# Federal Polytechnic Ilaro

## Journal of Pure & Applied Sciences {FEPI- JOPAS}

Published by:

The School of Pure and Applied Science

The Federal Polytechnic Ilaro, Ogun State, Nigeria.
https://fepi-jopas.federalpolyilaro.edu.ng
E-mail:fepi.jopas@federalpolyilaro.edu.ng

ISSN: 2714-2531


Federal Polytechnic Ilaro
Journal of Pure and Applied Sciences
(FEPI-JOPAS)

DECEMBER
2022
EDITION

Vol. 4
Issue 2

## FOREWORD

It is with great delight I welcome you to volume 4 issue 2 of Federal Polytechnic – Journal of Pure and Applied Sciences (FEPI-JOPAS). It is a peer-reviewed open-access multi-disciplinary Journal of global recognition which is referenced and indexed in African Journal Online (AJOL). It is a highly commendable Journal that publishes excellent research contributions and exhibiting also special attention to experience papers coming from the many application areas of pure and applied Sciences. FEPI-JOPAS publishes full-length research work, short communications, critical reviews and other review articles.

The aim of FEPI-JOPAS is to provide intellectual bedrock for both indigenous and international scholars with quality research outputs to express and communicate their research findings to a broader populace. It serves as a valuable platform for the dissemination of information to 21st Century researchers, professionals, policymakers, manufacturers, production staff, R & D personnel as well as governmental and non-governmental agencies. It also aimed to provide a platform for academics and industry practitioners to share cases on the application of management concepts to complex real-world situations in pure and applied sciences and related fields.

This volume 4 issue 2 of FEPI-JOPAS is loaded with quantum and well-featured diversity of trending topics in applied and basic research. These hot and trending topics are: Sustainable Art and Design: Activating Sighting as the Phenomenon of Representational Drawing; Assessment of Heavy Metals in Processed Meat (Tinko) Sold within Igbesa Community; The Hypoglycemic Effect of Musa Sapientum in Alloxan Induced Diabetic Albino Wistar Rat; Rainwater Quality Evaluation for Agricultural Use: Case Study of a Portland cement Producing Area; Analytical Approach to Investigating the Influence of Blood Group and Blood Genotype on the Performance of Students of Federal Polytechnic, Ilaro; Dough Mixing Time: Impact on Dough Properties, Bread-Baking Quality and Consumer Acceptability; Chemical Composition of Harvested Rainwater Around a Cement Factory in Ibeshe, Yewa North, Ogun State.

Furthermore, other topics to be encountered in this issue that have added colour and beauty to this edition are: Physicochemical properties and sensory evaluation of milk candy ‘toffee’ (a

NIGERIA candy) enrich with coconut, tigernut and groundnut; Informal Settlements in Developing Countries: Issues, Challenges and Prospects; Comparison of Sensory Properties of Meals Produced from Cowpea and Pigeon Pea; Automated Lecture Timetable Generation Using Genetic Algorithm; Septic Tanks Contamination in Groundwater Quality around Elementary Schools in Ibadan, Oyo State Nigeria; and Waste Disposal Systems in Some Selected Abattoirs Located in Ilaro Metropolis. FEPI-JOPAS has been centered on discerning the changing needs of the academic world and is committed to advancing research around the world by publishing the latest research in various academic fields and ensuring that the resources are accessible in print, digital, and online formats.

In addition, I would like to thank many people who worked so hard to ensure that publishing this issue 2 of volume 4 is a reality. I would like to thank the Editorial Board for their guidance and the publishing team for the continued support and effort in streamlining the publication process. I am grateful to the reviewers who provided timely and constructive reviews for the papers assigned to them. The authors are solely responsible for the information, date and authenticity of data provided in their articles submitted for publication in the Federal Polytechnic Ilaro – Journal of Pure and Applied Sciences (FEPI-JOPAS).

I am looking forward to receiving your manuscripts for the subsequent publications. You can visit our website (https://fepi-jopas.federalpolyilaro.edu.ng) for more information, or contact us via e-mail us at fepi.jopas@federalpolyilaro.edu.ng

Thank you and best regards.

Prof. Olayinka Oyewale AJANI

(Editor-in-Chief)

## TABLE OF CONTENTS

https://fepi-jopas.federalpolyilaro.edu.ng Experimental

# Chemical Composition of Harvested Rainwater around a Cement Factory in Ibeshe, Yewa North, Ogun State

**Oguntade B.K[1*] Ajibode C.P[1]**

*Department of Science Laboratory Technology, School of Pure and Applied Sciences, Federal Polytechnic, Ilaro*

✉ ***bukunola.oguntade@federalpolyilaro.edu.ng***

**Abstract**

This study assessed the physicochemical properties of rainwater in Ibeshe, an area around the Dangote Cement factory in Ogun State. Rainwater samples were collected as bulk precipitation from April – September 2022 at weekly intervals. Collected rainwater samples were analyzed for basic composite variables (pH, electrical conductivity, temperature, and total dissolved solids using a portable pH meter and conductivity meter respectively), and major cations (magnesium, sodium, calcium, iron, arsenic, lead, and silicon). The AGILENT 720 ICP-OES was used for $Mg^{2+}$, $Na^{+}$, $Ca^{2+}$, $Fe^{2+}$, $K^{+}$, and $Pb^{2+}$. All the results obtained show that rainwater in the study area was basic (6.73 – 7.63) and all the parameters were within the WHO limit. Also, it was observed that the activities of the cement mining plant had little or no influence on the chemistry of the rainwater in the study area.

**Keywords: rainwater, cations, cement, chemical, composition.**

## INTRODUCTION

One of the fundamental human rights is access to clean and affordable water. Water is essential to life and is also a life foundation for the social and economic development of any country (Adeniyi and Olabanji, 2015). Among the natural resource available to mankind, water constitutes one of the most precious resources, without it there will be no form of livelihood (Ikotun et al., 2012). Rainwater is one of the many sources of water. The chemical component of rainwater is characterized by the environment where it falls. It has been reported that about 36 % of the world's population experiences a water crisis. Also, it has been documented that countries whose water resource is below 200 $m^3$ per capita per year may face difficulties in meeting their population water demand while those below 1000 $m^3$ per capita per year are considered to be a water deficit (Orlińska-Woźniak et al., 2013).

In most rural and urban areas of Nigeria, the availability of potable water is a major challenge and a poverty-related phenomenon. Around the globe, there is an evident similar scenario (Ashbolt, 2004). Nigeria as a country is already faced with a shortage of water supply despite all of the available land water resources in all the climatic zones of the country. This is because of the increase in human population, urbanization, poor implementation of water policies, pollution, and inadequate infrastructure (Olowoiya and Omotayo, 2010).

Rainwater harvesting is a procedure widely used to provide and supply portable and non-portable water to consumers most especially in developing countries like Nigeria where the potable water is insufficient to meet the increasing needs of the people due to rapid industrialization and development as well as population growth or to supplement the supply of water by easing the burden of collection from other points or sources (Olaoye and Olaniyan, 2012; Vikaskumar et al., 2007). Of all the ways that rainwater is harvested, the collection from household roof runoff is the most common way of harvesting rainwater. The many advantages of rooftop runoff like cost effectiveness, less contamination, and ease of maintenance for effective long-term system operation in comparison to the other methods like ground catchment system makes it the most common. The roof catchment method also supplies water at the consumption point (Gould and Nissen-Peterson, 1999). The rooftop runoff harvest is also very relevant in areas with a significant amount of rainfall but lacks conventional water supply sources. Despite its many advantages over other water sources, rainwater use is often rejected because of concerns about water quality (Chang et al., 2004).

Several factors influence the chemical composition of rainwater, some of which include natural and anthropogenic emissions. Other factors include some of the chemical and physical reactions that take place in and below the clouds. A lot of factors like the local and long-range transport of gases, meteorological conditions, the geographical distribution of the emission sources and their emission profiles, and removal of chemicals by rain are related to the acidity and concentration of the chemical species present in rainwater (Celle-Jeanton et al., 2009; Strayer et al., 2007). Household roofs give or provide a very good and ideal surface for a catchment in the harvest of rainwater provided that the roof materials are clean and without contamination. Rainwater contamination may occur from a number of the materials that the rainwater comes in contact with, the first of which is the atmosphere. Rainwater could dissolve gases and wash off chemicals from contacting dust particles (Quek and Forster, 1993).

The chemistry of rainwater has raised a lot of environmental concerns and thus has been considered a matter of global concern especially during the last three decades because of the observed detrimental environmental effects (Keresztesi et al., 2020). This has resulted in a wide investigation in both urban and rural environments (Keresztesi et al., 2020; Pu et al., 2017). Several research work has been carried out on the chemical composition of rainwater harvested from the Southwestern part of Nigeria, but data on rainfall chemistry in the location does not exist (Tobin et al., 2013; Eletta and Oyeyipo, 2008; Adekola et al., 2001). Therefore, the objective of this present study was to determine the chemical composition of rainwater harvested in Ibeshe, Ogun State.

## MATERIALS AND METHODS

### Study Area

The research was carried out in Ibeshe, a Yoruba-speaking community located in the Yewa South Local Government Area of Ogun State, Nigeria between Latitude 6° 57' 33" N and Longitude 3° 2' 15" E. The vast community is Yoruba, but other ethnic groups are represented including Igbo and Hausa. The community is home to The Dangote Cement Plant which has a capacity of about 12,000 TPD (tonnes per day) of clinker output ("Dangote Cement" 2022).

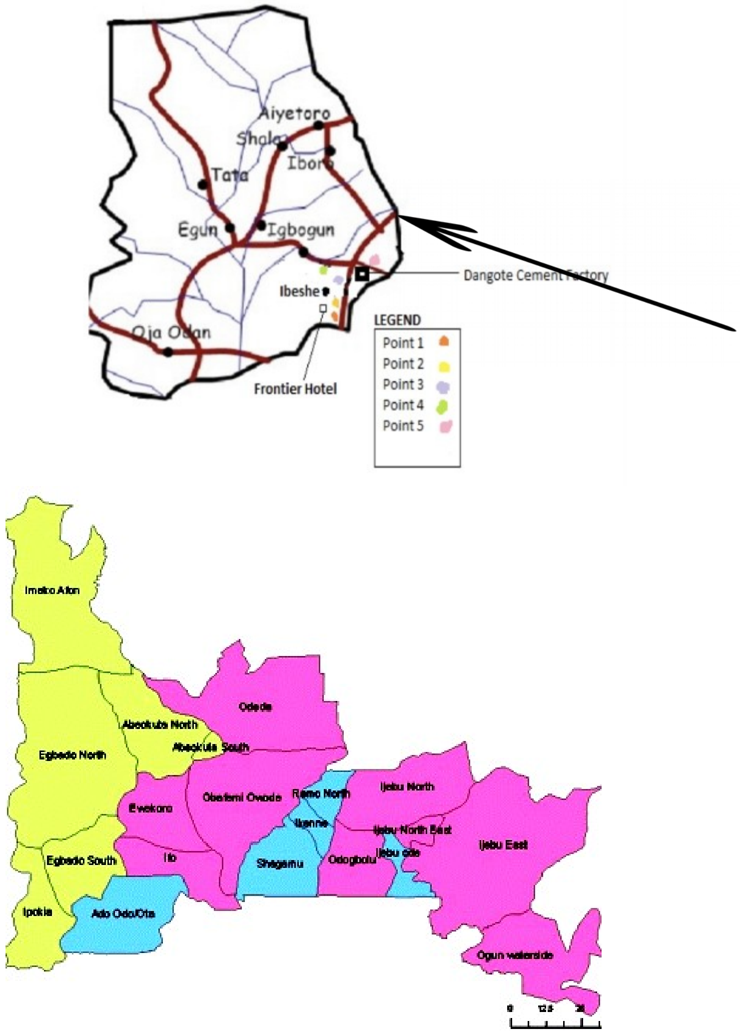


Figure 1: Map of Ibeshe showing Dangote cement factory and the five sampling points.

**Sampling**

Rainwater samples were collected from April- Sept 2022. Roof-top run-off collections were obtained at a weekly event. The materials used as bulk sampler consist of a 5 L high-density polyethylene (HDPE) bottle connected to a 20 cm diameter HDPE funnel. The collector was placed on a stand at a height of 2 m above ground level to prevent contamination from the ground around the sampling points. Prior to collection, sample bottles were thoroughly washed, rinsed with 20 % nitric acid, and rinsed severally with distilled water. At the end of each rain event (weekly), the funnels and collection bottles were replaced with another that has been previously washed and cleaned. The sampling mediums were divided into two. One bottle was used for the analysis of pH, Electrical conductivity (EC), Total Dissolved Solids (TDS), and Temperature, while the other was used for the metal analysis. Preservation of samples for heavy metals was achieved using concentrated $HNO_3$ on-site and refrigerated at 4°C before the analysis. The measurement of pH was done in the unfiltered fraction using a previously calibrated portable HANNA pH Meter. Electrical Conductivity (EC), Temperature ($T^0$), and Total Dissolve Solids (TDS) were measured on-site with a previously calibrated portable MRC CD-43075D Conductivity Meter. For the analysis of metals, a 100 mL aliquot of well-mixed samples were measured into beakers, 7 ml of aqua regia was added and heated to a temperature in the range of 90 - 95$^0$C without allowing it to boil. The beaker was removed and allowed to cool, and digest was washed down with deionized water, filtered and made up to 100 mL using deionized water. Analysis of the samples for cations, Magnesium ($Mg^{2+}$), Sodium ($Na^+$), Calcium ($Ca^{2+}$), Iron ($Fe^{2+}$), Potassium ($K^+$), and Lead ($Pb^{2+}$) was done using the AGILENT 720 ICP-OES (Baird et al., 2017).

## RESULTS and DISCUSSION

The results of the physical and chemical analysis are presented in Table 1 below:

**Table 1:** Result of Physicochemical Parameters (Mean ±SD)

| Sample Location | pH | Temp (°C) | EC (µS/cm) | TDS (mg/L) | $Ca^{2+}$ (mg/L) | $Mg^{2+}$ (mg/L) | $Na^{+}$ (mg/L) | $K^{+}$ (mg/L) | $Fe^{2+}$ (mg/L) | $Pb^{2+}$ (mg/L) |
|---|---|---|---|---|---|---|---|---|---|---|
| **Site 1** | 7.15 ± 0.21 | 30.40 ± 3.39 | 35.40 ± 8.20 | 23.50 ± 5.23 | 9.15 ± 2.56 | 0.75 ± 0.11 | 4.70 ± 0.08 | 2.17 ± 0.16 | 0.04 ± 0.5 | 0.04 ± 0.02 |
| **Site 2** | 6.73 ± 0.25 | 28.65 ± 1.63 | 54.25 ± 15.91 | 36.35 ± 10.96 | 15.08 ± 10.29 | 1.19 ± 0.63 | 3.28 ± 0.52 | 2.71 ± 0.71 | 0.01 ± 0.02 | 0.03 ± 0.02 |
| **Site 3** | 7.63 ± 0.04 | 30.6 ± 3.54 | 26.80 ± 13.72 | 17.95 ± 9.40 | 6.72 ± 1.26 | 0.57 ± 0.04 | 2.86 ± 0.79 | 1.90 ± 0.16 | 0.21 ± 0.23 | 0.06 ± 0.02 |
| **Site 4** | 7.33 ± 0.04 | 32.15 ± 0.64 | 97.70 ± 1.70 | 66.05 ± 0.31 | 24.66 ± 13.28 | 1.31 ± 0.62 | 3.72 ± 0.34 | 2.23 ± 0.15 | 0.05 ± 0.06 | 0.08 ± 0.01 |
| **Site 5** | 7.45 ± 0.21 | 33.15 ± 1.48 | 122.40 ± 4.67 | 81.75 ± 2.76 | 26.39 ± 10.42 | 1.53 ± 0.55 | 5.24 ± 1.87 | 3.18 ± 1.89 | 0.03 ± 0.04 | 0.05 ± 0.02 |
| **WHO** | 6.5 - 8.5 | 20 – 32 | 1200 | 1000 | 250 | 150 | 200 | 12 | 0.3 | 0.01 |

The pH of the rainwater in all samples in this analysis ranged between 6.73 – 7.63 indicating the basic characteristics. This could be attributed to the presence of dust particles which contain particles of alkaline compounds such as calcium carbonate (Özsoy and Cemal, 2000). However, the value was within the WHO range of 6.5 – 8.5 for potable water (WHO, 2011). It would be expected that the rainwater should be acidic because of the proximity of the study area to a cement mining site where gases are constantly being flared. The dissolution of these gases and other mineral particles can induce acidity in the rainwater. Another factor may be anthropogenic resulting from bush burning, and vehicular emissions. This is in line with the results from Ogbeide et al., 2022 where rainwater samples from six (6) different locations in Ebonyi State close to a mining site were observed to be acidic at four of these locations with values ranging between 4.35 – 4.70, a slightly acidic pH of 5.40 for the fifth location and a pH of 6.79 for the sixth location.

The conductivity values obtained fell within the range of 26.80 – 122.40 µS/cm and are lower than the WHO limit. This is different from the values obtained by Ikhioya et al., 2016 in Rivers state with values in the range of 40 – 66 µS/cm and those obtained by Mendez et al., 2010 with values in the range of 18 - 61 µS/cm. However, these values are within the permissible limit and are considered safe. It has been postulated that low electrical conductivity concentrations of rainwater show less pollution of the atmosphere with particulate matter (Cobbina et al., 2013). We can infer that the low values for conductivity in this study indicate good atmospheric environmental quality.

The results obtained for TDS ranged between 17.95 – 81.75 mg/L. TDS in rainwater is usually caused by naturally occurring environmental features like carbonate deposits, and salt deposits that accumulate on roofs. It also includes pollutants such as leaves, dust, and animal dung. Pollutants like sulfur and nitrogen oxide can also dissolve in the rainwater from the air (Cruden, 2015). The values obtained for TDS when compared to the WHO limit of 1000 mg/L are a small fraction and therefore, the water is safe with regards to the presence of Total Dissolved Solids.

The results for $Ca^{2+}$ ranged from 7.33 – 34.05 mg/L and this is far lower than the WHO permissible limit of 250 mg/L. According to Oyelude et al., 2013, the sampled rainwater may be classified as soft as a result of <50 mg/L concentration of $Ca^{2+}$. The $Mg^{2+}$ content obtained in this study was in the range of 0.57 – 1.53 mg/L and this was within the permissible limit of 150 mg/L. Amponsah et al. (2015) and Adetunji et al. (2008) also obtained results in similar ranges of 0.18 – 2.40 and 1.5 – 1.53 mg/L respectively. Mg is an important mineral in human nutrition, and it acts as a cofactor and activator of a lot of enzymatic reactions in the human body (Ahmad and Bajahlan, 2009). Mg, as well as Ca, make water hard. Although, there is currently no evidence of any adverse effect particularly attributed to these two (Oyelude et al, 2013), their low concentrations in soft water (water low in calcium and magnesium) can cause diseases. The association of soft water with mortality and morbidity from cardiovascular diseases has been reported by Donato et al, 2003.

The concentration of $K^+$ levels ranged from 2.01 – 4.52 mg/L and was within the WHO limit. As reported by Ceron et al., 2008 and Shukla and Sharma 2010, the presence of K might be caused by biomass burning and fossil fuel combustion. This could be a potential source of potassium as there are a lot of vehicular activities in the study area. Although the levels of potassium in this study are within the safe limits, it is very unlikely for adverse effects to occur from the ingestion of potassium in healthy humans and this is because of its fast rate of leaving the body through excretion in the absence of pre-existing kidney damage (Flythe et al., 2021).

The concentration of $Fe^{2+}$ in all the samples ranged from 0.00 – 0.38 mg/L with site 3 recording the highest value while the other sampling locations had values that were below the permissible limit of 0.3 mg/L. This is similar to the results obtained by Williams and Tighiri, 2015 with a Fe range of 0.078 - 0.991 mg/l. The high value of iron recorded for site 3 could be due to the presence of old iron sheets in the area (Rawan et al., 2022). Fe is an essential element that is required by all living organisms in small quantities (Crichton 1991). However, if it is present in a quantity more than is required, it causes acute toxicity in the physiological systems of human beings which eventually leads to diabetes and diseases of the lung, liver, and lungs. Other implications could also include a maladjusted immune system and hormonal abnormalities. The presence of Fe in water in high quantities makes water bitter, colored, and also leaves the water with a characteristic odor (Gurzau et al. 2003).

The observed values for Na were in the range of 2.07 – 7.10 mg/L and were found to be far lower than the WHO limit of 200 mg/L. These results, although lower are similar to the results obtained by Amponsah et al., 2015 in the range of 0.05 – 2.01 mg/L. The concentration of Na in rainwater is usually lesser than 20 mg/L but it can exceed this level in some places due to the pollution of the environment. There has been no adverse health effects associated with Na levels in water due to the lack of evidence. Therefore, no health-based limit has been proposed but if it exceeds 200 mg/L, Na may give rise to an unpleasant and unacceptable taste (WHO, 2017).

The concentration of $Pb^{2+}$ ranged from 0.03 – 0.08 mg/L, showing a higher value than the permissible limit of 0.01 mg/L. The water can be considered unsafe in this regard (WHO, 2011). The results obtained in this study are in line with those obtained by Sazarkli et al. (2007) with $Pb^{2+}$ values in the range of 2.0 – 6.9 mg/L, Al-Momani et al., 2008 with 1.98 – 3.60 mg/L and Radaideh et al., 2009 with 0.23 – 4.41 mg/L also having lead concentrations higher than the WHO permissible limit value of 0.01 mg/L. The possible sources of lead in rainwater are usually vehicular exhaust and discharge from industries which have risen a lot due to the presence of the cement plant in the area. Lead which ranked second on the 2015 hazardous materials list has been identified as a possible carcinogen and this is because there is a lack of solid proof of its carcinogenic abilities (ATSDR 2015). It has been associated with various adverse health effects such as anemia and also affects the reproductive organs (Kumar and Puri, 2012; Flora *et al.*, 2011; Renner, 2010).

## CONCLUSION

In this study, the chemical and physical composition of the rainwater collected in the study area were analyzed for the quantification of pH, temperature, and major ions, with the purpose to obtain and provide data on the quality of the rainwater in the area. The rainwater quality was expected to be influenced by the proximity to the Cement Plant as the rainwater was harvested directly and not from any catchment surfaces. However, the results of this study show that the analyzed parameters were not a big issue as their concentrations were usually below the recommended WHO permissible limits with the exception of Pb. It has however been proven that environmental factors usually have a negative impact on harvested rainwater quality. Therefore, the public should be educated on the harmful effects associated with the usage and consumption of untreated rainwater. It can also be concluded that more attention needs to be given to the other water quality parameters like turbidity, alkalinity, anion content, microbiological parameters, etc.

## REFERENCES

Abdullah, S.N.F., Ismail, A., Juahir, H., Ahmad, R.B., Lananan, F., Hashim, N.M., Ariffin, N., Zali, M.A., Mohd, T.A.T., Hussin, M.H.F., Mahmood, R.I.S.R, Jamil, J.R.A., Desa, S.M. (2021). Chemical composition of rainwater harvested in East Malaysia. Environmental Engineering Research. 27(2) 200508.
https://doi.org/10.4491/eer. 2020.508

Adekola, F. A., Eletta, O. A. A. and Atanda, S. A. (2001). Some heavy metals concentration in rainwater run-off on paved roads in Lagos and Ilorin, Nigeria, *Academy Journal of Science and Engineering*, 1, 88-96.

Adeniyi, I. F., Olabanji, I. O., and State, O. (2005). The physico-chemical and bacteriological quality of rainwater collected over different roofing materials in Ile-Ife , southwestern Nigeria. *Chemistry and Ecology*, *21*(3), 149–166. https://doi.org/10.1080/02757540500117318.

Adetunji, M. B., Eludoyin, A. O. and Tanimola, M. (2018). An Evaluation of Rainwater Quality around a Cement Producing Firm in Southwest Nigeria. *Savanna* 24(2), 86-96.

Agbede, T. O., Ayedun, H., and Umar, B. F (2015). Major and Trace Elements in Rainwater Collected from Industrial and Non-Industrial Areas of Ogun State, Nigeria. *Journal of Chemical Society, Nigeria*, 40 (1), 19-23.

Keresztesi, Á., Nita, I., Boga, R., Birsan, M., Bodor, Z., and Szép, R.E. (2020). Spatial and long-term analysis of rainwater chemistry over the conterminous United States. *Environmental research*, *188*, 109872.https://doi.org/10.1016/j.envres.2020.109872.

Ahmad, M. and Bajahlan, A. S. (2009). Quality comparison of tap water vs. bottled water in the industrial city of Yanbu (Saudi Arabia). *Environmental Monitoring and Assessment*, 159, 1-14.

Ashbolt, N. J. (2004). Microbial contamination of drinking water and disease outcomes in developing regions. *Toxicology*, *198*, 229–238. https://doi.org/10.1016/j.tox.2004.01.030

B. Walna, I. Kurzyca, E. Bednorz, L. Kolendowicz (2013). Fluoride pollution of atmospheric precipitation and its relationship with air circulation and weather patterns (Wielkopolski National Park Poland). *Environmental Monitoring and Assessment*, 185, 5497-5514.

Báez, S., et al. (2013). Effects of Experimental Rainfall Manipulations on Chihuahuan Desert Grassland and Shrubland Plant Communities. *Oecologia*, 172, 1117-1127. https://doi.org/10.1007/s00442-012-2552-0.

Bashir, M. T., Ali, S. and Bashir, A (2012). Health Effects from Exposure to Sulphates and Chlorides in Drinking Water. Pakistan Journal of Medical and Health Sciences 6(3):648-652.

Bonvicini G., Fregni, A., and Palmonari, C., 2006. Fluorine compounds in gaseous emissions from industrial sources: The case of ceramic industries. In: Tressaud, A. (Ed.), Fluorine and the Environment, Atmospheric Chemistry, Emissions, & Lithosphere, Vol 1, Chap 7. Elsevier, 225-249.

Candelone, J., Hong, S., Pellone, C. and Boutron, C.F. (1995). Post-Industrial Revolution changes in large-scale atmospheric pollution of the northern hemisphere by heavy metals as documented in central Greenland snow and ice. *Journal of Geophysical Research 100: doi: 10.1029/95JD00989. issn: 0148-0227.*

Cape, J.N., Fowler, D., Davison, A., 2003. Ecological effects sulphur dioxide, fluorides, and minor air pollutants: recent trends and research needs. *Environment International*, 29, 201-211.

Celle-Jeanton, H., Travi. Y., Loye-Pilot, M. D., Huneau, F., and Bertrand, G. (2009) Rainwater chemistry at a Mediterranean inland station (Avignon, France): local contribution versus long-range supply. *Atmospheric Research*, 91: 118-126.

Chang, M; McBroom, W and Beasley, R. (2004). Roofing as a source of non-point water pollution. *Journal of Environmental management.* 73(4): 307-315.

Cobbina, S. J., Michael, K., Salifu, L., and Duwiejua, A. B. (2013) Rainwater quality assessment in the Tamale Municipality. *International Journal of Scientific & Technology Research;* 2(5): 1-10

Cruden, A., Rainwater, Why It Is Safe, IWA Water Wiki, 2015.

EC – European Commission: Directive 2007/60/EC of the European Parliament and of the Council of 23 October 2007 on the assessment and management of flood risks (Floods Directive), 2007.

Eletta, O. A. A. and Oyeyipo, J. O (2008). Rainwater harvesting: effect of age of roof on water quality. *International Journal of Applied Chemistry*, 4, 157—162.

Flora, S. J., Pachauri, V. and Saxena, G. Academic Press; 2011. Arsenic, cadmium, and lead. Reproductive and Developmental Toxicology; pp. 415–438.

Flythe, J. E., Assimon, M. M., Tugman, M. J., Chang, E. H., Gupta, S., Shah, J., Sosa, M. A., Renaghan, A. D., Melamed, M. L., Wilson, F. P., Neyra, J. A., Rashidi, A., Boyle, S. M., Anand, S., Christov, M., Thomas, L. F., Edmonston, D., Leaf, D. E., and STOP-COVID Investigators (2021). Characteristics and Outcomes of Individuals with Pre-existing Kidney Disease and COVID-19 Admitted to Intensive Care Units in the United States. *American journal of kidney diseases: the official journal of the National Kidney Foundation*, 77(2), 190–203.

Galán, E., González, I., and Fabbri, B. (2002). Estimation of fluorine and chlorine emissions from Spanish structural ceramic industries. The case study of the Bailén area, Southern Spain. *Atmospheric Environment.* 36, 5289-5298.

Gould, J. and Nissen-Peterson, E. (1999) Rainwater Catchment Systems for Domestic Supply. IT Publications Ltd.

Ikhioya, P., Charles, I.O., and Obuzor, G.U. (2016). Physiochemical characteristic of Harvested Rain water from Bodo Community in Rivers State, Nigeria. *Journal of Applied Sciences and Environmental Management*, *19*, 671-677.

Ikotun, O. O., Olafusi, O. S., Quadri, H. A., & Bolarinwa, O. A. (2012). Influence of Human Activities on the Water Quality of Ogun River in Nigeria. *Civil and Engineering Research*, *2*(9), 36–48.

John Wiley and Sons Inc., ( 1993) Aquatic Pollution. E.A. Laws., ,. 2nd ed. pp 148-149. New York

Kumar, M., and Puri, A. (2012) A Review of Permissible Limits of Drinking Water. *Indian Journal of Occupational and Environmental Medicine*, 16, 40-44.

Mainston, C. P., & Parr, W. (2002). Phosphorus in rivers--ecology and management. *The Science of the total environment*, *282-283*, 25–47. https://doi.org/10.1016/s0048-9697(01)00937-8

Mendez, B. C., Brigit, R. A., Kerry, K., Micheal, E. B., and Mary, K. (2010). Effect of Roof Material on Water Quality for Rainwater Harvesting Systems. Texas water Development Board Report, p. 2

Nguyen, K., Zhang, H., Stewart, R. A. (2013). Development of an Intelligent Model to Categorize Residential Water End Use Events. *Journal of Hydro-Environment Research*, 7, 182–201.

Ogbeide, O., Kanu, M., Ossi, E., Ossai, I., and Nworu, J. (2022). Comparative assessment of physico-chemical properties of rainwater in ishiagu south-south-eastern region of Ebonyi state, Nigeria. *International Journal of Current Research*. 14. 20512. 10.24941/ijcr.43017.01.2022.

Olaoye, R.A. and Olaniyan, O.S. (2012). Quality of rainwater from different roof material. *International Journal of Engineering and Technology*, 2(8), 1413-1420.

Olowoiya, O. and Omotayo, A. (2010). Assessing the Potential for Rainwater Harvesting. *Water Resourse Management*, *24*, 2129–2137.

Orlińska-woźniak, P., Pawel, W., and Gębala, J. (2013). Water availability in reference to water needs in Poland. *Meteorology Hydrology and Water Management*, *1*(1), 45–50.

Özsoy, T. and Cemal, S.A. (2000). Acidic and alkaline precipitation in the Cilician Basin, north-eastern Mediterranean Sea. *Science of the Total Environment*, 253 (1–3): 93–109.

Pu, W., Quan, W., Ma, Z., Shi, X., Zhao, X., Zhang, L., Wang, Z., and Wang, W. (2017). Long-term trend of chemical composition of atmospheric precipitation at a regional background station in Northern China. *Science of the Total Environment*, 580: 1340–1350. DOI:

https://doi.org/10.1016/j.scitotenv.2016.12.097.

Quek, U, and Forster, J. (1993). Trace metals in roof runoff. *Water, Air, and Soil Pollution* 68(3–4):373–389

Renner, R. (2010). Exposure on tap: Drinking water as an overlooked source of lead. *Environment Health Perspectives*, 118:A68–A74.

Saether, O., Andreassen, B. T. and Semb, A. (1995). Amounts and sources of fluoride in precipitation over southern Norway, *Atmospheric Environment*, 29, 1785–1793.

Strayer, H., Smith, R., Mizak, C. and Poor, N. (2007). Influence of air mass origin on the wet deposition of nitrogen to Tampa Bay, Florida – an eightyear study. *Atmospheric Environment*, 41, 4310–4322.

Terer, E., Kipngetich, M., Hillary, T. and Thangiah, A. S (2013). Determination of levels of phosphates and sulphates in domestic water from three selected springs in Nandi County, Kenya. *International Journal of Pharmacy & Life Sciences*, 4(7): 2828-2833.

Tobin, E. A., Ediagbonya, T. F., Ehidiamen, G. and Asogun, D. A (2013). Assessment of rainwater harvesting systems in a rural community of Edo State, Nigeria *Journal of Public Health and epidomology*, 5, 479- 487.

Vikaskumar, G. S., Hugh, D., Phillip, M. G., Peter, C., Timothy, K. R, and Tony, R. (2007). Comparison of water quality parameters from diverse catchments during dry periods and following rain events, *Water Research*, 41(16): 3655-3666.

Wang, H. and Han, G. (2011). Chemical composition of rainwater and anthropogenic influences in Chengdu, Southwest China. *Atmospheric Res*earch, 99(2), 190–196.

WHO (2011): Guidelines for drinking-water quality, 4th Edition, World Health Organization, Geneva.