Faculty of Natural and Applied Sciences Journal of Scientific Innovations
Print ISSN: 2814-0877 e-ISSN: 2814-0923
www.fnasjournals.com
Volume 6; Issue 1; September 2024; Page No. 19-26.

Evaluation of Microbiological and Physicochemical Quality of Borehole Water in Mini-Campus, Federal Polytechnic, Offa, Kwara State, Nigeria

[*1]Usman, K.M., [1]Popoola, O.D., & [2]Adigun, M. A.
[1]Department of Science Laboratory Technology, Federal polytechnic, Offa, Kwara State, Nigeria
[2]Department of Biological Science, Federal Polytechnic, Offa, Kwara State, Nigeria

***Corresponding author email**: muftau.usman@fedpoffaonline.edu.ng

Abstract
One of the reliable means of meeting up with rural water demands is through groundwater exploitation and Federal Polytechnic, Offa community is not an exception. Thus, the microbiological and physicochemical qualities of portable water (boreholes) sunk in the mini-campus Federal Polytechnic, Offa were investigated using pour plate and other conventional methods. The bacterial means count ranged between 1.33 -2.0 (x 10^6 CFU/ml). The bacteria presumptively identified from the water samples analyzed included *Bacillus* sp. and *Staphylococcus epidermidis*. Findings from physicochemical analyses recorded the highest values of alkalinity and hardness of 50.15 and 71.4 respectively for the sample of water collected from source designated AD. Findings from the determination of heavy metal in water samples revealed that samples collected from source designated G recorded the highest values for Cu, Fe and Co with 0.21, 0.32 and 0.14 ppm concentrations. Also findings from antibiotic sensitivity test on isolates from water samples confirmed ofloxacin the most potent antibiotic among the selected antibiotics. Thus, findings of this study suggest that water from which the samples were collected should be properly treated before consumption especially that water from source designated BG.

Keywords: Physicochemical properties, bacterial means count, heavy metals, antibiotics

Introduction

Owing to the purifying process that occurs in the soil, ground water is generally regarded as a great supply of potable water. Every day, an average of 1.5 billion people globally benefit from underground water (Giordano, 2009; Margatan & Van Der Gun, 2013; Guppy et al., 2018). Even while borehole water is drinkable, it can get tainted or contaminated and may not be as safe as people think (USEPA, 1982). Southeast Asia and Africa have the lowest rates of improved water and sanitation, making them the regions most impacted by faecal contamination of groundwater (Bain et al., 2014).Sources of water can be considered as either improved or unimproved on the basis of whether or not they are "protected from outside contamination" (Onda et al., 2012). Sources like public taps or standpipes, tube wells or boreholes, protected dug wells, protected springs and rainwater collection are considered improved (Bain et al., 2014). Water disposal facilities, industrial pollution, agricultural practices, atmosphere fallout, clearing of vegetation, over-abstraction of groundwater and excavation below the water table can serve as sources of groundwater pollution (Idehen, 2020). The pollutants do not only affect water quality but also threaten human health, economic development and social prosperity (Milovanovic, 2007).

Groundwater is universally accepted as a safe source of potable water because it is associated with a low microbial load which may require little treatment before drinking (Lobina & Mercy, 2015). However, a lot of bacterial, viral and protozoan pathogens are causing waterborne infections. Some are primarily enteric bacterial pathogens such as *Vibrio cholerae*, *Salmonella* spp, *Shigella* spp and recognized pathogens from faecal sources such as *E. coli* (Szewzyk et al., 2000). Pathogens of bacterial genera; *Legionella* spp, *Pseudomonas aeruginosa* and *Mycobacterium* spp are found in potable water usually in low numbers and grow within the distribution system biofilms (Szewzyk et al., 2000). Inadequate public water supply has made boreholes and wells an indispensable and integral part of water supply systems in rural and urban areas, especially in Nigeria (MacDonald & Calow, 2009; Calow et al., 2011). More than one billion people have no access to clean safe water worldwide. In Sub Sahara Africa up to 300 million rural people have no access to safe water supplies.

Cite this article as:
Usman, K.M., Popoola, O.D., &Adigun, M. A. (2024). Evaluation of microbiological and physicochemical quality of borehole water in Mini-Campus, Federal Polytechnic, Offa, Kwara State, Nigeria. *FNAS Journal of Scientific Innovations*, *6*(1), 19-26.

Groundwater is the main source of domestic water upon which a large population of the world especially in sub-Sahara Africa depends (Calow et al., 2011), this is because it is accessible anywhere, less capital intensive to develop and maintain and is less susceptible to pollution, seasonal fluctuation and naturally has good quality (Bresline, 2007).

Human welfare is linked directly with quality water because of its vital role in the life of mankind. According to Ranjana (2010), public health status depends to a greater extent on the quality of groundwater. However, groundwater is believed to be of higher quality compared to surface water, its quality is aggregate of the natural geology of the environment and anthropogenic influences such as withdrawal, land use change, and solid waste dumping (Chapman & Kimstach, 1996). Water quality parameters reflect the level of contamination in water resources and show whether or not the water is suitable for human consumption. The safety of potable water is dependent on the physico-chemical and microbiological parameters of water (MacDonald & Calow, 2009) and their analysis is crucial for public health and pollution studies (Kot, 2003). Thus, this study aimed at assessing physicochemical and microbiological qualities, and antibiotic susceptibility patterns of bacteria present in portable water (Borehole) in Mini campus Federal Polytechnic Offa, Kwara State, Nigeria, with the view to have information on the status of borehole water in the Federal Polytechnic, Offa, Kwara State Mini Campus. It also gives the school management insight into the quality of borehole water and measures of adequate treatment where necessary.

Materials and Methods

Collections of samples

The water samples were collected from four different boreholes (admin office, botanical garden, boys' hostel and NAAS garden) in the Mini Campus of the Federal Polytechnic Offa, Kwara State. The samples were collected in a sterile universal bottle, corked tightly to prevent cross-contamination, and brought to the laboratory to isolate and identify bacteria associated with borehole water.

Sterilization of Glassware and Working Environment

The glass wares which included Petri dishes, conical flasks, test tubes, beakers, and McCartney bottles were thoroughly washed with detergent, rinsed with distilled water, and sterilized at 160 °C for 1 hour in the oven. The workbench was disinfected with 75 % ethanol by mopping the surface with cotton wool moistened with 75% ethanol to reduce the microbial load of the working bench. An inoculating loop was dipped into the alcohol and then flamed but it was allowed to cool for seconds before use, while the liquid media were also sterilized using an autoclave at 121°C for15 minutes at 15 Pascal.

Preparation of media

The culture media used for this project were Nutrient Agar (NA) and Muller-Hinton Agar, they were prepared according to the manufacturer's instructions as stated on the container of the media.

Preparation of inoculums

This was carried out using a serial dilution technique where 1 ml of the sample (borehole water) was accurately measured and transferred into 10 ml sterile distilled water (serving as stock) and serially diluted into ten folds under aseptic conditions.

Isolation and enumeration of microbial population of borehole water sample

This was carried out using pour plate techniques. One millilitre (1 ml) of prepared inoculum from 10" and 10" diluents were aseptically transferred into about 20 ml of freshly prepared nutrient agar, rocked gently and allowed to set. The plates were made in duplicate alongside with control MSC (Medium Sterility Control) all were accurately labelled and incubated at 37 for 24 hours. The emergent colonies were counted using a colony counter and recorded accurately.

Preparation of pure isolates

After 24 hours of incubation, pure isolates were prepared from the mixed culture with the aid of a sterile wire loop, a distinct colony was taken and streaked on a freshly prepared solidified nutrient agar and incubated for 24 hours at 37 °C to get pure and distinct colonies. This was repeated severally for a satisfactory pure isolate to be obtained.

Identification of bacterial isolates

Cite this article as:
Usman, K.M., Popoola, O.D., &Adigun, M. A. (2024). Evaluation of microbiological and physicochemical quality of borehole water in Mini-Campus, Federal Polytechnic, Offa, Kwara State, Nigeria. *FNAS Journal of Scientific Innovations, 6*(1), 19-26.

The colonial morphological characterization was carried out based on the shapes, colour, size, edge, optical characteristics, surface texture, and consistency of the different colonies observed The cellular morphology was carried out by microscopic observation based on the arrangement of the cells, the shapes of the cells and the reaction of cells to the gram staining Further characterization and identification tests were carried out using some biochemical tests such as Catalase test, Indole test, Motility test and Coagulase test (Cheesbrough, 2010)

Antibiotics sensitivity test

The sensitivity of the bacterial species isolated was performed on Mueller-Hinton agar (MHA) (Merck) plates by disk diffusion method as described by the National Committee for Clinical Laboratory Standards (CLSI, 2017). About 0.1 ml of each bacterial isolate was seeded into the Petri dishes containing Mueller-Hinton agar and allowed to stand for 30 minutes to enable the inoculated organisms to pre-diffuse. The discs contain the following antibiotics: augmentin (AUG, 30ug). ofloxacin (OFL. 5ug), gentamicin (GEN,10ug), ceftazidime (CAZ 30ug), cefuroxime (CRX 30ug), cloxacillin (CXC 5ug), ceftriaxone (CTR 5ug), erthromycin (ERY 5ug), were placed on the surfaces of the sensitivity agar plates with sterile forceps and incubated aseptically at 37°C overnight. Zones of inhibition after incubation were observed and the diameters of inhibition zones were measured in millimetres

Physiochemical analysis of borehole water samples: The assessment of the physiochemical parameters of borehole water such as pH, temperature, total hardness, carbonate, bicarbonate, total solid, total dissolved solids, dissolved oxygen, biochemical oxygen demand and presence of minerals such as (Magnesium, chlorine and calcium) determined by method described by APHA (2005)

pH: The Jenway 1910 multipurpose set was used, the instrument is an automated digital one and handheld, the pointer (electrode) was dipped into 10ml of water sample and held in place for 2-3 minutes to stabilize the pH value was then read off the instrument while still in the water.

Temperature: A mercury-in-glass thermometer was used to measure the temperature. The thermometer was dipped into the water samples and held in place for 2-3 minutes to stabilize before taking the reading.

Total dissolved solid (TDS): The percentage of dissolved solids was determined gravimetrically. A measured volume of the water sample was filtered through Whatman No 42-grade filter paper. The Filtrate was used for the percentage of dissolved solids in the water samples.

Total Hardness (Using EDTA Titrimetric method): Fifty millilitres (50 ml) of the water sample was measured into a 250 ml conical flask. About 4ml of buffer solution and 6 drops of ferrochrome black T indicator solution were added prior to titration against 0.01 EDTA to the endpoint indicated by a distinct blue coloration. Titration was repeated for consistent titer was calculated. It was calculated this; total hardness ($MgCaCO_3$) = ML Titrant X 100ml/sample

Electrical conductivity: The electrode was wetted thoroughly and plugged into the conductivity meter (Cyber-Scan CON510) before it was inserted into a 250 ml beaker containing distilled water. The conductivity meter was switched on and zero error was corrected. The distilled water was replaced with sachet water samples and the electrode was inserted in each case. The system was allowed to stabilize and the reading was recorded.

Alkalinity determination: Fifty millilitres (50ml) of the sample was measured in a conical flask. Two drops of phenolphthalein indicator were added and the resulting mixture was titrated against a standard 0.10N H_2SO_4 solution until the pink colour disappeared. The burette reading was recorded and five drops of methyl orange indicator were added to the solution and titrated against the standard 0.10. N H_2SO_4 solution to the first permanent pink colour pH 4.5. The calculation was done using: Total Alkalinity= Ml titrant x Normality of acid x 50000/ml sample.

Heavy metals analysis: The heavy metals: Copper (Cu), Nickel (Ni), Iron (Fe), and Cobalt (Co) were determined by Perkin Elmer 2380 Flame Atomic Absorption Spectrophotometer. APHA method (2005) was followed during the preparation of samples to be analyzed

Statistical analysis of data: In order to give a lucid representation of the data analyzed, descriptive statistics such as mean, frequency, standard deviation, percentage and graph were used in the discussion of the results;

Statistical Package (IBM-SPSS) version 20 was used to test for the level of significance of the results obtained. Differences were considered significant at $p < 0.05$.

Results

Mean counts of bacteria isolates of borehole water samples (BWS)

The mean count of bacterial isolates from borehole water samples collected from Federal Polytechnic, Offa, Offa Local Government Area, Kwara State, Nigeria is shown in Table I. The findings revealed that water samples from sources designated with the letter D recorded the highest means bacterial count (2.0 $x10^6$ CFU/ml) while water samples from sources designated B and C recorded the lowest means count of 1.33 $x10^6$ CFU/ml and there was no significant difference among the values obtained in all samples of water analyzed at $p \leq 0.05$

Bacterial isolates from borehole water samples (BWS)

Using standard conventional methods, the bacteria presumptively identified to be present in samples of water obtained from sources designated with letters A and D included *Bacillus* sp. and *Staphylococcus epidermidis* while in samples of water from sources designated with letters B and C *Bacillus* sp. was presumptively confirmed present (Tables II and III.)

Physicochemical analysis of borehole water samples (BWS)

Findings from physicochemical analysis of water collected from boreholes sunk in Federal Polytechnic, Offa revealed that sample collected from source designated NA recorded the highest pH value of 6.165, while, samples from sources designated AD recorded the highest values for alkalinity and hardness of 50.15 and 71.4 respectively. Also, samples collected from a source designated BH recorded the highest values for conductivity and acidity of 71.4 and 66.2 respectively, while samples collected from a source with BG designation recorded the lowest value of 0.52 for chloride ion (Table IV).

Heavy metal (in ppm) in borehole water samples (BWS) analyzed

The findings from heavy metal analysis of borehole water samples collected from Federal Polytechnic, Offa revealed that samples collected from sources designated with the letter BG recorded the highest values for Cu, Fe and Co with 0.21, 0.32 and 0.14 ppm concentrations. However, none of the water samples contain Ni (Table V.)

Antibiotic sensitivity pattern of bacteria isolates of borehole water samples (BWS).

The findings from the antibiotic sensitivity pattern revealed that isolates from all boreholes' water samples **(BWS)** were all susceptible to ofloxacin and resistant to other antibiotics used (Table VI)

Results

Table I: Mean counts of bacteria isolated from borehole water samples (BWS)

S/N	Samples' sites	Samples' sites coordinate	Means population x 10^6 CFU/ml
1	AD	Lat. N8^O 8'1.08270 Long. E4^0 43'024950	1.67 ±0.58^a
2	BG	Lat. N8^O 8'1.09720 Long. E4^0 43'0.32540	1.33 ±0..58^a
3	BH	Lat. N8^O 8'1.092420 Long. E4^0 42'48.80290	1.33 ±0.58^a
4	NA	Lat. N8^O 8'0.68450 Long. E4^0 42'53.36880	2.00 ±0.00^a

Values are mean ±SD of replicates (n=3).
Values with the same alphabet in the same column are not significantly different while values with a different alphabet are significantly different ($\alpha < 0.05$)

Key: S/N = Serial Number, Lat= latitude, Long=longitude, AD=Admin Office, BG = Botanical Garden, BH= Boys Hostel, NA= NAASS borehole

Cite this article as:
Usman, K.M., Popoola, O.D., &Adigun, M. A. (2024). Evaluation of microbiological and physicochemical quality of borehole water in Mini-Campus, Federal Polytechnic, Offa, Kwara State, Nigeria. *FNAS Journal of Scientific Innovations, 6*(1), 19-26.

Table II: Bacteria isolated from borehole water samples (BWS)

S/N	Samples' sites	Samples' sites coordinates	Bacterial isolates
1	AD	Lat. N8^{O} 8'1.08270 Long. E4^{0} 43'024950	*Bacillus* sp. and *Staphylococcus epidermidis*
2	BG	Lat. N8^{O} 8'1.09720 Long. E4^{0} 43'0.32540	*Bacillus* sp.
3	BH	Lat. N8^{O} 8'1.092420 Long. E4^{0} 42'48.80290	*Bacillus* sp.
4	NA	Lat. N8^{O} 8'0.68450 Long. E4^{0} 42'53.36880	*Bacillus* sp. and *Staphylococcus epidermidis*

Key: S/N = Serial Number, Lat= latitude, Long=longitude, AD=Admin Office, BG= Botanical Garden, BH= Boys Hostel, NA= NAASS borehole

Table III: Conventional characterization of bacterial isolates from borehole water samples (BWS)

Serial number	Colonial morphology	Gram reaction	Shape	Structural arrangement	Catalase reaction	Indole test	Methyl red test	Simmon citrate test	Oxidase test	Vegetative	spore	Nitrate reduction	Coagulase test	hydrolysis	Motility	Glucose fermentation	Mointol	Hydrogen sulfide	Inositol fermentation	Microorganisms suspected
2	Circular, opaque, convex yellowish, smooth colony	+	Cocci	Clustered	+	-	-	Na	-	Ab	-	+	-	Na	-	Na	G	Nd	Na	*Staphylococcus epidermidis*
3	Cream, circular, smooth, entire	+	Bacilli	Singly	Na	Na	-	-	Na	Ab	-	Na	-	urea	Na	Na	Na	Na	Na	*Bacillus sp*

(+) = positive, (G) = Gas, (-) = negative, (Nd) = Not determined, (Na) = Not aplicable, (Ab) = Absent,(P) = Present (AG) =Acid and G

Table IV: Physicochemical Analysis of borehole Water samples (BWS)

S/N	Parameters	Water samples' sources			
		BH	BG	AD	NA
1	pH	5.62±0.014	5.43±0.007	5.63±0.000	**6.165±0.007**
2	Alkalinity	37.55±0.007	39.70±0.141	**50.15±0.007**	45.35±0.007
3	Hardness	60.4±0.000	42.05±0.007	**71.4±0.000**	36.35±0.007
4	Conductivity	**71.4±0.000**	28.6±0.000	24.2±0.000	42.6±0.000
5	Acidity	**66.2±0.000**	59.5±0.007	48.0±0.000	56.1±0.000
6	TDS	12.4±0.000	18.6±0.000	24.2±0.000	**38.4±0.000**
7	Chloride	0.60±0.000	**0.52±0.000**	**0.90±0.000**	0.87±0.000

Values are means ± S.D of replicate (n=3)

Key: S/N = serial number, BH = Boys Hostel, BG = Botanical Garden, AD= Admin Office, NA= NAASS Borehole

Table V: Heavy metal (in ppm) in borehole water samples (BWS)

S/N	Heavy metals	Water samples			
		BH	BG	AD	NA
1	Cu	0.03	**0.21**	0.12	0.01
2	Fe	0.10	**0.32**	0.04	0.06
3	Co	0.01	**0.14**	0.00	0.02
4	Ni	0.00	0.00	0.00	0.00

Key: S/N = serial number, Cu = copper, Fe = iron, Co= cobalt, Ni= Nickel, BH = Boy hostel BG = Biological Garden AD= Administrative block NA= NASS garden.

Table VI: Antibiotic susceptibility pattern of isolates from borehole water samples (BWS)

S/N	Isolates	Antibiotic used(mm zone of inhibition)									
		CXC	OFL	AUG	CAZ	CRX	GEN	CTR	ERY	MAR	MARI
1	*Bacillus* spp.	R	20	R	R	R	R	R	R	7	0.88
2	*Staphylococcus epidermidis*	R	22	R	R	R	R	R	R	7	0.88

Key: S/N = serial number, CXC = cloxacillin, OFL = oflaxacin , AUG = augumentin, CAZ = ceftazidine, CRX = cefuroxime , GEN = gentamincin, CTR= ceftriazone, MAR= Multiple Antibiotic Resistance, MARI = Multiple Antibiotic Resistance Index

Discussion

The means counts of bacteria isolated from the borehole water sample (BWS) recorded no significant difference at p< 0.05. The total aerobic counts of this study agreed with the findings of Ibe and Okplenye (2008) who reported 1.5 x 10^2 to 5.9 x 10^4 CFU/ml as mean counts of bacteria from borehole water in Uli, Nigeria. However, findings from the microbiological study of Ibe and Okplenye (2008) vary greatly from the findings of the present study, Ibe and Okplenye (2008) confirmed the presence of *Escherichia coli*, *Klebsiella* sp., *Proteus* sp., *Enterobacter* sp. and *Staphylococcus aureus*, the disagreement was due to difference in the location of borehole water (BWS) the later was located in an unsanitary environment, near a pit latrine. Drinking such water has been connected with a countless majority of health issues. Cholera and typhoid fever are diseases associated with microbiologically contaminated drinking water (WHO, 2022).Also, the isolated bacteria from this study was different from those isolated by Lobina and Mercy (2015), who isolated *Escherichia coli*, *Salmonella* species and *Klebsiella* species and found out that the water samples from the selected borehole water were a cause of concern for human consumption but bacteria isolated in this study showed that water samples within the region of the selected borehole are within the standard set by WHO (2011)

Analysis of the physicochemical properties of the borehole water samples in the study showed that they all fall within the acceptable level for all the water samples, this is in agreement with the findings of Abugu et al. (2022). The pH values of the selected boreholes ranged between 5.62 and 6.165 indicating the slightly acidic to slightly alkaline (near neutral) nature of the ground waters and well are within the limits prescribed for various uses of water including drinking water supplies (WHO, 2011). Also, the values obtained for the total dissolved solid (TSD) of the four borehole water samples analyzed are within the standard recommended by NSDWQ, WHO, and NAFDAC (500 mg/l). The values of chloride contents were within the permissible limits for drinking water, in agreement with WHO (2004). Chlorides become more toxic when they combine with other toxic substances such as cyanides. The accumulation in little quantities can also lead to severe contamination which may be undesirable to the consumers because of its health risk implications. Alkalinity is a measure of the substances in water that have the acid-neutralizing ability; alkalinity buffers against pH changes and makes water less vulnerable to acid rain. In the borehole selected and tested the mean range values are less than the recommended permissible limit. The primary cations posing hardness are calcium and magnesium. It is an undisputable fact that groundwater is much harder than surface water; maximum hardness was observed (71.4 ± 0.000 mg/l). The hardness may be beneficial since it averts the corrosion in the pipes by forming a thin layer of scale that diminishes heavy metal contamination from the pipe to the water but water with hardness greater than 500 mg/l may lead to heart and kidney problems and is not recommended for drinking purposes (Lobina & Mercy, 2015).

Cite this article as:
Usman, K.M., Popoola, O.D., &Adigun, M. A. (2024). Evaluation of microbiological and physicochemical quality of borehole water in Mini-Campus, Federal Polytechnic, Offa, Kwara State, Nigeria. *FNAS Journal of Scientific Innovations, 6*(1), 19-26.

Findings from analysis of the heavy metal content of borehole water samples (BWS) revealed that the values recorded for the principal heavy metals fall below the permissible limit as recommended by NAFDAC. Also, findings from the antibiotic sensitivity test confirmed ofloxacin the most potent antibiotic as it was previously observed by Usman et al. (2021). It was discovered in this study that the levels of main physicochemical parameters and heavy metal content are within tolerable limits in the Federal Polytechnic Offa, Mini Campus. This confirmed the suitability of the water sample sources for drinking purposes. However, treatment of sources that fell short of standard such as source designated BG before drinking was recommended.

Conclusion

Findings from this study confirmed that means count of bacteria from borehole water samples (BWS) ranged from 1.33 x 10^6 to 2.0 x 10^6 CFU/ml, bacteria isolated from borehole water samples included *Bacillus* sp. and *Staphylococcus epidermidis* where *Bacillus* sp. Was predominant. A borehole water sample (BWS) collected from a source designated with BG recorded high levels of copper (Cu), iron (Fe) and cobalt (Co), however, the value ranges fall within the acceptable limit set by NAFDAC and ofloxacin confirmed the most potent among the antibiotics selected.

Recommendations

1. Based on the findings of this study, the Polytechnic Management should organize health -talks for members of staff and students on the implications of drinking microbial-contaminated water, and on a regular basis school management should assess the quality of the borehole water in school premises.
2. Finally, water from the borehole designated BG requires treatment before consumption.

References

Abugu, N. A., Patrick, O. N., & Yero, A. B. (2022). Assessment of The Physicochemical Properties of Borehole Water in Gwagwalada Area Council Abuja, Nigeria. *Global Journal of Geological Sciences* 20: 19-24. ISSN: 1596-6798. Doi. http://dx.doi.org/10.4314/gigs.v20i1.2

APHA (2005). Standard Methods for the Examination of Water and Wastewater, 21st Edition, American Public Health Association/American Water Works Association/Water Environment Federation, Washington DC.

Bain, R., Cronk, R., Wright J., Yang, H., & Bartram, J. (2014). Faecal contamination of drinking water in developing countries: a systematic review and meta-analysis. *PLoS Medicine 11, e1001644.*

Bresline, E. (2007): Sustainable Water Supply in Developing Countries. Water for People. *Paper No. 194-1.nbresline @waterfor people.org.*

Calow Roger, C., Alan, M. McDonald, Alan, L. Nicol & Nick Robins, S. (2011): Groundwater Security and Drought in Africa. *Linking Availability, Access and Demand.*

Chapman, D. & Kimstach, V. (1996): Selection of Water Quality Variables. Water Quality Assessments: A Guide to the use of Biota, Sediments and Water in Environmental *Monitoring. Chapman edition, 2ndEdn. E & FN Spon, London, pp: 595*

Cheesbrough, M. (2010). District laboratory practice in tropical Countries, 3rd edition, Cambridge, University Press, United Kingdom, page: 50; 70-95 and 143 – 176.

Clinical Laboratory Standards Institute (CLSI) (2017). Performance standards for antimicrobial susceptibility testing; Twenty-fourth informational supplement. CLSI document M100-S24 Wayne, PA: ISBN 1-56238-898-3. 34(1): 50-98.

Giordano, M. (2009). Global Groundwater? Issues and Solutions. *Annu. Rev. Environ. Resour.*, *34*, 153–178. [**Google Scholar**] [**CrossRef**]

Guppy, L., Uyttendaele, P., Villholth, K.G., & Smakhtin, V. (2018). *Groundwater and Sustainable Development Goals: Analysis of Interlinkages*; UNU-INWEH Report Series, Issue 04; United Nations University Institute for Water; Environment and Health: Hamilton, ON, Canada. [**Google Scholar**]

Ibe, S. N., & Okplenye, J. I. (2008). Bacteriological Analysis of Borehole water in Uli, Nigeria. *African Journal of Applied Zoology and Environmental Biology.* doi. 10.4314/ajazeb.v7i1.41158

Idehen, O. (2020). A Comparative Investigation of Groundwater Contamination in Typical Dumpsites and Cemetery Using Ert and Physicochemical Analysis of Water in Benin Metropolis, Nigeria. *Journal of Geoscience and Environment Protection*. Doi.: 10.4236/gep.2020.81005

Kot, M. (2003). Do invading organisms do the wave? *Canad. Appl.Math. Quarterly* 10*, 139–170.*

Lobina, G. P. & Mercy, A. (2015). Physicochemical and Microbial Analysis of Selected Borehole Water in Mahikeng, South Africa, *International Journal of Environmental Research and Public Health.*Vol(12): 8619-8630 ISSN: 1660-4601doi.: 10.3390/ijerph120808619

Cite this article as:
Usman, K.M., Popoola, O.D., &Adigun, M. A. (2024). Evaluation of microbiological and physicochemical quality of borehole water in Mini-Campus, Federal Polytechnic, Offa, Kwara State, Nigeria. *FNAS Journal of Scientific Innovations, 6*(1), 19-26.

MacDonald, A. M. & Calow, R. C. (2009).Developing Ground water for Secure Water Supplies in Africa. *Desalination, 248, 546 - 56*

Margat, J., & van der Gun, J. (2013). *Groundwater Around the World: A Geographic Synopsis*; CRC Press Taylor & Francis Group: Boca Raton, FL, USA, 376p. [**Google Scholar**]

Milovanovic, M. (2007). Water Quality Assessment and Determination of Pollution Sources Along The Axios/Vardar River, Southeast Europe. *Desalination* 213: 159-173

Onda, K., LoBuglio, J. & Bartram., J (2012). Global access to safe water: accounting for water quality and the resulting impact\ on MDG progress. *International Journal of Environmental Research and Public Health 9, 880–894.*

Ranjana, A. (2010): Physico-Chemical Analysis of some Groundwater Samples of Kotputli Town Jaipur, *Rajasthan India*. Vol(1), No.2, 111-113.

Szewzyk, U., Szewzyk, W. M. & Schhleifer, K. H. (2000). Microbiological Safety of Drinking Water, *Annual Review of Microbiology*, vol(54): 81-127.

USEPA (1982). Methods for Chemical Analysis of Water and Wastes. US Environmental Protection Agency. Office of Research and Development, ph in water by electrometric method.

Usman, K. M., Arotupin, D. J., & Ekundayo, F. O. (2021). Antibiotic resistance pattern of bacteria in untreated hospital wastewaters from Offa Local Government Area, Kwara State, Nigeria. *African Journal of Microbiology Research*, 15(1) PP 572 – 582. DOI: 10.5897/AJMR

World Health Organization (WHO) (2004). Water for development: A practical advocacy guide for world water day 2002 3rd edition. Internet *URL:http//www.worldwaterday, org/advocacy/adv.html (accessed on 27th November, 2009)*

World Health Organization (WHO) (2011). Drinking Water: Equity, Safety and Sustainability. WHO/UNICEF, Geneva, Switzerland.

World Health Organization (WHO) (2022). Cholera Annual Report 2022. Weekly Epidemiological Record 38, 22 September 2023, Vol(98), (pp 431-452)

Cite this article as:
Usman, K.M., Popoola, O.D., &Adigun, M. A. (2024). Evaluation of microbiological and physicochemical quality of borehole water in Mini-Campus, Federal Polytechnic, Offa, Kwara State, Nigeria. *FNAS Journal of Scientific Innovations, 6*(1), 19-26.