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Microbial Elimination Efficiency Of Water Treatment Methods Commonly Used In Households In Ago Iwoye, Southwest, Nigeria

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Abstract

Lack of clean water in developing countries creates an enormous health concern, resulting in a variety of severe diseases such as diarrhea. This study evaluated the performance of four frequently used water treatment methods in Southwest Nigeria: boiling, sedimentation, alum treatment, and water guard. Groundwater samples were collected and analyzed for physicochemical and bacterial loads and characterization before and after treatment. The study found an average turbidity level of 10 NTU, electrical conductivity (EC) of 484 µS/cm, total dissolved solids of 40 mg/L, biochemical oxygen demand of 3.8 mg/L, chemical oxygen demand of 48 mg/L, total hardness of 13.16 mg/L, and nitrate content of 0.989 mg/L. Untreated groundwater samples had bacterial loads ranging from 1.37×10^6 cfu/mL to 2.57×10^6 cfu/mL. Bacterial species identified are: *Escherichia coli, Staphylococcus aureus, Pseudomonas spp., Proteus mirabilis, Shigella spp., Salmonella spp., and Klebsiella spp*. Following treatment, water guard treatment showed the lowest bacteria load across the water sampled, followed by boiling, alum treatment, and sedimentation. Although water guard treatment has been proven as very effective for drinking and household water use, using different disinfection methods concurrently may improve overall water safety

Keywords: Water treatment. Boiling. Sedimentation. Alum treatment. Water guard treatment

INTRODUCTION

Globally, around 1.1 billion people lack access to improved water supply (Ahmadi et al., 2020). One of the consequences of this shortage is an estimated one hundred million cases of diarrhea annually, as well as thousands of resultant deaths (Kristanti et al., 2022). Furthermore, the acute shortage of potable freshwater is exacerbated by lack of proper management, industrial development, population growth, increased pollution, corruption, and poor implementation of water-related infrastructure projects, which continue to put a heavy strain on the provision of adequate water resources in terms of distribution, availability, access, and quality in Nigeria "(Salehi, 2022).

Water treatment is critical to guaranteeing access to safe and clean drinking water, particularly in locations like Southwest Nigeria where waterborne diseases pose considerable health hazards (García-Ávila et al., 2021). The efficiency of water treatment procedures used in households is critical in establishing the quality of drinking water and protecting public health (Wu et al., 2021). Despite the extensive usage of various water treatment procedures by households in Southwest Nigeria, there is still a need to evaluate their effectiveness in eliminating pollutants and pathogens from drinking water sources. Understanding the efficiency of these methods is vital for influencing policies and interventions that aim to improve water quality and reduce the burden of waterborne diseases in the region. Common treatment methods used in low income households in southwest Nigeria include boiling, purifier, water guards and filters, ceramic filters, microfiltration, anion exchange, reverse osmosis, Aquatab, Aqua Guard, and Zero-B Purifier –(Chaukura et al., 2023; Getachew et al., 2022; Mangueina et al., 2024).

This study presents a comprehensive evaluation of the efficiency of water treatment methods commonly used in households of Ago Iwoye, Southwest Nigeria. These treatments include water guards (dilute sodium hypochlorite), Boiling, Sedimentation, Alum (Potassium aluminum sulfate ($KAl(SO4)2.12H2O$)

Materials and Methods

Sampling sites

This research was carried out in Ago-Iwoye, situated within the Ijebu North Local Government Area (LGA) in the southwestern region of Nigeria. Geographically, it is positioned between latitudes 6.056′ north and 7.000′ N, and longitudes 3.054′ E and 4.000′ east. This area encompasses various towns, including Ago, Awa, and Ijebu Igbo.

Collection of Sample

Between October and November 2023, four well water samples (5ml) were collected in sterile containers from each of the twelve commonly used ground water sources in Ago Iwoye and promptly conveyed to the Microbiology Laboratory at Olabisi Onabanjo University, Ago Iwoye, Ogun State for the analysis of various treatment methods used in the community. Here, four primary water treatment techniques including water guard usage (dilute sodium hypochlorite), Boiling, Sedimentation, and Alum treatment (Aluminum sulfate) were applied. Subsequent to this, thorough physicochemical and microbiological analyses were conducted.—

Physicochemical Properties

The physicochemical properties were analysed using the APHA procedure, as described by Atlas & Bartha, (1998). The study measured a range of water quality properties, including temperature, pH, atmospheric pressure, biochemical oxygen demand (BOD), chemical oxygen demand (COD), electrical conductivity, and concentrations of calcium, iron, magnesium, nitrate, and phosphorus. These measurements were conducted using specific methods and instruments to ensure accuracy and reliability.

At the sampling site, temperature, atmospheric pressure, and pH were recorded using a calibrated thermometer, digital barometer, and pH meter, respectively. Biochemical oxygen demand (BOD) was determined using the Winkler titration method, while chemical oxygen demand (COD) was quantified via a titrimetric method. For the measurement of electrical conductivity, a digital conductivity meter was employed, calibrated according to standard procedures.

The concentrations of calcium, iron, magnesium, nitrate, and phosphorus were analyzed using spectrophotometric and colorimetric methods. Specific reagents and procedures were utilized for each parameter, following established protocols. For example, calcium and magnesium concentrations were determined using the EDTA titration method, iron concentrations were measured using a spectrophotometric method, and nitrate and phosphorus levels were quantified using colorimetric assays. All instruments and reagents were calibrated and standardized prior to use, ensuring consistent and accurate results.

Sterilization of Glassware

All glass equipment underwent a comprehensive cleaning process involving detergent washing, followed by rinsing with fresh water, and sterilization in an oven at 160°C for a minimum of 2 hours. Prior to commencing any experiments, both the laboratory benches and work tables were disinfected using 95% ethanol. All laboratory procedures were conducted under strict aseptic conditions to ensure optimal hygiene.

Bacteriological Analysis

Standard Plate Count (SPC) for Bacteria Enumeration

The enumeration of bacteria in water samples was conducted using the standard plate count method. The pour plate technique described by Nester et al., (2009) was employed. Serial dilutions were prepared from the water samples by adding 1ml of the water samples to 9mls of distilled water for the first dilution and 1 ml from each previous dilution for the subsequent dilutions. With 1ml of each dilution dispensed onto labeled sterile Petri dishes, 15ml of plate count agar (HiMedia-M091A), pre-warmed to 45°C, was then poured onto each plate. The plates were gently rotated clockwise and anticlockwise, allowed to solidify, and then aerobically incubated at 37°C for 24 hours in an inverted position. This process of dilution and plating was performed in triplicate. A colony forming unit (cfu) range of 30 – 300 per plate was targeted to ensure accurate enumeration. The same procedure was repeated for both pre- and post-treatment water samples. After 24 hours of incubation, bacterial colonies on each plate were counted using an automatic colony counter (Scan 500- Interscience, France). Counts were recorded as colony forming units per mL (cfu/mL), and bacterial loads were determined by multiplying the average counts by the dilution factor.

$$\text{cfu/mL} = \frac{\text{No of colonies counted X dilution factor}}{\text{Volume plated (ml)}}$$

Characterization and Identification of Isolates from Raw water samples

Following serial dilution, samples were cultured in Eosin Methylene Blue agar, Mac Conkey agar, and Salmonella Shigella Agar using pour plate technique. Resulting colonies after a 24h incubation was subcultured on appropriate media and incubated for anther 24h to obtain pure colonies for identification and characterization. Examination of morphological and biochemical characteristics were then used for identification as outlined by Cheesbrough, (2005).

Water Treatment Methods

The collected water samples underwent traditional water treatment techniques commonly used by residents of Ago Iwoye for groundwater sources. Water Guard was administered at a concentration of 0.02 milliliters per 100 milliliters of water before inoculation. In the boiling method, 100 milliliters of water sample were heated in a water bath at 100 degrees Celsius for 30 minutes and then allowed to cool prior to inoculation. For sedimentation, the water samples were left to settle overnight before being cultured the following morning. Additionally, 1 gram of alum (Potassium aluminum sulfate (KAl(SO4)2.12H2O) were introduced into 100 milliliters of water for the alum treatment method before inoculation.

RESULTS

Physicochemical Parameters

The analysis of the physicochemical parameter revealed that the average temperature of the well water was recorded at 32°C, with a pressure of 158 kPa. The electrical conductivity (EC) measured 484 µS/cm, total dissolved solids amounted to 40 mg/L, biochemical oxygen demand was 3.8 mg/L, and chemical oxygen demand was found to be 48 mg/L. Additionally, the total hardness was measured at 13.16 mg/L, total alkalinity at 16 mg/L, and turbidity at 10 NTU. Predominant cations identified were calcium (Ca^{2+}), magnesium (Mg^{2+}), and potassium (K^{+}). The concentration of calcium in the groundwater stood at 52.76 mg/L. Magnesium concentration was measured at 15.21 mg/L, while potassium concentration was found to be 1.80 mg/L. Iron (Fe) concentration was negligible at 0.000, while nitrate (N) concentration in the groundwater reached 0.989 mg/L within the study area (Table 1).

Microbiological Examination of the Raw water samples

The water samples underwent culture on various media to examine their colony traits, aiding in the identification of the microorganisms. Subsequent to assessing the colony characteristics and conducting additional biochemical tests, the bacteria were identified as *Escherichia coli, Staphylococcus aureus, Klebsiella species, Proteus species, Pseudomonas species, Salmonella species,* and *Shigella species.*

The study also assessed the total heterotrophic bacteria count in the water samples by utilizing colony forming units (CFU) on nutrient agar to ascertain the bacterial population. The lowest count recorded was 1.37×10^{6} CFU/ml while the highest count observed was 2.57×10^{6} cfu/ml as illustrated in Table 2.

Table 1: Physicochemical Parameters of Well Water Sample

Parameters	Average for water samples
Temperature (^{0}C)	32
Pressure (kpa)	158
Conduction (us/cm)	484
TDS (mg/l)	40
BOD (mg/l)	3.8
COD (mg/l)	48
Total hardness (mg/l)	13.16
Total alkaline (mg/l)	16
Turbidity (NTU)	10
Ca (mg/l)	52.76
Mg (mg/l)	15.21
K (mg/l)	1.80
Fe (mg/l)	0.000
Nitrate (mg/l)	0.989

Key: TDS= Total Dissolved Solids, BOD= Biological Oxygen Demand, COD= Chemical Oxygen Demand, Ca= Calcium, Mg= Magnesium, K= Potassium, Fe= Iron.

Table 2: Total heterotrophic bacteria count s of untreated Well water Sample

Samples	TBC(x10^6cfu/ml)
AGS 1	2.22
AGS 2	1.51
AGS 3	2.57
AGS 4	2.08
AGS 5	2.63
AGS 6	2.45
AGS 7	2.20
AGS 8	1.83
AGS 9	1.37
AGS 10	1.81
AGS 11	2.04
AGS12	1.59

Total heterotrophic bacteria count Following Water treatment methods

Following the subsequent treatment of the water samples employed in this study, they were inoculated into nutrient agar and incubated for 24 hours to assess the bacterial populations resulting from each treatment method. Samples treated with water guard alone exhibited no bacterial colonies, except for AGS 6, which displayed a count of 8 x 10^4 cfu/ml. While most samples subjected to boiling showed no bacterial growth, four samples exhibited colonies ranging from 12 x 10^4 cfu/ml in AGS 6 to 24 x 10^4 cfu/ml in AGS 4. In the sedimentation method, no bacterial colonies were observed in five samples, whereas colonies ranging from 12 x 10^4 cfu/ml in AGS 8 to 30 x 10^4 cfu/ml in AGS 3 were found. Alum treatment resulted in bacterial colonies in five samples, with counts ranging from 18 x 10^4 cfu/ml to 21 x 10^4 cfu/ml (Table 3). The comparison of bacteria population reduction percentages between untreated water samples and treated ones showed distinct results. Water guard treatment exhibited a significant range of 96% to 100% reduction, while the boiling method ranged from 88.46% to 100%. Sedimentation displayed a reduction range of 81.75% to 100%, whereas alum treatment showcased a reduction range of 85.40% to 100% (Table 4). In overall, untreated water samples had higher average total microbial count compared to the treated water samples. Among the treated water samples, samples treated with water guard exhibited the lowest average total microbial count while the water samples treated using sedimentation method has the highest average total microbial count (Figure 1).

Table 3: Total heterotrophic bacteria count of Treated water samples

Sample	Untreated ($x10^6$ cfu/ml)	Water Guard ($x10^6$ cfu/ml)	Boiling ($x10^6$ cfu/ml)	Sedimentation ($x10^6$ cfu/ml)	Alum ($x10^6$ cfu/ml)
AGS 1	2.22	0	0	0	0
AGS 2	1.51	0	0	0.21	0
AGS 3	2.57	0	0.18	0.30	0.20
AGS 4	2.08	0	0.24	0	0.21
AGS 5	2.63	0	0.15	0.14	0
AGS 6	2.45	0.08	0.12	0.17	0
AGS 7	2.20	0	0	0.13	0.18
AGS 8	1.83	0	0	0.12	0.18
AGS 9	1.37	0	0	0.25	0.20
AGS 10	1.81	0	0	0	0
AGS 11	2.04	0	0	0	0
AGS12	1.59	0	0	0	0

Table 4: Percentage removal of bacteria in treated water samples

Samples	Water Guard (%)	Boiling (%)	Sedimentation (%)	Alum (%)
AGS 1	100.00	100.00	100.00	100.00
AGS 2	100.00	100.00	86.09	100.00
AGS 3	100.00	93.00	88.33	92.22
AGS 4	100.00	88.46	100.00	89.90
AGS 5	100.00	94.30	94.68	100.00
AGS 6	96.73	95.10	93.06	100.00
AGS 7	100.00	100.00	94.09	91.82
AGS 8	100.00	100.00	93.44	90.16
AGS 9	100.00	100.00	81.75	85.40
AGS 10	100.00	100.00	100.00	100.00
AGS 11	100.00	100.00	100.00	100.00
AGS12	100.00	100.00	100.00	100.00

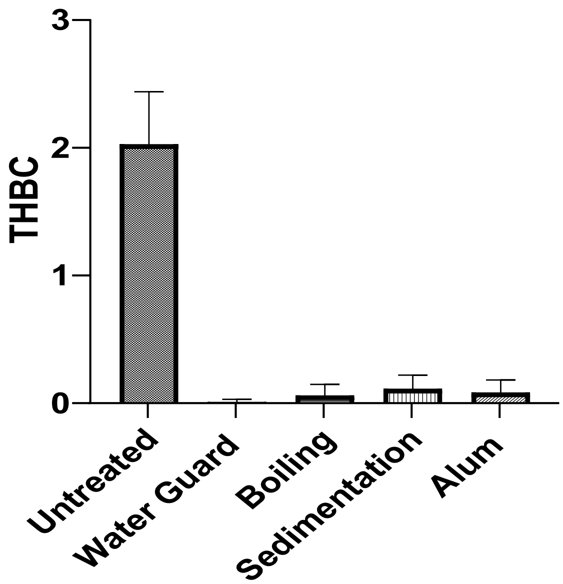

Figure 1: Average Total Heterotrophic bacteria count of Untreated water and water Treated Using Household Water treatment technologies in Ago Iwoye Communities

DISCUSSION

According to Ajibade et al., (2020), the alkaline pH of the groundwater in the studied area indicates that human activities have had an impact. Inadequate sewage and waste disposal, poor sanitation practices, aquifer leaching, and animal faeces are all potential sources of pollution. Furthermore, because pH levels can influence biological enzymes and hormones that regulate metabolism, growth, and development, maintaining groundwater alkalinity is critical to preventing acidity buildup, which is mostly caused by the aforementioned human activities. This finding is consistent with the observations of Ukpong & Peter, (2012), who emphasised the importance of pH values on groundwater quality.

Furthermore, the transparency of the groundwater samples, which showed turbidity levels of 10 NTU, exceeding the prescribed maximum limit of 5 NTU set by the Standard Organisation of Nigeria (SON), may lead to the false conclusion that the groundwater in the area is safe to drink without disinfection. This conclusion is consistent with the findings of Bisiriyu et al., (2020), who also reported high turbidity in an assessment of groundwater quality in Tudun Fulani, Bosso, Niger State, Nigeria.

The total dissolved solids (TDS) in the research area, measured at 40mg/l, are relatively high and tend to surpass the total suspended solids (TSS), Abulude et al., (2023) reported higher values in his study carried out in southwest Nigeria. While the water sample's nitrate content is 0.989mg/l, which is significantly lower than the SON's permitted maximum of 50mg/l and were within acceptable limits as similarly reported by Olusola, (2020). There have been no known health hazards associated with low nitrate levels, however it may be prudent to adopt a treatment strategy that monitors nitrate compounds into the water supply.

The examination of water samples in the research revealed the presence of diverse bacterial species, including *Escherichia coli, Staphylococcus aureus, Klebsiella species, Proteus species, Pseudomonas species, Salmonella species, and Shigella species*. This finding aligns with the Egberongbe et al., (2022) investigation into microbial presence in groundwater sources near poultry wells. This finding highlights the significant impact of human activities near groundwater sources on groundwater contamination.

The microbial load of the water samples was determined by quantifying the total heterotrophic bacteria count. The untreated samples revealed a high total heterotrophic bacteria count, and none of them fulfilled WHO drinking water guidelines of heterotrophic bacteria count limit of 100 cfu/ml, making them unsafe for consumption without treatment (WHO, 2017). However, the overall heterotrophic count in treated water samples varied depending on the treatment method used.

Except for one sample, the bulk of those treated with water guard had no bacteria, showing a 100% reduction. This finding is consistent with a study conducted by Hagos et al., (2020), who found a significant decrease in bacterial load after treating water samples with water guard as part of an inquiry into the Effect of Water-Guard on Bacterial Load in Drinking Water. Similarly, boiling treatment resulted in the elimination of bacterial load in 8 of 12 samples, while the other four showed a significant reduction ranging from 88% to 95%. This supports the findings of Clasen et al., (2008), who demonstrated the efficiency of boiling in lowering microbial burden. Additionally, Cohen & Colford, (2017) revealed that boiling water protects against different diseases, including *Vibrio cholerae* infections, Blastocystis, protozoal, viral, and nonspecific diarrheal diseases. Alum treatment resulted in a 100% reduction in bacterial presence in 7 samples, while the five remaining samples exhibited a bacterial population reduction of 85% to 92% when compared to untreated water samples. 'Fasuan et al., (2019) found similar findings in a study aimed at lowering bacterial population using several compounds. However, it is vital to highlight that increasing alum content can improve microbial removal while also dramatically altering the physical properties of drinking water.

Regarding sedimentation treatment, only a few samples obtained a complete reduction (5), while others exhibited a significant reduction ranging from 82% to 95%. Although sedimentation is frequently effective in reducing water turbidity, its ability to reliably reduce microbiological contamination varies. This could be related to the influence of undesired small suspended particle matter like as sand, silt, clay, and some biological pollutants, all of which are affected by gravity. The longer the water is allowed to settle, the more suspended particles and bacteria settle to the bottom of the storage container.

Largely, untreated water samples had a greater average load of bacteria than treated water samples. However, the water guard treatment approach proved to be the most successful in this investigation.

CONCLUSION

The study revealed contamination of groundwater resources in the area, necessitating treatment for safe human consumption. Four procedures were commonly used in the study region were employed: water guard, boiling, sedimentation, and alum treatment. Among all, water guard had the highest efficacy in removing all identified organisms. Nonetheless, further study is needed to develop standards for these procedures, as well as public awareness efforts to educate people about disinfecting groundwater sources. Although Water guard treatment is regarded as the most effective option for drinking and domestic water use, using two or three disinfection treatments simultaneously may improve overall safety.

REFERENCES

Abulude, F. O., Adeoya, E. A., Arifalo, K. M., Adeyemi, O. O., & Jiddah-Kazeem, B. S. (2023). Physiochemical Quality Assessment of Surface and Groundwater Sources A Case Study of Southwest, Nigeria. *Nigerian Journal of Science and Engineering Infrastructure*, *10*(1).157-173

Ahmadi, M. S., Sušnik, J., Veerbeek, W., & Zevenbergen, C. (2020). Towards a global day zero? Assessment of current and future water supply and demand in 12 rapidly developing megacities. *Sustainable Cities and Society*, *61*, 102295.

Ajibade, O. M., Adesiyan, A. A., Ayodele, M. O., & Fakolade, O. R. (2020). Geochemical and structural combinations in the assessment of under-groundwater qualities of some emerging settlements in Ibadan, Southwestern Nigeria. *Ethiopian Journal of Environmental Studies & Management*, *13*(1): 108

Atlas, R., & Bartha, R. (1998). *Microbial ecology: Fundamentals and Applications* (Fourth). Benjamin Cummings Publishing Company.San Francisco, USA. 556-598

Bisiriyu, M. T., Ganiyu, M. A., Audu, L. I., Abdullahi, A. S., & Animashaun, I. M. (2020). *An Assessment of Groundwater Quality in Tudun Fulani, Niger State, Nigeria*. Sule Lamido University Journal of Science and Technology (SLUJST) Vol. 1 No. 2 [December, 2020]: 7-16

Chaukura, N., Moyo, W., Kajau, T. A., Muleja, A. A., Mamba, B. B., & Nkambule, T. T. I. (2023). Low-cost ceramic filtration for point-of-use water treatment in low-income countries. *Water Security*, *20*, 100145.

Cheesbrough, M. (2005). *District laboratory practice in tropical countries, part 2*. Cambridge university press. 38-39

Clasen, T., McLaughlin, C., Boisson, S., Nayaar, N., Desai, D., Gupta, R., & Shah, N. (2008). Microbiological Effectiveness and Cost of Disinfecting Water by Boiling in Semi-urban India. *The American Journal of Tropical Medicine and Hygiene*, *79*(3), 407–413. https://doi.org/10.4269/ajtmh .2008. 79.407

Cohen, A., & Colford, J. M. (2017). Effects of Boiling Drinking Water on Diarrhea and Pathogen-Specific Infections in Low- and Middle-Income Countries: A Systematic Review and Meta-Analysis. *The American Journal of Tropical Medicine and Hygiene*, *97*(5), 1362–1377. https ://doi.org/ 10.4269 / ajtmh.17-0190

Egberongbe, H. O., Bakare, O. O., Onajobi, I. B., Adekola, H. A., Efuntoye, M. O., Adebisi, N. O., & Adeyemi, J. O. (2022). Comparative analysis of enteric bacteria in groundwater near poultry farm environments in Ijebu north, Ogun state, Nigeria. *Ethiopian Journal of Health Development*, *36*(4), 2–6. https://doi.org/10.20372/ejhd.v36i4.5567

Fasuan, O. S., Odeyemi, A. T., & Fasuan, S. O. (2019). Comparison of the Effectiveness of Alum, Chlorine, Sodium Hypochlorite and Moringa's Seeds in Reducing Bacterial Loads in the Treatment of Restaurant Wastewater. *Journal of Advances in Microbiology*, *16*(1), 1–7. https://doi.org/10.9734/jamb/2019/v16i130114

García-Ávila, F., Avilés-Anazco, A., Sánchez-

Cordero, E., Valdiviezo-Gonzáles, L., & Ordonez, M. D. T. (2021). The challenge of improving the efficiency of drinking water treatment systems in rural areas facing changes in the raw water quality. *South African Journal of Chemical Engineering*, *37*, 141–149.

Getachew, F., Gesese, A., Gebremariam, S., & Mezgebe, T. (2022). Water handling, sanitation, and hygienic practices and its association with under-five childhood diarrhea among households of Kirkos sub city, Addis Ababa, Ethiopia. *Journal of Nursing & Healthcare*, *7*(2), 1–7.

Hagos, L., Opadhi, N., Oljira, Y., & Akway, M. (2020). Effect of Water-Guard on Bacterial Load in Drinking Water. *International Journal of Research Studies in Science, Engineering and Technology*, *7*(7), 27–29.

Kristanti, R. A., Hadibarata, T., Syafrudin, M., Yılmaz, M., & Abdullah, S. (2022). Microbiological contaminants in drinking water: Current status and challenges. *Water, Air, & Soil Pollution*, *233*(8), 299.

Mangueina, D., Awuah, E., Fonteh, M. F., Antwi-Agyei, P., & Nadji, E. T. (2024). Assessment of current water, sanitation, and hygiene (WASH) practices in the third and ninth districts of N'Djamena, Chad. *Journal of Water and Health*, Feb;22(2):414-43

Nester, E. W., Anderson, D. G., Roberts, C. Evans, J., & Nester, M. T. (2009). *Microbiology : a human perspective* (6th ed). McGraw Hill Higher Education. https://cir.nii.ac.jp/crid/1130000796258993280

Olusola, F. O. (2020). Groundwater quality evaluation for drinking, domestic and irrigation uses in parts of Ode irele local government area of Ondo state, Nigeria. *Water Conservation and Management*, *4*(1), 32–41.

Salehi, M. (2022). Global water shortage and potable water safety; Today's concern and tomorrow's crisis. *Environment International*, *158*, 106936.

Ukpong, E. C., & Peter, B. U. (2012). Physico-chemical and bacteriological analyses of drinking water in Ibeno local government area of Akwa Ibom State. *Nigerian Journal of Technology*, *31*(2), 116–127.

WHO. (2017). *Guidelines for Drinking-water* (Fourth). World Health Organization. Geneva: World Health Organization; 2022. Available from: https:// www.ncbi.nlm.nih.gov/books/NBK579461/Wu, J., Cao, M., Tong, D., Finkelstein, Z., & Hoek, E. M. V. (2021). A critical review of point-of-use drinking water treatment in the United States. *NPJ Clean Water*, *4*(1), 40.