, Mn and NO_3 in PC1 and colour, Cu, Cr and PO_4 in PC2. Similarly, the cluster Zn which is a metal was closely associated with pH, Mn and NO_3, Cu and Cr were associated with PO_4 while Cd was associated with SO_4, TDS, conductivity and turbidity as shown in Fig. 2.

Conclusion

In this study, it has shown that non-roof harvested rainwater may be contaminated by atmospheric pollutants and particulate matters, considering the values of the physiochemical parameters obtained of which most of them are above the standard permissible limits by NSDWQ and WHO. This makes the water unfit for human consumption, with potentiality of causing health effect and possibly death.

It is a very important to monitor harvested rainwater and treat it appropriately before using it for domestic purposes. With the values of the physicochemical parameters and heavy metals recorded in this study, the residents of Enugu urban must ensure that they treat their harvested rainwater before consumption. A further study for an affordable treatment protocol is suggested for households and industries in Enugu.

Table 3 Pearson correlation of the physicochemical properties parameters in the non-roof rainwater

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	1														
2	−.742**	1													
3	−.764**	.992**	1												
4	−.639**	.927**	.942**	1											
5	.683**	−.453*	−.426*	−.252	1										
6	−.436*	−.131	−.103	−.218	−.290	1									
7	−.044	−.447*	−.407*	−.513**	−.201	.548**	1								
8	−.301	.402*	.419*	.439*	−.177	.118	−.346	1							
9	−.261	.137	.105	−.193	−.606**	.281	.260	−.110	1						
10	−.163	−.426*	−.370	−.437*	−.317	.579**	.528**	−.157	.306	1					
11	.026	.158	.246	.429*	.485*	−.147	−.252	.523**	−.609**	−173	1				
12	.590**	−.502**	−.467*	−.321	.956**	−.207	−.098	−.256	−.583**	−.177	.409*	1			
13	.607**	−.558**	−.511**	−.373	.897**	−.040	.002	−.364	−.439*	.020	.391*	.874**	1		
14	−.421*	.280	.313	.130	−.025	.168	−.190	.215	.278	.131	.089	.122	−.028	1	
15	−.188	.489**	.514**	.451*	.073	−.130	−.470*	.798**	.037	−.364	.564**	−.008	−.124	.526**	1

1: pH, 2: conductivity (µs/cm), 3: TDS (mg/l), 4: sulphate (mg/l), 5: nitrates (mg/l), 6: phosphate (mg/l), 7: colour (Pcu), 8: turbidity (NTU), 9: copper (mg/l), 10: chromium (mg/l), 11: nickel (mg/l), 12: manganese (mg/l), 13: zinc (mg/l), 14: lead (mg/l), 15: cadmium (mg/l)

**. Relationship notable at 0.01 level (2-tailed).; *. Relationship notable at 0.05 level (2-tailed)

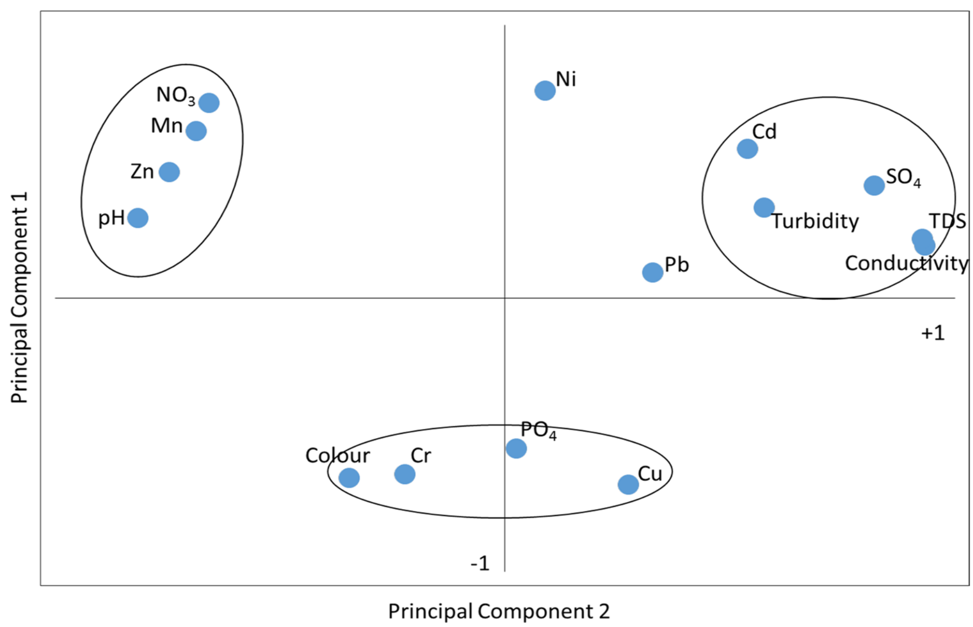

Fig. 2 Factor ordination and cluster of physicochemical properties of the non-roof harvested rainwater

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Declarations

Conflict of interest The authors have no conflict of interest to declare that are relevant to the content of this article.

Ethical approval Not applicable.

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