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Assessment of Groundwater Quality: A Case Study of Sierra Rutile Mining Communities Southern Sierra Leone

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Research Article

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ABSTRACT

The study focused on the potential water sources and the quality of the available source. In order to determine water quality, two sample sites were selected in each of the three mining communities namely: Moriba town, Mogbwemo, and Kpetama. Groundwater was analyzed for the physicochemical and biological parameter. All the parameters were compared to the WHO standard. The water quality indicators were in good agreement for potable water with three exceptions namely; pH, turbidity, and nitrate which really needed attention. In the study area, most people prefer hand dug well for drinking and domestic purposes like cooking, laundering, bathing, house cleaning, ablution, and dishwashing. Apparently, the study area clearly shows that people have a concern about clean and safe drinking water. Many respondents do not drink from the artificial dam created by the company because they don't trust the quality but it is used for other purposes.

INTRODUCTION

Water quality and or safety issues are a major and growing challenge facing governments in both developed and developing countries [1]. Safe water implies that drinking water (water used for drinking, cooking, food preparation, and personal hygiene) is free from pathogens and any levels of toxicants at all times and poses no significant threat to health [2].

The thrust was to determine the quality and sources of drinking water in Moriba town, Mogbwemo and Kpetama villages. It is suggestible that water in the study area is of the different source(s) thus operations of the Sierra Rutile Mining Company and anthropogenic activities remain a challenge to the communities' water quality sources. However, the quality of water was always questionable due to the predominance use chemical by the Company.

Water quality is becoming a major problem, as evidenced by frequent outbreaks of waterborne diseases in both rural and urban areas of developing countries. Waterborne diseases are still a major health burden in many parts of the world and estimated to cause about 842,000 diarrhea disease deaths per year [3]. At present, Safe drinking water is defined as water with microbial, chemical and physical characteristics that meet WHO guidelines [4]. For instance, the microbial guideline states that coliform bacteria must not be detectable in 100 ml samples of water to be considered as safe and their presence in drinking water indicates the guidelines state that water with turbidity values below 5 Nephelometric Turbidity Units (NTU) can be considered as safe, in these terms of turbidity possibility of pathogenic bacteria. Due to the fact that only one study has being done in the study area, this work can help to strengthen water quality. The studies will, therefore, try to fulfill this gap by providing information and technical advice in the best interest of people's health.

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METHODOLOGY

Description of Study Area

Moriba town, Kpetama and Mogbwemo villages are the specific villages targeted for the research due to their proximity to the Company. These are located partly in the Impere Chiefdom, Bonthe district and partly in the Lower Banta Chiefdom, Moyamba district in the Southern region of Sierra Leone. It lies approximately 137 km South-west of the capital Freetown and approximately 30 km east of the Atlantic Ocean **(Figure 1)**. Some areas are rich in silt and clay and agricultural activities are predominant. Titanium dioxide (TiO_2) commonly referred to as "Rutile" with Ilmenite and Zirconium dioxide (ZrO_2) as major bye products are predominantly mined around the study area [5].

Figure 1. Map showing the study area.

Procedure

A random sampling technique was done. Forty (40) residents from Moriba town, thirty (30) from Mogbwemo and thirty (30) from Kpetama were randomly selected; residential heads were interviewed using a structured questionnaire administered to help determine the perception of people about water quality and identified the source of drinking water **(Table 1)**. To determine the water quality a total of two samples from each community water source were collected during the dry season (December 2018-January 2019).

Table 1. Selected water sources versus GPS coordinate.

S No.	Selected water source (well)	GPS coordinate (UTM Zone 28 P)	
		Northing	Easting
1	Moriba town (GW01)	797984	861941
2	Moriba town (GW02)	798167	861964
3	Kpetama (GW03)	800378	859499
4	Kpetama (GW04)	500458	859306
5	Mogbwemo (GW05)	797233	858521
6	Mogbwemo (GW06)	797079	858964
7	Sierra rutile Ltd. plant site	798675	859278

Water Sampling and Physicochemical Measurements

A 500 ml high-density polyethylene bottle was used to collect samples. Each sample container was a label with the sample point name on it. The samples were collected using the local collecting containers available at each sampling point. Samples were then placed in a Coleman stacked with ice packs. After the whole collection process, the sample was transported into the laboratory where they were refrigerated until analysis using Standard Operating Procedures (SOPs). All samples were taken to the Sierra Rutile Limited laboratory for analysis.

The physical parameters investigated include pH, temperature, turbidity, Electrical Conductivity (EC), Total solid substance and Total Dissolved Solids (TDS). For the chemical parameters investigated were: iron, copper, manganese,

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nitrate, and sulfate. The physical parameters were immediately measured *in-situ* using a combined Acumen AC 85 Fischer Scientific pH, temperature and conductivity meter. The meter was calibrated using buffer solutions recommended by the manufacturer. All chemical parameters were analyzed using Palin test photometer and the photometer is preprogrammed with test calibration which gives a direct-reading of the test result, the standard operating procedures for all the chemical species were followed during analyses in the laboratory.

Microbiological Parameters

The Wagtech testing kit was used for the bacteriological examination. The equipment and all its accessories are sterilized before use in order to prevent inaccurate result due to contamination. 100 ml of each sample is measured using a standard sterilized measuring cylinder. The water sample is pumped through a membrane filter of pore size 0.45 microns. The filtrate then was placed on petridishes containing endo broth media on a filter pad for the resuscitation of microbes thereafter placed in an incubator for 18 to 24 hours, at 37°C. The samples were removed and metallic sheen colonies counted and recorded as *E. coli*. The Oxoid media brilliant green bile agar was prepared a day prior to sampling and left to gel at 4°C. 0.1 ml inoculum was pipetted and poured on the media in a petri-dish and aseptically spread all over the media and incubated as above time and temperature. This was to enable indicator bacteria such as fecal coliforms to grow independently.

Data Analysis

Excel software package was used for the descriptive analysis and Data denoting perceptions were analyzed using the IBM SPSS program version 16 or percentages.

RESULT AND DISCUSSION

Source of Water

The research revealed that all respondents in the study area do not trust some of the water sources (dams and unprotected boreholes) created by the Company. Apparently, Majority prefer hand dug wells for drinking and other domestic purposes like laundry, bathing, ablution, house cleaning and dishwashing **(Table 2)**. The research also shows that hand dug wells are more used as compared to other categories.

Table 2. Water sources versus their respective uses.

Use categories	Artificial dam	Hand dug well	Borehole	Tap water	Sachet water	Bottled water
Drinking	0	50	10	10	15	15
Cooking	5	48	17	30	0	0
Laundry	15	40	8	35	1	1
Bathing	15	45	15	25	0	0
House cleaning	20	50	10	20	0	0
Dish washing	20	55	10	15	0	0
Ablution	13	42	15	30	0	0
Total	88	330	135	165	16	16

Water Quality

pH, Temperature, Conductivity, TDS, Turbidity, TSS, Manganese, Copper, Iron, Nitrate, Sulphate, Total coliform, and fecal coliform were parameters checked to determine the quality of water for the different sampling points.

pH: The pH values of the samples in the study area ranged from 4.36 to 5.50 **(Table 3)**, most water samples tested were found to be above the acceptable limit value for safe drinking water [4]. Kpetama (KGW04) which has 4.30 and the plant effluent (PE07) which has 4.36 are in similar range thus, indicating apparent leaching. A character with the strongest acid content of 4.32 is evidence of strong mineral acids [5].

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Table 3. Showing the comparison between sample parameters and the WHO Standard.

Parameters	MGW01	MGW02	KGW03	KGW04	MGW05	MGW06	PEE07	WHO Standard
pH	5.5	4.84	4.83	4.3	4.41	4.93	4.36	6.5-8.5
Temperature (°C)	22.9	22.8	22.7	22.8	22.7	22.7	22.8	-
Conductivity (µS/cm)	155.46	145.2	32.9	135.5	81.01	43.52	41.02	450
TDS (mg/l)	76.46	73.56	16.26	58.28	39.89	21.43	20.18	1500
Turbidity (NTU)	9.89	4.72	6.83	13.2	1.1	0.47	52	<5.0
TSS	19	12	15	2	8	7	42	50
Manganese (mg Mn/l)	>>0.03	>>0.02	>>0.030	0.03	>>0.030	>>0.02	>>0.04	0.1
Nitrate mg (NO_3/l)	24.5	14.2	26.2	22.3	28.5	22	24.2	10
Copper (mg Cu/l)	0.3	0.5	0.4	0.22	0.4	0.3	0.03	1
Iron (mg Fe/l)	0.2	0.03	0.14	0.02	0.01	0.03	0.03	0.3
Sulphate (mg/l)	20	30	60	7	8	25	30	400
F/Coliform (per 100 ml)	0	0	0	0	0	0	0	0
T/Coliform (per 10 100 ml)	0	0	0	0	0	0	0	0

Turbidity: The permissible limit is 5 NTU [6]. The analysis conducted in the study area shows that MGW01, KGW03, KGW04, and PE07 are above the permissible limit of WHO **(Table 3)**.

The parameters such as conductivity, temperature, total dissolved solids, total suspended solids, manganese, copper, iron, and sulfate [7-10] analyzed for thus fall within the acceptable limit of the WHO standard as shown in **(Table 3)**.

Nitrate (NO_3): The values of nitrates in the study area range from (14.2-28.5) mg/L. nitrate, which is above the recommended limit of WHO for safe drinking water [11,12]. Evidence of higher NO_3Ï levels in potable water has been reported to cause or induce methemoglobinaemia, gastric cancer, goiter, birth malformation and hypertension [5].

CONCLUSION

In the current study, groundwater sources were drawn from six main hands dug wells two from each community and analyzed for physical, chemical and biological parameters respectively and results were compared with WHO water quality standards for drinking purposes. The water quality indicators were in good agreement for potable water with three exceptions namely; pH, turbidity, and nitrate which really needed attention. Among the sources of water, hand dug well was predominantly used for domestic purposes like cooking, laundry dishwashing, housecleaning, and bathing. Despite the quarterly monitoring made by the company; it is recommended for improvement in the area of regular monitoring and treat water sources on quarterly bases to ensure safe drinking water.

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