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RESEARCH ARTICLE OPEN ACCESS

Niger Delta University Campus Borehole Water Quality Analysis for Domestic Purposes: Treated Versus Untreated Water

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Abstract:

This study compared the quality of treated versus untreated water of the Niger Delta University campus borehole water for domestic purposes. Consequently, one untreated water, and 6 treated water samples were collected from source, and taps in 6 different hostels, respectively. Total heterotrophic bacteria (THB) count showed no THB for the treated samples, while 1.04 x 10^4/ml and 3.2 x 10^3/ml were Nutrient agar and MacConkey agar nutrient media, respectively for the untreated water.These values exceed the WHO maximum value (100/ml) for potable water. Similarly, themorphological characterization and biochemical tests revealed seven bacteria species in the untreated water sample, whereas none was identified in the treated samples.Results of the untreated water sample showed the presence of faecal coliform bacteria (FCB);while FCB was absent in the treated water samples.

The physiochemical parameters of the samples showed that the water is mildly acidic. The EC, TDS, turbidity, TSS, Cl^-, SO_4^{2-}, NO_3^-, HCO_3, TA, TH, Ca^{2+}, Mg^{2+}, Na^+, K^+, and Fe contents of the treated and untreated samples were below WHO permissible limits. Overall, results suggest treated water for domestic use. However, we recommend that water users should boil and disinfect water before use.

Keywords —Borehole water, Niger Delta University, faecal coliform bacteria, anions and cations.

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1.INTRODUCTION

Water is indispensable for living organisms, human health, food production, economic development and ecological systems. It is the most essential solvent for humamwelbeing (Livinus, 2014).There are various sources of water including rain water, surface water and ground water. Borehole water (BHW) is abstracted from ground water (GW); which is the best source of water for drinking, domestic, and irrigation purposes. Hence it is essential not only to know the groundwater contamination but also to examine and preserve the resource (Mayuri et al., 2018). However, GW quality is severely declining due to changes in the environment and increasing anthropogenic activities, resulting in a high impact on human health through intake of contaminated water. GW is contaminated with bacteria, viruses, heavy metals, nitrates, salts among others due to indiscriminate and improper disposal of wastes, unlawful waste management practices; which is more common in the cities due to high level of industrialization (Singh et al., 2011). Since one cannot do without water, there is high need for water in the society in all works of life. Thus, to service the water needs in any society, government and/or organization must provide potable water for her people and ensure its

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quality. Consequently, the Niger Delta University has her own borehole that supplies water to the various student hostels and other quarters.

Environmental pollution and GW pollution can be related to human health, which are the most widespread problems in both the arid and semi-arid regions(Adimalla &Venkatayogi, 2018). According to (Penwick, 2006),2.5 billion people have no access to improved sanitation, and more than 1.5 million children die each year from diarrhea. World Health Organization (WHO, 2006) also reported that the mortality rate attributed to water associated diseases exceeds five million (5 million) people per year. From these records, more than 50% are microbial intestinal infections with cholera standing out as first. Also, GW pollution has been reported to have caused epidemic and chronic diseases in human beings.However,limited studies have shown a correlation between cardiovascular deaths and polluted water consumption (Olias et al., 2004; Pitt et al., 1995). Teeth and bones disorder was attributed to the consumption of fluoride-rich water (Susheela, 1999).

Freshwater is probably the most valuable of the natural resources. However, chronic GW contamination may reduce the availability of freshwater, breaking the balance between water supply and demand leading to socioeconomic crises and even wars. Water shortages induced by contamination may become a factor causing conflicts among citizens in the future (Schillinger et al., 2020), possibly delaying the socioeconomic development of a nation. In addition to contamination of GW, trace elements can be transported via GW into surface waters and into oceans. It is glaring that GWis a prime source of water for human wel-being, it can also be a pathway for disseminating diseases. Thus, efficient and cost-effective technologies for removal of trace elements from groundwater, and wholistic water quality measures are crucial for the sustainable management of water resources.

The physicochemical quality of GW in Yenagoa metropolis, Bayelsa State, including the Niger Delta University campus BHW was investigated (Okiongbo & Douglas, 2013). The authors concluded that the GW (not-treated) in the study area was unsuitable for drinking and irrigation due to high total hardness and total dissolved solids. In terms of iron contents, > 90% of the samples exceeded the permissible limit for drinking water and needs treatment. It is pertinent to mention that there is nodocumented research yet on the microbial quality of BHW in Bayelsa State. Thus, there is little or no study on the microbial quality of the NDU BHW till date. More importantly, discussions with students living in the various hostels revealed that bathing the NDU BHW without disinfection causes itching, and skin infections. Hence, there is urgent research need to examine the water quality parameters of the NDU BHW for the well-being of students and staff living on campus. Consequently, this study is focused on the microbial quality and physio-chemical parameters analysis of the NDU BHW.

2. MATERIALS AND METHOD

2.1 Study area and sampling

Niger Delta University is located in Amassoma, Southern Ijaw Local government area of Bayelsa State, Nigeria (Figure 1). A total of seen (6 treated and 1 untreated) water samples were collected using 50cl plastic bottles. Prior to sampling, the sample bottles were soaked in 1:1 dilute HCl overnight and properly washed with distilled water before used for sample collection. Furthermore, sample bottles were rinsed 2–3 times with the sample water. Taps were opened, and allowed to run for 4-5 minutes before sampling to attain steady conditions. Sixtreated water samples were collected from six different hostels on campus, and onenot-treated water sample was collected from the water works (source) on campus. The temperature, pH, and electrical conductivity (EC) of each sample was measured by hand-held digital meters before samples were labelled appropriately and sent to the Central Research laboratory of the Niger Delta University for analysis.

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All apparatus used for testing were properly sterilized before and after use to avoid cross contamination. Samples were analyzed for physio-chemical parameters (pH, electrical conductivity-EC, turbidity, temperature, total dissolved solids-TDS, iron-Fe, total alkalinity-TA, total hardness-TH, nitrates-NO_3, sulphate-SO_4, bicarbonate-HCO_3, chloride-Cl, calcium-Ca^{2+}, sodium-Na^{+}, potassium-K^{+}, and magnesium-Mg^{2+}); and microbiological parameters including *Baciliusspp, Enter bacteraerogene spp, pseudomas spp, micococcus spp, Citrobacter spp, streptococcus spp and protons spp.*

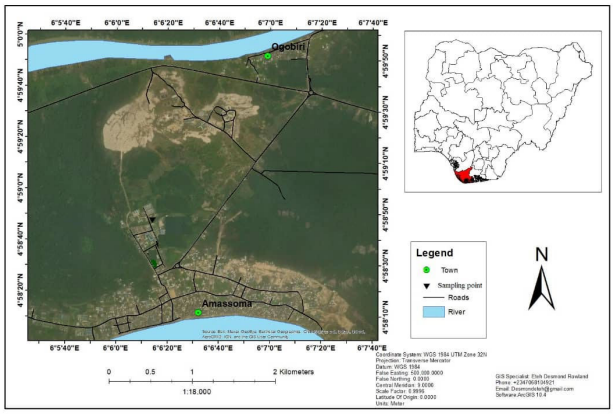

Figure 1: Water Sampling location-Niger Delta University. All the water samples were collected from the sampling location indicated in the map.

Microbiological Parameter Analysis: For quality assurance/quality control, all apparatus and/or equipment used for testing were properly sterilized before and after use. The microbiological parameters: *Bacillus spp, Enterobacteraerogenespp, Pseudomonas spp, Micrococcus spp, Citrobacterspp, Streptococcus spp and Protons spp* were analyzed usingsterilized bottles filled up allowing a small air space to allow for shaking.

Sterilization: Sterilization and disinfection were carried out to ensure that the apparatus used do not transmit microbial organism. The glassware, petri-dishes, nutrient media and reagents were sterilized by moist heat sterilization method using the autoclave. The instrument to be sterilized were first wrapped with aluminum foil. Then, the materials were arranged to ensure uninterrupted flow ofsaturated steam. The material was sterilized at 121^0C for 15 minutes to effect sterility. Sterilant liquid (alcohol at 70%) concentration was used to disinfect materials not suitable for moist heat sterilization. The bench was swab with alcohol before and after work.

Preparation of Nutrient Media: Nutrient Agar is a general medium use for the enumeration of heterotrophic colonies count. 28g was dissolved in 1000ml of distilled water in a borosilicate glass bottle. MacConkey agar is a differential medium use to distinguish Lactose-fermenting from the non-fermenting bacteria. 51.53g MacConkey agar was suspended in demineralize water. Salmonella Shigella Agar is a selective medium use for the identification of salmonella and shigella bacterial. 63grams of the powder was dissolved in 1000ml of distilled water. Kliger iron agar, simmon citrate, and peptone water were also included. The media was heated to dissolve completely in a water bath and sterilized by autoclaving for 15 minutes at 121ºC, in accordance with the manufacturer instruction.

The formulation of SIM media is designed to allow the detection of sulfide production, indole formation and motility. 30 grams of the medium was suspended in 1000 ml of distilled water, then heated to boiling with agitation to completely dissolve; and dispense into tubes and sterilized by autoclaving at 121°C for 15 minutes. MacConkey broth was prepared by dissolving 40g in 1 liter of distilled water, distributed into containers fitted with fermentation (Durham) tubes and sterilized by autoclaving at 121°C for 15 minutes

Calculation:

Based on the manufacturer's instruction for the use of nutrient agar, 28.g of nutrient agar was dissolved in 1000ml of water.

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Bacteriological analysis: 1ml of the sample was also collected from the dilution factor of 1:100 and distributed into sterile broth contain in the Biju bottle with inverted Durham tube free of bubble. It was inoculated with the respective sample aseptically. The inoculated broths were incubated at 37°C for 24 hours with loosely capped. This was done to ensure the most probable number (MPN) of micro-organism.

Coliform forming unit (CFU) = Degree of dilution

× aliquot × No of colonies (1)

The colonies were randomly selected from the mixed culture using a sterile wire loop. The pick colonies were sub-cultured on a fresh nutrient agar plate by streaking method. The sub-cultured plate was inverted and incubated at 37° C to obtain a pure culture. The pure isolate was used for Gram staining and series of biochemical test in line with standard operational procedure.

Interpretation of Microbial Growth: Petri-dishes containing 30-300 colonies on nutrient agar plate, MacConkey agar and salmonella shigella agar were counted using the colony counter and multiply by the reciprocal of the appropriate dilution factor to obtain the viable count and expressed in CFU/g/cm^2.

The most probable techniques were examined for 24 to 48 hours. The bottle which had produced both acid and gas were counted. Acid production changes the colour of MacConkey Broth from purple to yellow and gas production by the collection of bubble in the Durham tube.

Characterization and Identification of Bacteria

Gram Staining: Gram staining of the various bacteria isolated were performed using the method introduced by Danish Bacteriologist Hans Christian Gram (1884). The microscopic glass slide was clean by washing with water and then wipe with alcohol and dry for use. The slide was labelled. Bacteria isolate were smear on the slide using sterilized wire loop and fixed by heating. Crystal violet staining reagent was poured and allow for 60 second and washed off with water. Lugol iodine solution was poured and allowed for 60 second and washed off with water. 95% of ethanol was poured to decolorize the dyes and allowed for 10 second, then it was washed off with water. Safranin was poured, allowed for 60 second and was washed off with water. This was allowed to air dry. The stained smear was observed using oil immersion under a light microscope.

Biochemical Test: The Biochemical test used in identification of the bacteria isolate are: Oxidase, catalase test, citrate test, indole test, motility and use of Klingler iron agar test involving "gas, H_2S, glucose and lactose.

Oxidase: A piece of filter paper was placed in sterile petri dish and 3 drops of freshly prepared oxidase reagent was added. A plastic loop was used to pick a small portion of the test organism which was rubbed on the soaked filter paper and observed for 10 minutes. Purple coloration on the smeared portion indicates positive result for oxidase test while no change in color on smeared portion indicates negative oxidase test.

Catalase Test: This test was performed in test tubes, 3ml of hydrogen peroxide was introduced into sterile test tubes using a sterile glass rod, colony of the pure culture was picked and dipped into the test tube and observed for the production of gas bubbles.

Citrate Test: Test organisms were streaked into sterile Simon's citrate agar pour in the test tube and incubated at 30°C for 24 hours. Growth with blue coloration indicate positive result while dark green coloration indicated negative result.

Motility and Hydrogen Sulfide Test: Using isolated colonies from an 18-24hour culture on solid media, inoculate in the SIM media by stabbing the center of the test tube containing 9ml medium to

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a depth of 1/2 inch. Incubate the inoculated medium aerobically at 35ºC for 18-24hours. Observe for H_2S production and motility. Positive H_2S test is denoted by a blackening of the medium along the line of inoculation. A negative H_2S test is denoted by the absence of blackening. While positive motility test is indicated by a diffuse zone of growth flaring from the line of inoculation, negative motility test is indicated by growth confined.

Indole Test: This test was performed by culturing the isolate in peptone water containing tryptophan and incubated for 48 hours at 37ºC. Indole production was detected by adding 2-3 drops of Kovac's reagent to the 48 hours culture broth. Red ringed coloration indicated a positive result.

Sugar Fermentation Test: Klingler iron agar was prepared and 9ml of molten media were slanted and allow to be solidified. The isolate was stabbed and streaked on the slanted molten. It was placed in the incubator for 24 hours. Glucose fermentation indicated yellow coloration at the bottom giving a positive result. Lactose formation indicated yellow coloration at the slanted area giving a positive result while red indicated negative result.

Hydrogen Sulphide and Gas Production: The Klingler iron agar medium were prepared in a slanted test tube and organism were inoculated by streaking and stabbing and then incubated for 24-48 hours. Hydrogen sulphate production was indicated by black Mucor coloration on the surface of the slant while gas was indicated by cracking of the agar.

The material was sterilized at 121ºC for 15 minutes to affect sterility. Sterilant liquid such as alcohol at 70% concentration were used to disinfect materials not suitable for moist heat sterilization. The bench was swab with alcohol before and after work.

3. RESULTS AND DISCUSSION

3.1 Microbial analysis

Table 1 shows the analysis of the THB counts of the water samples analysed. Results indicate the presence of total heterotrophic bacteria in the not-treated water sample,while no THB was found in the treated water samples. The probability table for estimating the most probable number (MPN) of faecal coliform bacteria in the water samples are displayed in Table 2. Similarly, results confirm that the treated water samples analysed contain no faecal coliform bacteria, except the untreated samples. Furthermore, morphological characterization and biochemical tests revealed seven (7) isolates: *Proteus mirabilis; Micrococcus letues; Esichiaher coli; Enterococcus faecali; Staphylococcus aureus; Bacillus subtilis; and Streptococcus pyogene bacteria species* in the not-treated water sample, whereas none was identified in the treated samples. The results are presented inTable 3. Their presence indicates fecal contamination which might be due to the introduction of microbial contaminants into the borehole from the soakaway. The soakaway is about 15m away from the borehole, however, there is the posibiliy that microbes from the soakaway can infiltrate the borehole if the flow direction of soakaway is against the borehole location. Currently, there is no study on microbial quality analysis in borehole water in Bayelsa state to compare against the results of this study. However, (Onuoha et al., 2019) investigated the bacteriological quality of borehole water in Anambra state, Southern Nigeria and discovered the presence of total bacteria, total coliform, feacal coliform and vibrio choleraein borehole water.The authors recommended sand filtration, chlorination and boiling before drinking as treatment measures to avert a public health hazard.

3.2 Physio-chemical parameter analysis

The analysed results of the physio-chemical properties of water samples of the current study: treated and not-treated are presented in Table 4.The electrical conductivity (EC), turbidity, total dissolved solids (TDS), total suspended solids (TSS), Cl^-, SO_4^{2-}, NO^-_3, HCO_3, TA, TH, Ca^{2+}, Mg^{2+},

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Na^+, K^+, and Fe levels of all the samples are all below WHO permissible limits. The physio-chemical parameters of same sample (not-treated) were analysed in 2013; and recommended for treated (Okiongbo& Douglas, 2013). As such, the results of the current study (treated and not-treated) were compared against those (Okiongbo& Douglas, 2013) and included in Table 4. The results current study were far better than those reported by(Okiongbo& Douglas, 2013), except the TA value. A plot of the not-treated 2013 data against the not-treated 2021 data was further generated in Figure 2; which clarifies the discrepancies that existed between the two data sets. The results could be attributed to better treatment and/or probably improved quality assurance and quality control measures put in place by the management over the years. However, the pH, TA and Ca^{2+} results deviated from the expected. That is, while the TA for the treated and not treated are same (i.e., 18), the pH, and Ca^{2+} of the treated were higher than those of not treated. Themean values of the physio-chemical properties of watersamples of the current study are presented in Table 5. Results were compared with WHO Standard, 2006. The results are all below WHO acceptable limits for drinking water. However, the treatment rather increased the concentrations of the pH, NO^-_3, and HCO_3; while the value for Fe was constant (i.e; 0.03). This may be attributed to the targeted treatment.

Table 1: Heterotrophic and enumeration bacteria count on nutrient media. **CFU**= coliform forming unit.

S/ID	Media	No. of colonies plate count	Mean CFU/ml
A^+	Nutrient agar	99 108 105	104 1.04 x 10^4
	MacConkey agar	32 34 30	32 3.2 x 10^3
	Salmonella shigella agar	** ** **	** **
A	Nutrient agar	** ** **	** **
	MacConkey agar	** ** **	** **
	Salmonella shigella agar	** ** **	** **
B	Nutrient agar	** ** **	** **
	MacConkey agar	** ** **	** **
	Salmonella shigella agar	** ** **	** **
C	Nutrient agar	** ** **	** **
	MacConkey agar	** ** **	** **
	Salmonella shigella agar	** ** **	** **
D	Nutrient agar	** ** **	** **
	MacConkey agar	** ** **	** **
	Salmonella shigella agar	** ** **	** **
E	Nutrient agar	** ** **	** **
	MacConkey agar	** ** **	** **
	Salmonella shigella agar	** ** **	** **
F	Nutrient agar	** ** **	** **
	MacConkey agar	** ** **	** **
	Salmonella agar	** ** **	** **

where **= absence of microorganisms; **A^+** = not-treated; **A-F** = treated; **S/ID** = sample identification

Table 2: Probability table for estimating the most probable number (MPN) of faecal coliform bacteria in the water samples

Volume of sample in each bottle	**50ml**	**10ml**	**1ml**	
Number of bottles used	**1**	**5**	**5**	**MPN/100ml**
RAW WATER SOURCE	1	3	3	18
TREATED WATER **A**	0	0	0	0
TREATED WATER **B**	0	0	0	0
TREATED WATER **C**	0	0	0	0
TREATED WATER **D**	0	0	0	0
TREATED WATER **E**	0	0	0	0
TREATED WATER **F**	0	0	0	0

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Table 3: Results ofcharacterisation and identification of isolates from treated and raw borehole water samples.

Isolates	Morphology	GS	CAT	CI	IND	MOT	OX	GL	LAC	H_2S	Gas	Bacteria species
1	Rod	-	+	+	+	+	-	+	-	+	-	Proteus mirabilis
2	Coccus	+	+	+	-	-	+	-	-	-	-	Micrococcus letues
3	Rod	-	-	-	+	+	-	+	+	+	-	Esichiaher coli
4	Coccus	+	+	+	-	-	-	+	+	-	-	Enterococcus faecali
5	Coccus	+	-	-	-	-	-	+	+	-	-	Staphylococcus aureus
6	Rod	+	+	+	-	+	-	+	-	-	-	Bacillus subtilis
7	Coccus	+	-	-	-	-	-	+	+	-	-	Streptococcus pyogene

+ = indicates presence of bacteria;**-** = indicates absence of bacteria; **GS** = gram staining; **CAT** = catalase; **CI** = citrate; **IND** = indole, **MOT** = motility; **OX** = oxidase; **GL** = glucose; and **LAC** = lactose

Table 4: Results of current study compared with a previous study in 2013. Both studies sampled from same borehole**.**

a& b = current study;**c**= not treated;**na** = not analysed.

Properties	Untreated water[a]	Treated water (average)[b]	[11] [C]
pH	6.7	6.38	6.18
EC	49.4	60.30	495
Turbidity	0.01	0.34	NR
TDS	24.7	30.15	248
NO^-_3	0.13	0.12	1.6
Cl^-	7	10.00	14.2
SO_4^{2-}	0.51	0.65	4.7
HCO_3	1.2	0.40	36
TA	21	18.00	18
TH	10	29.00	42
Ca^{2+}	4.85	5.64	3.5
Mg^{2+}	1.18	1.43	1.8
Na^+	2.36	2.82	13.8
K^+	0.56	0.72	6.5
Fe	0.03	0.03	0.86

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Table 5: Mean values of the physio-chemical properties water samples compared with WHO Standard, 2006.

Properties	Water: B-E (treated)	Water: A (untreated)	WHO (2006)max. permissible limit
pH	6.26	6.38	6.5-8.5
EC	45.40	60.30	1400
Turbidity	0.54	0.34	5
TDS	22.70	30.15	1000
NO^-_3	0.13	0.12	50
Cl^-	9.00	10.00	250
SO_4^{2-}	0.45	0.65	400
HCO_3	0.50	0.40	40
TA	16.00	18.00	500
TH	7.00	29.00	500
Ca^{2+}	5.04	5.64	75
Mg^{2+}	1.28	1.43	50
Na^+	2.54	2.82	200
K^+	0.67	0.72	55
Fe	0.04	0.03	0.3

TDS = Total Dissolved Solids; **TSS** = Total Suspended Solids; **TA** = Total Alkalinity; **TH** = Total Hardness; **EC** = electrical conductivity. All parameters have been expressed as mg/L, except pH and EC. The unit of EC is µS/cm while that of TA and TH is mg/L$CaCO_3$.

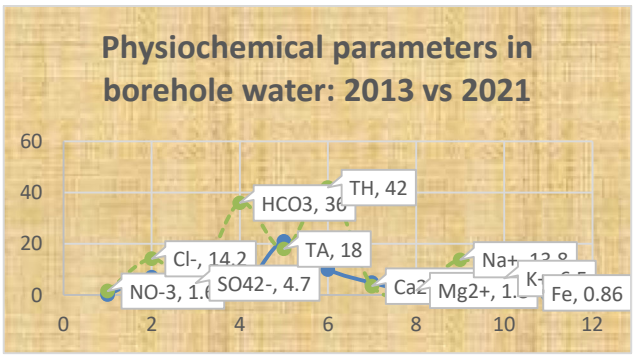

Figure 2: A plot of physio-chemical parameters of NDU campus borehole water for 2013 and 2021. Dashed curve represents 2013 parameters, while undashed represents 2021 parameters.

4. CONCLUSION

This study investigated and compared the quality of treated versus untreated water of the Niger Delta University campus borehole water for domestic consumption. Consequently, one raw water sample (source) and six (n = 6) treated water samples from 6 different student hostels were collected and analysed for both microbial quality and physio-chemical parameters. While there was no total heterotrophic bacteria (THB) for the treated water samples, the THB for the raw water sample for Nutrient agar and MacConkey agar nutrient media were 1.04 x 10^4/ml and 3.2 x 10^3/ml, respectively. Analysis on the faecal coliform count (FCC) showed the presence of faecal coliform bacteria (FCB) in the untreated water sample; whereas, no FCB was found in the treated water samples. Results of characterisation and identification of isolates from untreated water samples also revealed the presence of *Proteus mirabilis; Micrococcus letues; Esichiaher coli; Enterococcus faecali; Staphylococcus aureus; Bacillus subtilis; and Streptococcus pyogene bacteria species*. None of these isolates was identified in the treated water samples. The absence of the FCB, and the isolates in the treated water samples could be attributed to the effectiveness of the treatment measures by managers.

The physio-chemical parameter analysis of the water samples showed that the average value of pH

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were 6.26 and 6.38 for the treated samples (n = 6), and the raw water, respectively. These values are within the WHO permissible limits for drinking water. The results of electrical conductivity, turbidity, total dissolvedsolids, total suspended solids, Cl^-, SO^{2-}_4, NO^-_3, HCO_3, TA, TH, Ca^{2+}, Mg^{2+}, Na^+, K^+, and Fe levels of all the samples were all below WHOacceptable limits. Overall, results of both the microbial and physio-chemical analysis suggest that the treated water is good for domestic consumption. However, the following recommendations are made: (a) the water should be boiled and disinfected before use since students reported that bathing the water without disinfection causesitching, and skin infections; (b) more research should investigate the causes of itching and skin infections as mentioned in (a) above; and (c) NDU borehole water managers should guide against rupture of water distribution pipe networks, as this may attract infiltration of dirts and microbes that may further contaminate the water.

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