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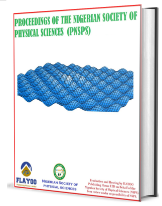

Comparative analysis of water quality in covered and uncovered hand-dug wells in Oye-Ekiti

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ABSTRACT

Access to safe and clean drinking water is critical to sustainable development. It remains a significant public health issue, particularly in rural and peri-urban areas of third-world countries like Nigeria, where hand-dug wells are common drinking water sources. This preliminary research investigated the water quality of covered and uncovered hand-dug wells in Oye-Ekiti, Nigeria, to inform sustainable well water management practices. Using judgmental sampling and standard analytical methods, water samples from two wells (covered and uncovered) were collected and analysed for physical, chemical, and microbiological parameters. The results indicated that covered well water generally has better quality, with lower concentrations of suspended solids, dissolved solids, and total hardness (80, 50, 31.5 mg/L, respectively) than uncovered (330, 80, 59 mg/L, respectively). However, heavy metals (Cd, Cr, and Pb) and coliform counts in both wells exceeded WHO limits, except for Cu and Zn. Notably, *E. coli* was absent in both wells, but the presence of coliforms (3 MPN/100 mL) signals potential vulnerabilities in the water safety, specifically the uncovered water (5 MPN/100 mL). The research findings corroborated the protective role of covering wells in reducing contamination. However, additional measures, including regular maintenance, improved construction, and monitoring, are recommended to ensure water quality. This pilot research provides a foundation for larger-scale investigations to support evidence-based policies for improved public health and to achieve Sustainable Development Goal 6 on clean water and sanitation by 2030.

Keywords: Water quality, Hand-dug wells, Covered wells, Sustainable water management.

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1. INTRODUCTION

The pervasive lack of access to safe drinking water remains a critical public health challenge globally [1], particularly in third-world countries such as Nigeria. Despite the unanimous decision to achieve sustainability by 2030 through the United Nations Sustainable Development Goals (SDGs) [2], access to clean water and sanitation remains challenging due to the rising global population and economic development [3]. More than 2 billion people do not have access to clean water globally [1], and by 2030, global water consumption is expected to rise to ~ 160% of the current volume [4]. Additionally, billions of people rely heavily on groundwater worldwide [5], including in Nigeria, where a significant proportion of the populace depends on groundwater as a primary source. For example, Imam [6] reported that most north-

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ern Nigerians utilise hand-dug wells and borehole water as their primary water source. Shockingly, >50% of these water sources were unfit for consumption, with only about 13% of portable water accessible to the populace. Furthermore, they observed that most hand-dug wells are usually uncovered, especially in rural areas, which may be attributed to the poor quality of these waters [6] and contamination from several directions as a result of their unprotected nature [7]. Additionally, uncovered wells with proximity to contamination sources and low levels of hygiene are susceptible to contamination [8].

Given that a large populace relies heavily on these water sources, there is a need to develop a fast and short-term approach to achieve sustainability. While it is believed and accepted that covering food, water, and other consumables protects against external contamination, research evidence is lacking to back it up regarding well water quality. This left us with an unanswered question: does covering well water affect the water quality? Furthermore, this knowledge gap hinders the development of targeted, cost-effective interventions to improve water quality and safety to ensure access to clean water and sanitation for all by 2030 (SDG goal 6). Therefore, this pilot research aims to scientifically investigate the validity or otherwise of this claim regarding covered and uncovered well water for evidence-based interventions and policy decisions to improve water quality and public health in Nigeria.

2. METHODOLOGY

2.1. SAMPLING

Water samples from two hand-dug wells were collected using judgmental sampling [9]. The hand-dug wells were located at latitude 7.805979° and longitude 5.344274° (uncovered well) and latitude 7.805652° and longitude 5.344357° (covered well), beside GOF Gas station, along Ayede Road, Oye Ekiti. The selection was based on geolocation and proximity (~ 40 m apart). One of the wells is properly covered (open only when in use and always covered when not in use), while the other is uncovered (all the time), making them the perfect choice for comparison. All the samples were collected using plastic bottles (1L), washed with ion-free detergents, soaked in 10% HNO_3 acid overnight (24 hours), rinsed with distilled water and dried. Water samples in the hand-dug wells were withdrawn from the two wells using the same material to fetch water from each well. The sample was collected during the daytime (Morning) and transported to the laboratory in an ice block for immediate analysis.

2.2. SAMPLE PREPARATION

There was no prior sample treatment for the physical parameters (such as pH, EC, Temperature, etc). However, 50 mL of the water sample was digested into a conical flask for the heavy metal analysis by adding 10 mL of HNO_3. The mixture was concentrated on a hot plate for 30 minutes to oxidise the organic matter in the water. The solution was allowed to cool to room temperature and filtered using Whatman filter paper into a 50 mL standard flask. The residue was rinsed with water, and distilled water was added to the filtrate up to the 50 mL flask calibration mark.

2.3. PHYSICOCHEMICAL PARAMETERS

The physical parameters were determined using standard analytical methods, as reported by [10]. The parameters investigated were pH, temperature, viscosity, colour, suspended solids (SS), dissolved solids (DS), total solids (TS), and electrical conductivity (EC). The chemical parameters were hardness and heavy metals (Cd, Cr, Cu, Zn, and Pb). The pH and temperature were determined at the point of sample collection [11] using a pH and mercury thermometer, respectively, by taking 50 mL of the sample water in a beaker and suspending the meter probe until the reading stabilised. TS, DS, and SS were determined using the Gravimetric method. For TS, 50 mL of unfiltered water samples were evaporated to dryness using an oven at 105 °C, and the residue was weighed. For SS, 50 mL of water was filtered on a pre-weighed filter paper, and the residue trapped by the filter paper was dried in an oven and measured. Mathematical differences between the TS and SS give the DS. All solids were expressed in milligrams per litre (mg/L). The water hardness was determined using the titrimetric method, where 100 mL of the sample was titrated in triplicate with 0.01 M EDTA using an Eriochrome Black T indicator. The physicochemical parameters were determined in the 3-in-1 laboratory of the Chemistry Department at Federal University Oye-Ekiti. However, the heavy metals were determined using a flame atomic absorption spectrometer (FAAS), Buck Scientific model 211 VGP, following APHA 20th Edition 3111B and 3111D, ASTM D3561, and ASTM D5198 guidelines at Afe Babalola University Ado-Ekiti (ABUAD).

2.4. MICROBIOLOGICAL PARAMETERS

The microbiological parameters - total coliforms and Escherichia coli (E. coli) in the water samples were determined following the standard protocols recommended by the American Public Health Association [12] and the United States Environmental Protection Agency [13]. The MacConkey broth was prepared according to the manufacturer's specifications, and 25 mL was put into the test tube. Inverted vials were introduced into the tubes, plugged with cotton wool and wrapped with aluminium foil. It was sterilised in an autoclave at 121 °C for 15 minutes. Serial dilutions were carried out on the samples; the last three sets of dilutions were inoculated with 1 mL of the inoculums, and each tube was plugged with cotton wool and incubated at 37 °C for 24 hours. Fermentation and the formation of gas were observed after 24 hours. The tubes where fermentation or formation of gas occurred were taken as positive, and non-fermented tubes were taken as negative. Coliform was determined using the Most Probable Number (MPN) method, and the density of coliform bacteria was computed using the MPN. The results were recorded as MPN/100 mL, while E. Coli was reported in CFU/mL.

3. RESULTS AND DISCUSSIONS

3.1. PHYSICOCHEMICAL PARAMETERS

The results of the physicochemical parameters are presented and visualised in Table 1 and Figure 1, respectively. The pH values for covered and uncovered well water samples are 6.78 and 6.73, respectively, and fall within the recommended (6.5 to 8.5) acceptable range for drinking water by the World Health Organization [14]. The slight acidity in both samples varies insignificantly,

Table 1. Physicochemical parameters of covered and uncovered well water.

S/N	Parameters	Results	
		Covered	Uncovered
1	pH	6.78	6.73
2	Temperature (°C)	26	25
3	Viscosity (N s m^{-2})	6.12	6.22
4	Conductivity (mS/m)	85.4	113.3
5	Suspended solids (mg/L)	80	330
6	Dissolved solids (mg/L)	50	80
7	Total solids (mg/L)	130	410
8	Total hardness (mg/L)	31.5	59

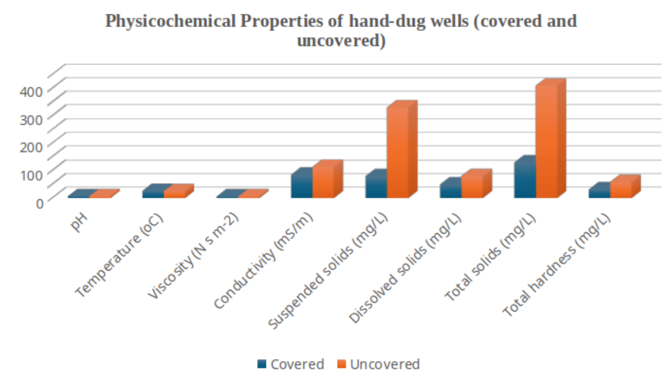

Figure 1. Physicochemical properties of the covered and uncovered hand-dug wells.

likely due to covering. pH is an important parameter in drinking water as it helps determine its corrosivity and indicates water's acidic and/or base state [7, 10].

While temperature is a major factor that affects the rate of reaction, there is no specific limit recommended for drinking water, but it should not exceed 30°C for aesthetic reasons. In water quality assessment, temperature helps assess the overall quality of water (physicochemical and biological characteristics), such as a decrease in the solubility of gases and an improvement in the tastes and colours [15, 16]. The temperatures observed (Table 1) for the water sampled are 26 °C and 25 °C for covered and uncovered wells, respectively, and fall within the recommended 30 °C for aesthetic reasons. These values are typical for well water in temperate regions and do not significantly affect water quality [13]. It is worth noting that the water temperature of the covered well is slightly higher than that of the uncovered well by 1 unit (Figure 1).

The viscosity of the water was also determined, and the values obtained were similar for covered and uncovered wells (Table 1). Based on the results, we infer that covering well water has a minimal impact on the water's flow properties. However, the well water conductivity is higher in uncovered (Figure 1) than in covered water. The higher conductivity in uncovered wells shows a greater ionic content, likely due to exposure to environmental contaminants, which in turn cause ionic dissolution in the water. Conductivity expressed in micromhos per centimetre (μ mhos/cm) determines the flow of electric current. It is directly proportional to the amount of dissolved minerals in the water but does not indicate which element/ion is present. However, a higher conductivity value could be linked to the presence of sodium, potassium, chloride or sulphate ions [17]. Similarly, according to Gupta [18], conductivity is a good indicator of the total dissolved ions and is directly related to the total solids in the water sample. Ultimately, the higher the value of dissolved solids, the greater the number of ions in water [19]. The conductivity of the covered and uncovered water is 85.4 mS/m and 113.4 mS/m, which shows that the uncovered water has more dissolved ions than the covered water, most likely due to contamination from nearby surroundings.

The suspended solids are significantly higher in uncovered wells (330 mg/L) than in covered wells (80 mg/L), as clearly visualised in Figure 1. This confirmed that uncovered wells are more susceptible to particulate contamination, obviously due to the open nature of the uncovered well. The dissolved solids in uncovered wells are equally higher than in covered wells (Figure 1), bolstering the idea that uncovered wells may accumulate more soluble substances from the surrounding environment. The findings also corroborate the observed values on conductivity. Generally, the total solids are significantly higher in uncovered wells (410 mg/L) than in covered wells (130 mg/L). These findings validated the notion that covering wells reduces contamination by preventing particulate matter and dissolved substances from entering the water. The dissolved solids (TDS) in both wells (Table 1) are below 500 mg/L, which is within the WHO permissible limit for drinking water [14]. Water is often considered a universal solvent because it can dissolve many inorganic and organic minerals or salts such as potassium, calcium, sodium, bicarbonates, chlorides, magnesium, sulphates, etc. These minerals usually produce unwanted taste and diluted colour in the appearance of water. According to the literature, water with a high TDS value is highly mineralised. Bonotto [20] demonstrated this relationship, indicating significant mineral content with a high TDS concentration of 2898 mg/L corresponding to sodium-(bi)carbonate hydrogeochemical facies. Similarly, Ta [21] reported thermal groundwater in Chongqing, China, with TDS ranging from 1620 to 2929 mg/L, characterised as SO_4-Ca type waters, further supporting the correlation between high TDS and mineralisation.

As observed in other parameters (Table 1), the total hardness is higher in uncovered wells (59 mg/L) than in covered wells (31.5 mg/L), likely due to calcium and magnesium ions introduced by environmental sources such as soil and rock weathering. Total hardness in water quality determines the suitability of water for domestic, industrial and drinking purposes. It is attributed to the presence of bicarbonates, sulphates, chloride and nitrates of calcium and magnesium [22–24]. There is no specific limit for hardness in water. However, hardness levels above 200 mg/L may affect palatability. Therefore, the hardness level recorded in uncovered water further calls for the need for proper well water covering.

3.2. LEVELS OF HEAVY METALS

The levels of Cd, Cr, Cu, Pb, and Zn metals in the well water were analysed and presented in Table 2. The metal levels were higher in covered water than in uncovered water, except for Pb and Zn, with higher concentrations in uncovered water (Figure 2). Three metals, Cd, Cr and Pb, exceeded the respective permissible limit of 0.003 mg/L, 0.05 mg/L, and 0.01 mg/L (Table

Table 2. Heavy metals (mg/L) levels in covered and uncovered well water.

		Concentration (mg/L)		
3-S/N		Covered	Uncovered	Standard (WHO)
1	Cd	0.01200 ± 0.00000	0.00850 ± 0.00071	0.003
2	Cr	0.11550 ± 0.00071	0.09600 ± 0.00283	0.05
3	Cu	0.14850 ± 0.00212	0.13050 ± 0.00354	2.00
4	Pb	0.01800 ± 0.00283	0.02400 ± 0.00141	0.01
5	Zn	0.14750 ± 0.00354	0.17450 ± 0.00212	5.00

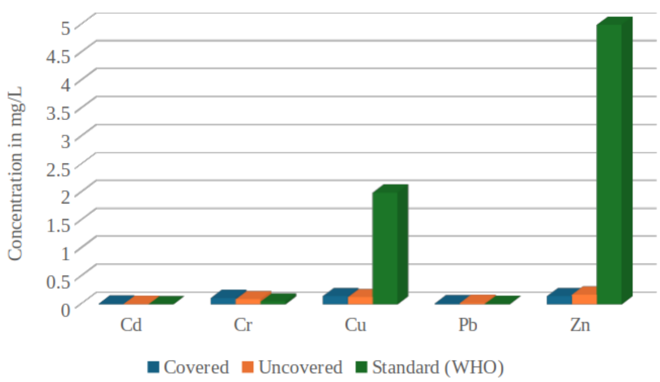

Figure 2. Levels of heavy metals in hand-dug wells.

2), as set by WHO [14]. The two other metal concentrations–Cu and Zn—were within the acceptable limit of 2 mg/L and 5 mg/L, respectively [25] in both covered and uncovered wells, indicating no immediate health risk. Importantly, the findings further demonstrate the deviation in the quality of uncovered well water compared to properly covered well water.

Comparatively, Pb levels were slightly higher in uncovered water (0.024 mg/L) than in covered water (0.018 mg/L). These levels indicate potential contamination that could pose health risks, particularly to children [26].

3.3. MICROBIOLOGICAL PARAMETERS

3.3.1. Total coliforms

The microbial analysis results are presented in Table 3 and provide the levels of total coliforms in the two well water samples (uncovered and covered). Total coliform bacteria are a collection of environmental microorganisms, including soil, water, and vegetation. Their presence in water indicates it may be contaminated with pathogens or faecal matter [27]. According to the WHO guidelines, the presence of coliform bacteria in drinking water should be 0 MPN/100mL. Unfortunately, 5.000 MPN/100 mL and 3.000 MPN/100 mL values were reported for the uncovered and covered water samples. This worrisome figure exceeded the 0 MPN/100 mL limit, suggesting significant coliform contamination. Notably, the uncovered water is more contaminated (Table 3), further supporting the premise that covering well water is a step towards a more sustainable water world. Moreover, the higher counts in uncovered well water indicated a greater level of contamination, possibly from surface runoff, agricultural activities, or faecal contamination. The presence of coliform is a serious concern for water quality and highlights the potential presence of harmful pathogens, making the water unfit for consumption.

Table 3. Microbial results of total coliform and E. Coli.

	Total coliform (MPN/100 mL)	E. coli (CFU/mL)
Uncovered (M)	5.000	0.000
Covered (N)	3.000	0.000

3.3.2. E. coli

For both uncovered and covered well water (Table 3), the levels of E. coli are recorded as 0.000 CFU/mL. While E. coli is a specific indicator of faecal contamination, a value > 0 CFU/mL in water can directly indicate the presence of pathogens that can cause diseases such as diarrhoea, urinary tract infections, and other illnesses [28]. The absence of E. coli in both samples is a positive sign, implying that there is no direct faecal contamination in the water samples. This is important as E. coli contamination is a more direct indicator of recent faecal contamination and the potential presence of more dangerous pathogens. However, the total coliforms, even without E. coli still indicates a potential health risk and hints at possible integrity breaches in the water system.

According to the USEPA, total coliforms are commonly used as a baseline indicator for the microbiological quality of water. The USEPA stipulated that no more than 5% of samples in a month can test positive for total coliforms for systems collecting at least 40 samples per month. No more than one monthly sample should be tested positive for smaller systems. The WHO recommends that drinking water should have no detectable coliform bacteria per 100 mL. The presence of coliforms necessitates further investigation and immediate corrective actions to identify and eliminate sources of contamination [24]. While the absence of E. coli in the samples is reassuring, the presence of total coliforms at levels above recommended limits indicates potential contamination risks. To ensure the water's (covered and uncovered water) safety for consumption, it is necessary to investigate and address the sources of coliform contamination.

4. CONCLUSION

This research investigated the water quality of covered and uncovered hand-dug wells in Oye-Ekiti, Nigeria, to assess the impact of covering. While the research is a pilot investigation, the findings revealed that covered water had significantly better quality than uncovered well water. However, heavy metals (Cd, Cr, and Pb) and total coliform counts exceeded WHO limits in both hand-dug wells, which is a source of concern for water safety. The absence of *E. coli* in both wells was reassuring, indicating no direct faecal contamination. However, coliforms count, particularly higher in uncovered wells, highlighted the risks of environmental contamination from sources like agricultural runoff or poor hygiene practices from the surrounding environment. The results scientifically supported the protective role of covering wells in reducing contamination risks and demonstrated the need for additional measures for sustainable water safety. While we are working towards large-scale comprehensive research to develop evidence-based strategies for sustainable water management, it is recommended that improved well construction techniques should be adopted, and wells should be adequately covered and sealed when not in use. Community education programs should also be created to raise awareness about proper hygiene and well-management practices. Additionally, policymakers are encouraged to establish and enforce regulatory frameworks to standardise well construction, with particular emphasis on covering.

DATA AVAILABILITY

The data will be available on request from the corresponding author.

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