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Research Article

Evaluation of water quality from hand-pump and hand-dug well in southern Sierra Leone

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Njala, WHO, samples, microbial, faecal coliform.

Abstract

This study delves into the physicochemical and bacteriological characteristics of the Bonganema hand-pump and the Njala Junction hand-dug well, both vital sources of water for drinking and domestic purposes in the Kori Chiefdom of southern Sierra Leone. We meticulously analyzed a range of physicochemical parameters, including pH, electrical conductivity (EC), turbidity, total dissolved solids (TDS), and concentrations of sodium (Na mg/L), magnesium (Mg mg/L), calcium (Ca mg/L), iron (Fe mg/L), zinc (Zn mg/L), and copper (Cu mg/L). Additionally, we assessed crucial microbiological factors, focusing on both faecal and non-faecal coliforms. The water samples were transported to the Environmental Management and Quality Control Laboratory at Njala University, where they underwent rigorous analysis. The findings were then compared with the guidelines established by the World Health Organization (WHO), ensuring a thorough understanding of water quality and safety in this important region. The physical parameters of both the hand-pump and hand-dug well were under within the WHO guidelines. However, the hand-pump exhibited a concerning turbidity level of 8.46 NTU, significantly surpassing the WHO standard for drinking water turbidity of less than 5.0 NTU. While the chemical parameters for both sources remained within acceptable limits, the iron content raised alarms: the hand-pump recorded 0.67 mg/L, and the hand-dug well measured 2.817 mg/L, both well above the WHO's permissible threshold of less than 0.3 mg/L. The bacteriological analysis of the hand-pump revealed alarming levels of faecal coliform at 16.67 and non-faecal coliform at 15.00, both of which surpassed the World Health Organization (WHO) safety limits. Likewise, the hand-dug well-presented even more concerning figures, with faecal coliform levels at 30.67 and non-faecal coliform at 28.67. Moreover, every water sample assessed demonstrated disturbingly high concentrations of NTUs, iron (Fe), faecal coliform, and non-faecal coliform, all far exceeding the WHO limits. As a result, this water is unequivocally deemed unfit for drinking and other domestic uses, underscoring the urgent need for intervention and improvement in water safety.

1. Introduction

According to the World Health Organization (WHO) and UNICEF, approximately 319 million people in sub-Saharan Africa lack access to basic water supply services. This means that a large portion of the population in Africa does not have access to clean drinking water for daily needs, hygiene, and sanitation [1]. Groundwater sources in Africa are commonly used for drinking water and cooking with

GPS Coordinates

Njala Junction hand-dug well
N 8°16′27.63861″,
W 12°3′26.33487″

Bonganema hand pump
8°07'41.88" N, 12°03'19.32" E

Figure 1. Map of Moyamba District showing study area in circle.

no (or very limited) treatment, and as such, understanding the raw chemical and microbiological quality of these sources remains a key priority from a human health perspective [2]. In Sierra Leone, clean and safe drinking water continued to pose a major challenge for both rural and urban settlements.

According to the WASH routine mapping report, the most common source of drinking water is protected dug wells (37.5 percent). The quality of water is affected by different environmental dynamics such as pH, temperature, opacity or turbidity, amount of nutrients, hardness, alkalinity, and the amount of oxygen present in water [3]. The Njala hand-dug well and the Bonganema hand-pump are situated in the Kori Chiefdom, Moyamba district. These two water sources serve as a major water points for both locals and students at the Njala Campus. One-third of the residents of these two environments are mostly students or University staff. Clean and safe drinking water is a major challenge at Njala University campus, therefore, most students have resolved to take residents within these two communities where there is the presence of hand-dug wells or hand-pumps. Most of the water sources are used for drinking and agricultural irrigation are contaminated with physical, chemical, or microbial parameters.

The assessment of physicochemical parameters is necessary to ascertain the level to which the quality of water can be appreciated by individuals, homes, and corporate bodies. Also, they are readily available tools to determine the level of water acceptability for consumption and irrigation purposes [4, 5]. The objective of this investigation is to determine the quality dynamics of the hand-pumps and hand-dug wells used for drinking and agricultural irrigation to ensure that they align with the World Health Organization (WHO) permissible limits for drinking water.

2. Materials and methods

2.1. Materials

2.1.1. Description of study area

The study was conducted in the Bonganema and Njala Junction communities in the Kori Chiefdom, Moyamba District, southern province of Sierra Leone. Kori Chiefdom is situated at latitude 8.0000 North and longitude 12.0000 West. The Kori Chiefdom is a predominantly agricultural region (Fig. 1). The Bonganema community has only one functional hand-pump that is used by the locals for drinking and other domestic activities. The Njala Junction hand-dug well serves as a major drinking water extraction point.

2.1.2. Description of sampling area

Water samples were meticulously collected from the Bonganema hand-pump and the Njala Junction hand-dug well over the course of three months: April, May, and July. These two water sources were chosen for their remarkable consistency in providing water year-round, showcasing their reliability under varying conditions.

2.1.3. Quality assurance

A pristine and sterilized cup, securely tied with a rope, was used to gather water from the hand-dug well. To

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ensure the utmost quality, each bottle was rinsed three times with the water being sampled before collection. This meticulous approach was equally applied to gathering samples from the hand pump, reflecting a dedication to precision in every drop of water.

2.1.4. Sample collection techniques

Sterilized and clean labeled water bottles were used for water collection, and samples were placed in an ice cooler and conveyed to the Environmental Management and Quality Control Laboratory for analysis, within 30 minutes of collection.

2.2. Methods

2.2.1. The pH determination

The pH of the water samples was determined using a calibrated pH meter and triplicate values were recorded.

2.2.2. Determination of turbidity

The turbidity of the water samples was determined by the use of a turbidity meter. 10 mL of the water sample was measured and poured into a clean test tube, and thoroughly shaken to allow homogeneity. The turbidity meter was inserted into the water sample; the button was switched on. The values were recorded in triplicates.

2.2.3. Determination of total dissolved solids (TDS)

The total dissolved solids were measurement using spectrophotometric methods. The sample container was thoroughly shaken and 10 mL of the sample was measured using a measuring cylinder. The sample was placed in a beaker and stirred. The TDS meter was turned on and the values were recorded.

2.2.4. Determination of cations (Na, Mg & Ca)

Flame photometry was used to determine the cation levels in the water samples. The equipment was calibrated as prescribed in the operational manual, and the samples were prepared by shaking and filtering with Whatman filter paper. A neutral solution of ammonium acetate solution, which was used for extraction, was added in equal volume. The flame photometer was ignited and the values were determined, respectively.

2.2.5. Determination of heavy metals (Fe, Cu and Zn)

The above metals were determined using an atomic absorption spectrophotometer, each with a separate cathode lamp. The instrument operates on a burning principle that allows the sample to burn with the support of acetylene and air. The instrument displays the results in terms of concentration and absorbance.

2.2.6. Microbial analysis determination

The microbial analysis (coliform and *E. coli*) of these samples was determined by Delagua kit. The water sample was thoroughly shaken and measured using a graduated measuring cylinder. A 100 mL of the water sample was passed through a filtration manifold mounted with a filter membrane. The petri dishes were prepared with membrane sulphate. The pads were prepared with the membrane sulphate for all the bacterial to feed on them. The filter membrane was removed after all the sample water passed through and was aligned with the pads. The sample membranes were mounted in the Delagua for an incubation period of 18 to 24h at 44^{0}C. Examination was done based on the colour indicator, blue-green for *E. coli* and pink for non-faecal coliform colonies.

3. Results and discussion

3.1. Physicochemical

The results of the water samples analyzed for the hand-pump and hand-dug well were presented in the statistical methods (Variance, means, and standard deviation). The results of the individual analyses are illustrated in Table 1-2 and Figs. 2-4.

3.2. pH

The mean pH recorded for the hand-pump (6.77), and the hand-dug well (6.59) fell within the WHO permissible guidelines. The WHO recommended that drinking water should have a pH range of 6.5 -8.5. The pH of water is mostly influenced by environmental factors such as the presence of carbon dioxide (CO_2), silt, clay, and other microscopic particles. Although pH has been found to have no direct impact on drinking water quality (no health-based guideline recommended for pH value of WHO, 2003). The World Health Organization (WHO, 2003) [11] recommended careful examination of pH at all levels of the water treatment plant to ensure disinfection and clarification, and also minimizing low pH entering the water producing machine to help control or minimize corrosion of the pipe.

3.3. Electrical conductivity

The mean Electrical Conductivity (EC) for the hand-pump (40.22 μS/cm) and the hand-dug well (124.67

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Table 1. Physicochemical and bacteriological parameters of the hand-dug well.

Parameters	Hand-Dug Well (Njala Junction) Months			Mean	Variance	Standard Deviation	WHO
	April	May	June				
pH	6.58	6.51	6.69	6.59	0.001	0.05	6.5-8.5
EC (μs/cm)	123.00	112	139.02	124.67	123.08	7.85	<450
TDS (ppm)	0.36	1.41	4.58	2.12	3.22	1.27	<248
Turb. (NTUs)	4.34	4.61	5.39	4.78	0.20	0.32	<5.0
Na (mg/L)	9.14	8.72	10.36	9.41	0.48	0.49	200m/L
Mg (mg/L)	7.68	9.22	33.8	16.90	143.20	8.46	<200
Ca (mg/L)	16.15	17.09	44.13	25.79	168.33	9.17	<250
Fe (mg/L)	1.20	2.03	5.22	2.82	3.08	1.24	<0.3
Zn (mg/L)	0.01	0.03	0.95	0.33	0.19	0.31	<5.0
Cu (mg/L)	0.55	1.22	1.01	0.93	0.08	0.20	<1.0
F. coliform	30.00	23.00	39.00	30.67	42.89	4.63	0.00
Non-faecal	20.00	11.00	55.00	28.67	360.22	13.42	<10.00

Table 2. Physicochemical and bacteriological parameters of the hand-pump well (Bonganema).

Parameters	Hand-Pump (Bonganema) Months			Mean	Variance	Standard Deviation	WHO
	April	May	June				
pH	6.77	6.66	6.88	6.77	0.008	0.06	6.5-8.5
EC (μs/cm)	12.00	14.0	94.66	40.22	1482.52	27.23	<450
TDS (ppm)	0.17	1.22	3.29	1.56	1.68	0.92	<248
Turb. (NTUs)	8.10	8.22	9.05	8.46	0.18	0.30	<5.0
Na (mg/L)	9.45	8.53	9.67	9.22	0.244	0.35	200
Mg (mg/L)	7.14	13.2	20.14	13.49	28.210	3.76	<200
Ca (mg/L)	14.39	21	56.31	30.57	338.64	13.01	<250
Fe (mg/L)	0.00	0.00	2.02	0.67	0.91	0.67	<0.3
Zn (mg/L)	0.39	0.46	2.49	1.11	0.95	0.67	<5.0
Cu (mg/L)	0.40	0.41	1.84	0.88	0.46	0.48	<1.0
F. coliform	20.00	16.00	14.00	16.67	6.22	1.76	0.00
Non-Faecal	11.00	7.00	27.00	15.00	74.67	6.11	<10

μS/cm) fell within the WHO bracket of ECs in drinking water. The WHO recommended range for ECs in drinking water is <450 μS/cm.

3.4. Total dissolved solids (TDS)

The mean Total Dissolved Solids for the hand-pump (1.56 ppm) and the hand-dug well (2.12 ppm) fell within the WHO limits of ECs. According to the WHO, drinking water should have a TDS of < 248.

3.5. Turbidity

The mean Turbidity of the hand-pump (8.46), and that of the hand-dug well (5.39) fell outside the WHO bracket for turbidity of drinking water (Table 1-2, Fig. 2). WHO recommends that the turbidity of drinking water should be <5.0 NTUs. However, the turbidity level for the hand-pump was extremely high, indicating a high level of contamination in the water sample. The high turbidity value in the water sample could result from the presence of dead organic matter, inorganic microscopic particles, and a low water level in the well. Turbidity is an important parameter for determining water quality. Another cause of turbidity increase in water is due to the transportation of solid waste and top soil particles as a result of runoff [6].

A similar research was carried out by Solomon et al. [4]. Similar increases in turbidity values were reported. Another analysis was carried out by Edeki et al. [7].

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Reported high turbidity values above the maximal admissible ceiling of 5 NTU for WHO and NSDWQ benchmarks, suggest an unsatisfactory condition of the water. High turbidity is often associated with the possibility of microbiological contamination; as high turbidity makes it difficult to disinfect water properly [10].

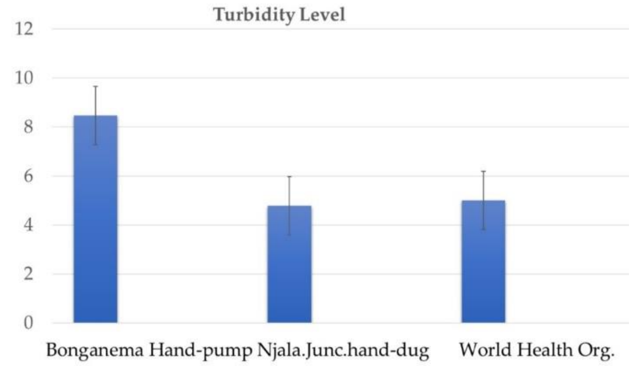

Figure 2. Turbidity level of the two water samples.

3.6. Chemical concentration (Ca, Mg, Na, Zn and Cu)

The mean chemical concentrations (Ca, Mg, Na, Zn and Cu) for the hand-pumps and hand-dug wells fell within the WHO recommended value for drinking water.

3.7. Iron (Fe)

The mean Fe concentration for the hand-pump (0.67mg/L) and hand-dug well (2.82mg/L) fell outside the WHO permissible limits for drinking water (Table 1-2, Fig. 3). According to the WHO, the acceptable level of Fe in drinking water should be <0.3mg/L. Iron is an element that occurs naturally on earth, and especially in surface water (rivers and streams) and in groundwater. Although it is an important mineral needed by the body for proper maintenance, however, its occurrence in large amounts above the threshold will pose a serious health challenge. Fe enrichment may be related to the dominant soil type in the region, in addition to contamination generated by agricultural activity, and urban and industrial effluents in the vicinity of these water bodies [8]. The presence of high concentrations of iron in water can cause several problems, including incrustation leading to clogging of water treatment setups, acidification of water leading to corrosion of pipes, decline in soil cultivation productivity, and an undesired taste in drinking water.

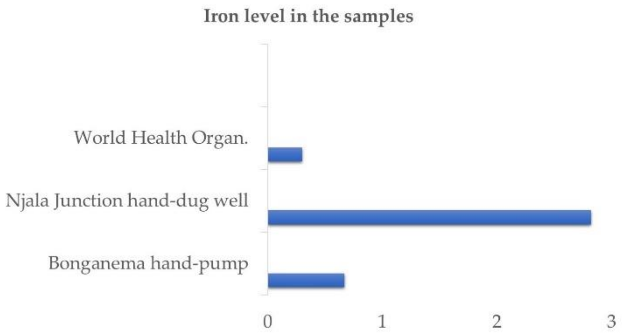

Figure 3. Iron concentration in the two water samples.

3.8. Microbial analysis

In 2022, at least 1.7 billion people globally, used drinking water sources contaminated with faeces. Microbial contamination of drinking water is a result of fecal contamination and poses the greatest risk to drinking-water safety (UN-Water. Summary progress update 2021: SDG 6 – water and sanitation for all).

3.9. Faecal coliform

The mean faecal coliform content for the hand-pump (16.67) and the hand-dug well (30.67) fell outside the WHO recommendation limits of faecal coliform in drinking water (Table 1-2, Fig. 4).

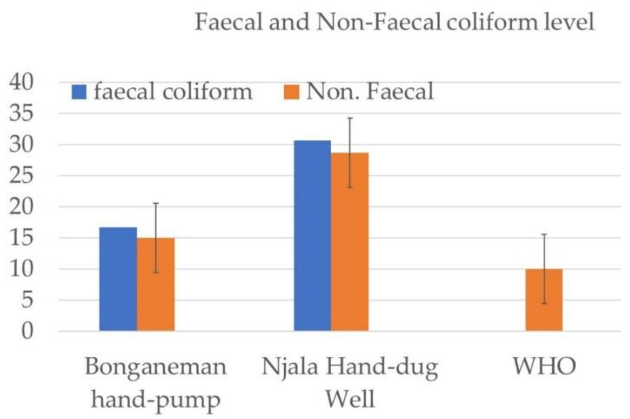

Figure 4. Faecal and non-faecal coliform level in the two water samples.

The WHO recommends that drinking water should not contain any faecal coliform. Faecal coliform enters the rivers or streams through indirect or direct discharge of waste material from birds, agriculture and storm water. Home flooded, septic tanks discharged waste, thereby making their way into water bodies, contaminating drinking water.

3.10. Non-faecal coliform

The mean values of non-faecal coliform for the hand-

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pump (15.00) and hand-dug well (28.67) show high concentrations of microbial contamination that are above the WHO threshold (Table 1-2, Fig. 4). The WHO recommends that total coliform bacteria should not be detected in 100 mL of drinking water. A similar study conducted to determine the bacteriological contamination of ground water sources, revealed that non-faecal coliforms were found in all the wells and boreholes sampled, analyzed [9].

4. Conclusions

Water is not just a necessity; it is crucial for the proper functioning of our body and the regulation of temperature. Given its vital importance, it is imperative to consistently monitor its quality. In the local community, two primary water sources—a hand pump and a hand-dug well—serve as lifelines for drinking and various domestic activities throughout the year. However, a recent analysis of the water samples unveiled alarming findings: elevated levels of both fecal and non-fecal contaminants, high iron concentrations, and significant turbidity. These results starkly reveal that the water sources relied upon by the residents of these two locations are far from safe for drinking or domestic use. It is essential for the community to address these issues urgently to safeguard their health and well-being.

Disclaimer (artificial intelligence)

Author(s) hereby state that no generative AI tools such as Large Language Models (ChatGPT, Copilot, etc.) and text-to-image generators were utilized in the preparation or editing of this manuscript.

Authors' contributions

Formal analysis, methodology, writing original draft, M.P.J.; Investigation validation, writing—reviewing, I.K.; Formal analysis, writing—review and editing, Y.K.K.; Investigation, writing—reviewing, S.P.

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Availability of data and materials

The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

Conflicts of interest

The authors declare no conflict interests.

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