

Assessment of the water quality of Bar-Bula Village well waters, Tafawa Balewa local government area, Bauchi State, Nigeria

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Abstract

There was a report of health challenges in our study area due to the consumption of water from wells sited in the community. The research was aimed at assessing the water quality parameters of the wells consumed by the villagers towards providing information on the possible health implication(s) of its consumption. Two sampling sites were selected, well 1 and well 2, which were hitherto the sole sources of water in the village. Physicochemical and microbiological quality parameters of samples were done in order to assess their conformance with the specification of Nigerian Standard for drinking water quality (NIS 554-2015). The results indicated that all physical water quality parameters have their mean concentration values below the maximum permissible limits, except colour which had total mean concentrations of 16.5 ± 0.65 TCU and 15.3 ± 0.65 TCU for well 1 and well 2 respectively, are relatively above the allowable unit range of 15 TCU (NIS-554-2015). The water quality assessment of wells also revealed high concentration of Cadmium (0.11 mg L^{-1} and 0.16 mg L^{-1} , for well 1 and 2 respectively as against 0.003 mg L^{-1} specified by standard) and Magnesium (185 mg L^{-1} and 105 mg L^{-1} for well 1 and 2 respectively as against the maximum permissible limit of 20 mg L^{-1} specified by the standard). The microbial values of samples fall below the maximum permissible limit prescribed by the NIS standard. From the study, it was concluded that the presence of Cadmium in the well waters indicated that the water is unfit for consumption.

Keywords: Cadmium, consumption, Bar-Bula village, water quality, standard, physicochemical parameters of water.

Avaliação da qualidade da água do poço da Vila Bar-Bula, área do governo local de Tafawa Balewa, Estado de Bauchi, Nigéria

Resumo

A pesquisa teve como objetivo avaliar os parâmetros de qualidade da água dos poços consumidos pelos moradores para fornecer informações sobre as possíveis implicações para a saúde de seu consumo. Dois locais de amostragem foram selecionados, poço 1 e poço 2, que até então eram as únicas fontes de água na aldeia. Parâmetros de qualidade físico-química e microbiológica das amostras, foram realizados para avaliar a sua conformidade com a especificação da Norma Nigeriana para a qualidade da água potável (NIS 554-2015). Os resultados indicaram que todos os parâmetros físicos de qualidade da água estão com seus valores médios de concentração abaixo dos limites máximos permitidos, exceto a cor que teve concentrações médias totais de $16,5 \pm 0,65$ TCU e $15,3 \pm 0,65$ TCU para o poço 1 e poço 2 respectivamente, estão relativamente acima do permitido faixa de unidade de 15 TCU (NIS-554-2015). A avaliação da qualidade da água dos poços também revelou alta concentração de Cádmio ($0,11 \text{ mg L}^{-1}$ e $0,16 \text{ mg L}^{-1}$, para poço 1 e 2, respectivamente, contra $0,003 \text{ mg L}^{-1}$ especificado pela norma) e Magnésio (185 mg L^{-1} e 105 mg L^{-1} para poço 1 e 2 respectivamente, em relação ao limite máximo permitido de 20 mg L^{-1} especificado pela norma). Os valores microbianos das amostras ficam abaixo do limite máximo permitido prescrito pelo padrão NIS. Do estudo concluiu-se que a presença de Cádmio nas águas dos poços indica que a água está imprópria para consumo.

Palavras-chave: Cádmio, consumo, vila de Bar-Bula, qualidade da água, padrão, parâmetros físico-químicos da

água.

1. Introduction

Water is a vital resource as well as a major factor in pollution studies. The physical, chemical and biological characteristics of the water defines its quality, which consequently is a factor of the area's geology and effects of human activities (Ishaku; Ezeigbo, 2010). Water resources can be termed to be polluted when there is/are presence of toxic contaminant(s) that could be injurious to humans and other organisms in that source of water (Wang et al., 2017). Natural constituent of water due to the geology of the area in which the water occurs (natural pollution) can cause pollution of the water or the pollution may be caused by the impacts of human activities on the water (Pan et al., 2018).

Fresh water can be obtained underground. The water underneath the surface of the earth that flows naturally to the earth surface through seeps or springs and are collected in wells, tunnels, or drainages are referred to as ground water (Ye et al., 2017; Ambrosi, 2017). Throughout the ages, ground water has been a major source of water. In modern times, they are important source of water for many municipalities and industries and for irrigation (Lee et al., 2007). Ground water is essentially the only water resources for all life forms (Zhuang et al., 2011).

Environmental pollution is a critical phenomenon in recent times (Ali; Khan, 2017). Environmental pollution and contamination by heavy metals is a menace to the environment with serious consequences (Hashem et al., 2017). Contamination of the environment by heavy metals has been increased by massive industrialization and urbanization, and their accumulation in the environment have greatly accelerated over the years (Khan et al., 2014; Shen et al., 2017). These metals occur naturally but are introduced into the environment through weathering of rocks containing the metals and volcanic activities, and also through human activities such as industrial emissions, mining, smelting, pesticides and phosphate fertilizers application (Tang et al., 2020).

Bar is a land village separated by Bununu river to the north and surrounded by hills both to the east and west with a population of about 1300 people. Narration has it that some mineral resources were once exploited in the area in quantities not viable for commercial purposes.

Some years back, a health crisis of grave concern was reported in the aforementioned village, after the community source of water was changed from surface water to well water for villagers' utilization. The irruption of the unfamiliar disease was characterized by severe clinical manifestations leading to the death of some members of the population. The disease was fingered to have started in October 2003 and was assumed to be caused by the consumption of the hand-dug well water in the area. This occurrence was broadcasted in national dailies and the once active population had been living in fear due to the unknown disease.

This work was therefore designed to investigate the cause of this strange disease by assessing the physicochemical and microbial properties of the well water and to try and give possible explanation to the causative agent of the disease.

2. Materials and Methods

2.1 Study area and sampling sites

The study was conducted in Bar village of Bununu district of Tafawa Balewa Local Government Area of Bauchi State, North-East Nigeria (Figure 1, A). The village, which is located in the wet Tropical Savannah zone, lies between latitude 9° 54' and 9° 18' North of the Equator and longitude 9° 41' and 9° 24' East of the Greenwich meridian. Bununu district is located in the Sayyawa Chieftdom of the Bauchi South senatorial district, and also lies within the Tropical Savannah agro-ecological zone. It is located at Lat/Long(dec) 9.9052,9.69015 (Figure 1, B and Figure 2 A and B).

The geology in the vicinity of Bar is primarily composed of granite and metamorphic rocks (Umar, 2011). The Bar and Bula communities (Bununu belt) are remarkably similar in all aspects to rocks that occur in the Jos-Plateau trending belts of Nigeria. Rocks are mainly dominated by birimian metavolcanics and metasedimentary rocks that are intruded by numerous granitoids, as well as felsic and mafic intrusives (Umar, 2011). Metamorphism in the study areas varies from moderate greenschist to high-grade amphibolite facies (Umar, 2011). The catchment area especially around Dass, Nabordo, Tashan Durumi, Zull and Toro has shown numerous prospects and occurrences of meteorites and gold. Gold mineralization is mainly associated with shear zones, which cut across metavolcanics, metasedimentary, and granitic rocks (Umar, 2011).

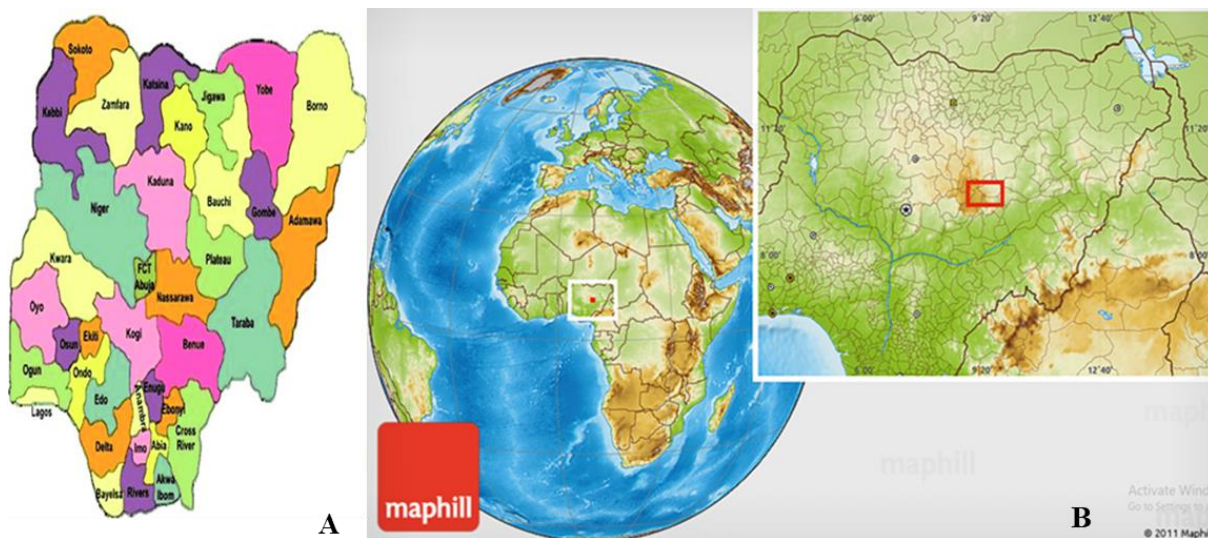


Figure 1. Map of Nigeria (A) and (B), location of Tafawa Balewa LGA, Bauchi State. Source: <http://www.maphill.com>.

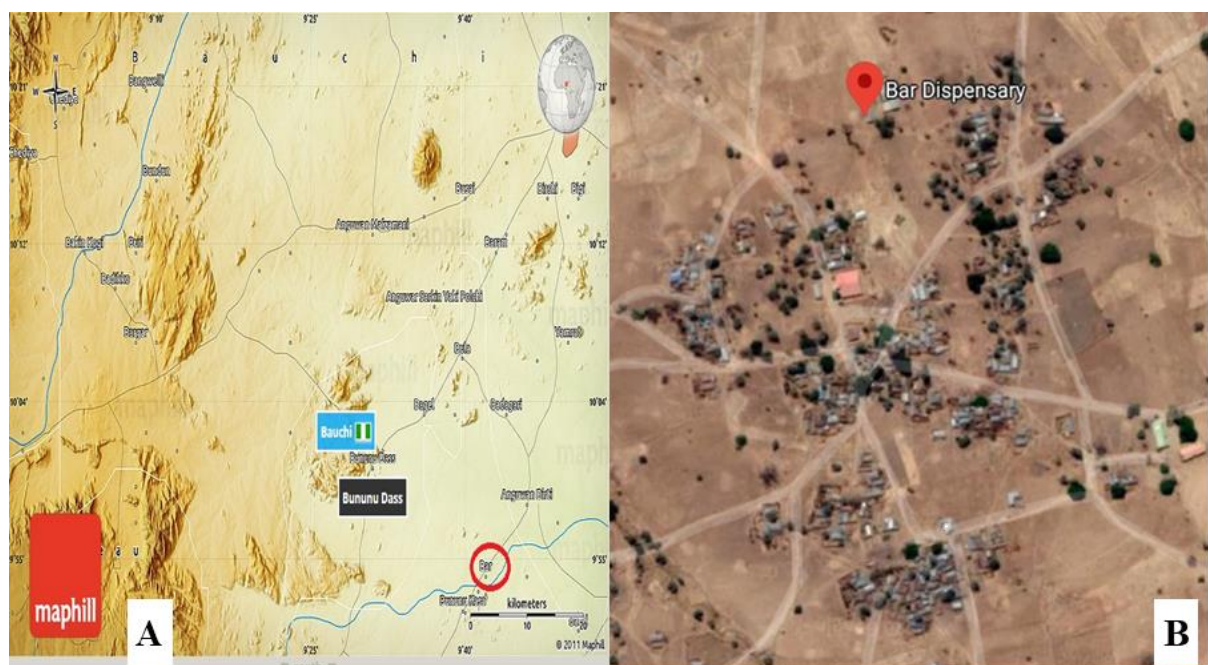


Figure 2. Location of Bar village, Tafawa Balewa LGA (A) and, (B) GPS capture of the study area. Source: <http://www.maphill.com>.

2.2 Water sampling

The representative water samples were collected from two (2) hand dug-out wells used by the people of Bar village of Tafawa Balewa L.G.A of Bauchi State for drinking, cooking and other domestic purposes. Samples of water (100 mL) from each well were collected in Sterile WhirlPak sampling bags for chemical analysis and the same quantity taken using special Sterile polyethylene containers (Samra et al, 2008) for microbiology analysis. When collecting the water samples from the hand-dug wells, a clean properly rinsed rubber bucket was used to fetch the well waters. Sample bottles were rinsed with deionized water twice before samples were collected.

One liter each of the samples collected were preserved with 0.5 mL of concentrated nitric acid [obtained from

Water and Sanitation Agency (WATSAN) laboratory, Bauchi] and kept in ice-chests with ice packs at a temperature of 4 °C before transporting them to the Water and Sanitation Agency (WATSAN) laboratory, Bauchi for analyses and also stored in that temperature until the analyses were completed.

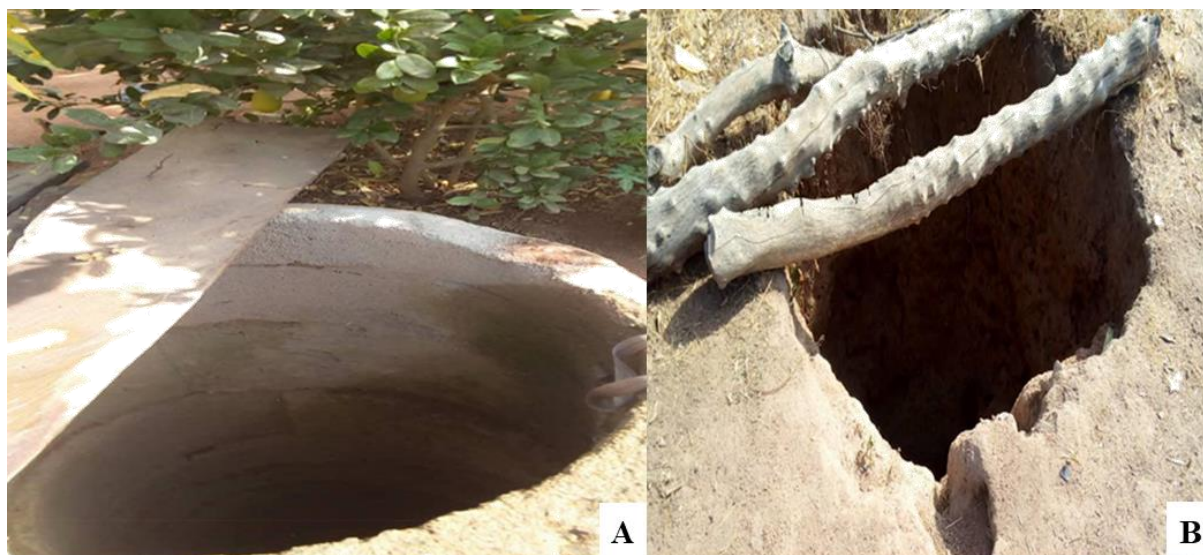


Figure 3. Sampling Well 1 (A) and, sampling Well 2 (B). Source: Authors, 2023.

2.3 Analyzed parameters

The determination of colour in the laboratory was carried out by the use of a spectrophotometer. The instrument gives a direct reading value of the colour. Physical water quality parameters, such as pH, temperature (TEMP), conductivity (COND), total dissolved solids (TDS) and dissolved oxygen (DO) were measured in situ using a special Multi-parameter meter HACH HQ40d (DO in mg L⁻¹) and a Mettler Toledo SevenGo portable meter (COND, TDS, TEMP & pH). Turbidimeter was used for turbidity measurement. Fluoride was measured by the use of potentiometric method while elemental analysis was carried out by the use of spectrophotometric method (AAS). The conventional Pour Plate method (Taylor et al., 1983) was used in culturing, enumeration and isolation of bacteria and fungi.

2.4 Statistical analysis

Data on the water quality parameters of the water samples from the wells were subjected to repeated measure analysis of variance (ANOVA) using SPSS software package (Version 21).

3. Results

3.1 Physical parameter of water samples

Table 1 shows the physical parameters of water samples obtained from the two wells in the study area. The results indicated that all water quality parameters have their mean concentration values below the permissible standards, except colour which total mean concentration values of 16.5 ± 0.65 TCU and 15.3 ± 0.65 TCU for well 1 and well 2 respectively, are relatively above the allowable unit range of 15 TCU (NIS-554-2015).

Table 1. Results of physical parameters of water samples obtained from two wells of the study area.

Parameter	Water Sample S ₁	Water Sample S ₂	NIS STD MPL
Temperature, °C	26.1 ± 0.21	25.6 ± 0.21	Ambient
TDS, mg L ⁻¹	210 ± 7.06	110 ± 7.06	500
CND, Us cm ⁻¹	430 ± 19.55	230 ± 19.55	1000
Turbidity, NTU	3.0 ± 0.05	2.5 ± 0.05	5
Colour, TCU	16.5 ± 0.65 ^a	15.3 ± 0.65	15
Odour/Taste	Unobjectionable	Unobjectionable	Unobjectionable
pH	7.4 ± 0.28	7.4 ± 0.28	6.6 – 8.5

Note: CND – Conductivity; TDS – Total dissolved solids; NTU – Nephelometric turbidity; MPL – Maximum permissible limit. Values are expressed as mean ± SEM, n = 4. ^aValues are significantly higher than MPL (*p* < 0.05). Source: Authors, 2023.

3.2 Elemental analysis of water samples

Table 2 shows the mean concentrations of the metal ions, DO, and BOD in the water samples obtained from the two water sources in the study area. The result showed that magnesium and cadmium ions were far higher than the maximum permissible limits in drinking water when compared to the NIS while other metals were within the permissible limit. For magnesium, the total mean concentration values of 185 ± 6.55 mg L⁻¹ and 105 ± 6.55 mg L⁻¹ for well 1 and well 2 respectively, are relatively above the allowable maximum permissible limit of 20 mg L⁻¹ (NIS-554-2015).

The heavy metal, Cadmium (Cd), is found to be significantly (*p* < 0.05) higher than the permissible limits in water samples S₂ (0.16 mg L⁻¹) and S₁ (0.11 mg L⁻¹). Zinc (Zn) concentration was observed to be slightly high in the S₂ (3.13 mg L⁻¹ + 0.13) as against the NIS value which is 3 mg L⁻¹.

Table 2. Chemical parameters of water samples obtained from two wells of the study area.

Parameter	Water Sample S ₁	Water Sample S ₂	NIS STD MPL
Ca ²⁺ mg L ⁻¹	62.24 ± 2.02	30.88 ± 2.02	150
Mg ²⁺ mg L ⁻¹	185 ± 6.55 ^a	105 ± 6.55 ^a	20
Al ²⁺ mg L ⁻¹	0.004 ± 0.001	0.003 ± 0.001	0.2
Cu ²⁺ mg L ⁻¹	0.15 ± 0.05	0.07 ± 0.05	1
Fe ²⁺ mg L ⁻¹	0.02 ± 0.01	0.08 ± 0.01	0.3
NO ₃ ⁻ mg L ⁻¹	18.92 ± 0.13	28.16 ± 0.03	50
CN ⁻ mg L ⁻¹	0.003 ± 0.001	0.001 ± 0.001	0.01
Ni ²⁺ mg L ⁻¹	0.001 ± 0.00	0.0012 ± 0.00	0.02
Cd ²⁺ mg L ⁻¹	0.11 ± 0.01 ^a	0.16 ± 0.01 ^a	0.003
Pb ²⁺ mg L ⁻¹	0.005 ± 0.00	0.0032 ± 0.00	0.01
Al ²⁺ mg L ⁻¹	0.006 ± 0.000	0.017 ± 0.000	0.2
Zn ²⁺ mg L ⁻¹	2.86 ± 0.13	3.13 ± 0.13	3
PO ₄ ²⁻ mg L ⁻¹	0.05 ± 0.13	0.0032 ± 0.13	0.1
SO ₄ ²⁻ mg L ⁻¹	1.0 ± 0.13	2.0 ± 0.13	100
Cl ⁻ mg L ⁻¹	34.0 ± 1.78	40.0 ± 1.78	250
F ⁻ mg L ⁻¹	0.17 ± 0.02	0.10 ± 0.02	1.5
DO mg L ⁻¹	8.8 ± 0.08	7.4 ± 0.08	30
BOD	1.98 ± 0.02	1.82 ± 0.02	25

Note: Values are expressed as mean ± SEM, n = 4. aValues are significantly different from standard ($p < 0.05$). Source: Authors, 2023.

3.2 Microbial analysis of water samples

Table 3 shows the mean values of the microbial parameters in the water samples obtained from the two wells in the study area. The microbial values for the wells all fall below the maximum allowable limit stated by the NIS standard.

Table 3. Results of Microbial parameters of the water samples obtained from two wells of the study area.

Parameter	Water Sample S ₁	Water Sample S ₂	NIS STD MPL
Total Coliform count CFU mL ⁻¹	8	6	10
<i>E. coli</i> CFU 100 mL ⁻¹	0	0	0
Protozoa – Giardia	0	0	3
<i>Streptococcus/Enterococcus</i> CFU 100 mL ⁻¹	0	0	0
<i>Clostridium perfringens</i> spore CFU 100 mL ⁻¹	0	0	0

Source: Authors, 2023.

4. Discussion

4.1 Concentrations of water quality parameters relative to their benchmark values

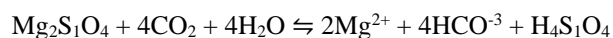
Assessing water quality status is crucial in comparing the measured water quality parameters with the Nigerian Standard for Drinking water quality (NIS-554-2015). Table 1 shows the results of the water quality parameter which indicated that all the water quality parameters have their mean concentration values below the maximum permissible limits, except colour which had a total mean concentration value of 16.5 ± 0.65 TCU and 15.3 ± 0.65 TCU for well 1 and well 2 respectively. These values are relatively above the maximum permissible limits of 15 TCU (NIS-554-2015). This may be due to the presence of some dissolved ions and organic matter.

However, according to the Nigerian standard, there is no feasible health impact on the consumption of water with high colour presence. The pH is a major factor that affects the colour of naturally occurring surface water. Indicator effect is a phenomenon where there is an increase in colour as a result of increasing pH of the test sample. Dissolved or colloiddally dispersed substances in water causes the absorption of certain wavelengths of light giving them a certain colour appearance. Colour alone cannot elicit adverse health effect, but the nature and composition of the dissolve particulates could be harmful.

4.2 Chemical and microbiological analysis of water

Comparison of the values of the parameters obtained after analysis of water from the two sources with that of NIS showed a higher concentration of Mg ions and Cd while other parameters measured fall within the permissible limit (Table 2). For Mg, the total mean concentration values of 185 ± 6.55 mg L⁻¹ and 105 ± 6.55 mg L⁻¹ for well 1 and well 2 respectively, are above the maximum permissible limit of 20 mg L⁻¹ (NIS-554-2015). Magnesium in conjunction with Ca when dissolved in water makes water hard. As the Mg content increases, the degree of the water hardness also increases and is related to the concentration of multivalent cation dissolved in the water. Hard water is not a common health hazard (De Oliveira et al., 2012), but it adds a little quantity Ca and Mg in human diets.

In some instance, water can be a main contributor of Ca and Mg to the diet where their dissolution in water is quite high, and the correlation between hard water consumption and reduced cardiovascular disease mortality had been suggested by some research (De Oliveira et al., 2012). Symptoms of Mg toxicity, which usually develop after serum concentrations exceed 1.74 to 2.61 mmol L⁻¹, can include nausea, regurgitation, reddening of the face, urine retention, ileus, depression, and drowsiness leading to muscle weakness, difficulty breathing, severe hypotension, spasmodic heartbeat, and cardiac arrest (Musso et al., 2010). The source of high Mg in the study area could be due to hydrolysis of Fosterite (Mg Olivine) shown in the reaction below:



If the specification of Nigerian Standard for drinking water quality (NIS 554-2015) is used as a reference, the maximum concentration levels of Cd exceed the risk screening values, which indicated that there existed a potential water contamination risk in the study area.

Cadmium is a heavy metal that is found to be far higher than the maximum permissible limit in water sample S2 which is 0.16 mg L^{-1} and is also high in water sample S1 (0.11 mg dl^{-1}) as against the NIS maximum permissible limit of 0.003 mg L^{-1} . However, the mean content of Cd in the waters was not only higher than risk screening value, but also exceeded the risk intervention value issued by the specification of Nigerian Standard for drinking water quality control criteria, suggesting a comparatively higher degree of contamination for Cd in water consumed in the village.

Cadmium is an inessential and harmful element for humans. Exposure to Cd^{2+} is harmful at even very low levels and with injurious health implications and as well as adverse environmental degradation. Cadmium, Cd chloride and some other Cd compounds exhibit similar range of toxicological properties. Cadmium alongside Arsenic (As^{3+}), lead and Mercury (Hg^{2+}) are among ten chemicals of major public health concern listed by WHO (IPCS, 2005–2007). Cadmium cannot be degraded *in nature* and thus once it finds its way into the environment, it remains in circulation. Compared to other heavy metals, Cd^{2+} and Cd compounds are relatively soluble in water. Therefore, they are more easily absorbed and mobile, for instance, in soil, generally more bio-available and tend to bio-accumulate in plants and animals, through uptake and drinking of water, or through the food chain.

Ingestion of the metal either via drinking water or through the food chain, leads to its accumulation in the human body, most especially the kidney and liver (Dabak et al., 2011; Dabak et., 2012). From recent studies, renal tubular damage is most likely the health implication generated from the consumption of this metal. Cadmium ingestion causes an increase in urinary protein excretion due to the damage of proximal tubular cell (Dabak et al., 2015a; Dabak et., 2015b). The degree of the effect depends on the length of action and amount of exposure.

At levels somewhat higher than those for which kidney proteinuria is an early effect indicator, skeletal damage is manifested. It is expected that public notification is required when any source of drinking water contains more than 5 parts per billion of cadmiums, as this could be a serious health consequence to the community (Genchi et al., 2020). The results of this study show that Cd^{2+} concentration is far above the 5 parts per billion. This could have been or part of the cause of the strange disease observed in the area.

Low-dose exposure to elevated levels of Cd^{2+} over a long period of time has different health consequences than a single high dose exposure. Acute health effects, such as flu-like symptoms, intestinal tract ailments and lung irritation, can be caused by intense short-term exposure (Genchi et al., 2020). Anomalously high isolated Cd^{2+} values in the two wells in the study area could be as a result of mineral deposits in the earth's crust where the wells were dug. The hazards of Cd are considered to be potential carcinogen and other causes of many diseases – especially cardiovascular, kidney, blood, nerve and bone diseases. Thus, local residents who are exposed to Cd^{2+} excessively through agricultural product consumption and contaminated water consumption are likely to come down with these ailments (Wei et al., 2009; Fu et al., 2012; Li et al., 2018).

Zinc concentration was observed to be slightly high in the S2 water sample ($3.13 \text{ mg L}^{-1} + 0.13$) as against the NIS value which is 3 mg L^{-1} . No possible health impact is expected from the consumption of water containing such amount of the metal. Bacteriological analysis shows that both of the samples have Coliform count that did not exceed recommended value (Table 3). The bacteria, Coliform, are not harmful microorganisms and they are also to be mildly infectious.

5. Conclusions

The assessment of the water quality revealed that most of the water quality parameters measured were within the maximum permissible limits with the exception of colour. Cadmium and Magnesium concentration values which were found to be above the maximum permissible limits of the NIS. The physicochemical parameters of well 2 were higher than that of well 1. Based on the findings of this study, Cadmium could have been the primary pollutant which could be the potential prime suspect involved in the adverse strange health challenges experienced by the villagers.

6. Acknowledgments

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7. Authors' Contributions

Chidi J. Ogham: contrived, planned, carried out and funded the study, and also prepared the manuscript. *Jonathan D. Dabak*: supervised, mentored and provided significant input to several sections to improve clarity and accuracy. *Kiri H. Jaryum*: reviewed, edited validated the draft. The final manuscript was perused and approved by all the authors.

8. Conflicts of Interest

The authors declare that there are no conflicts of interest related to this study.

9. Ethics Approval

Not applicable.

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