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Evidence of groundwater contamination in a shallow aquifer

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ABSTRACT

Groundwater use has intensified in recent years as uncertainties surrounding the capacity of public utility companies to provide sustainable drinking water increase. The upsurge has necessitated an unprecedented development of shallow groundwater sources by government, humanitarian agencies, and the private sector. There is a growing body of evidence which seem to suggest that the quality of groundwater used for drinking and other domestic use has been compromised.

The objective of this study is to first ascertain whether the quality of groundwater in a shallow aquifer system has been compromised and thereafter determine the extent of the deterioration of water quality. A complementary objective is ascertaining the sources of contamination if any, and to recommend actions that needed to be taken to eliminate the threat. To achieve these objectives bacteriological tests were carried out on shallow groundwater sources to determine the content of faecal and non-faecal coliform bacteria.

Bacteriological tests conducted on groundwaters in the area indicate that 46% of the sources investigated are of high risk, suggesting that they are highly contaminated and hence, unsafe for human consumption. The result also shows that only 27% of the drinking sources may be considered are safe for drinking, which calls into question the health status of users of the water. The principal source of contamination has been shown to be faecal coliform bacteria, which occurs in 73% of the sources investigated. To eliminate the threat of bacterial contamination, continuous chlorination is recommended on shallow dug wells considered to be of high risk until the threat is eliminated.

KEYWORDS : Shallow groundwater; water quality; contamination; faecal coliform bacteria; drinking sources; risk assessment.

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I. INTRODUCTION

Groundwater use in rural and peri-urban communities in Sierra Leone has intensified in recent years, attributable to the inability of government and humanitarian agencies to sustain the traditional surface sources which had provided sustainable drinking water to the mainly farming population. The upsurge in groundwater use may also be ascribed to the relative ease with which it could be harnessed, usually by constructing shallow dug wells that intercept groundwater at relatively shallow levels within the Regolith Aquifer.

The widespread development of shallow groundwater sources in other areas of the country by humanitarian agencies has raised serious concerns about the quality of drinking water, which evidence has shown to be deteriorating (Thomas, 2010; Thomas and Momoh, 2017). This study assesses the safety of drinking water obtained from the shallow aquifer by determining the content of faecal coliform bacteria present in the groundwaters. Most pathogens in drinking water are derived from faecal contamination (UNICEF Handbook on Water Quality, 2008). Since faecal coliform bacteria is invariably present in the intestines of humans and is passed out in the faeces, it may be associated with organisms that can cause disease in humans. Thus, it is used extensively as an indicator of groundwater contamination (WHO, 2011). The study assesses the level of faecal coliform contamination of the groundwater sources.

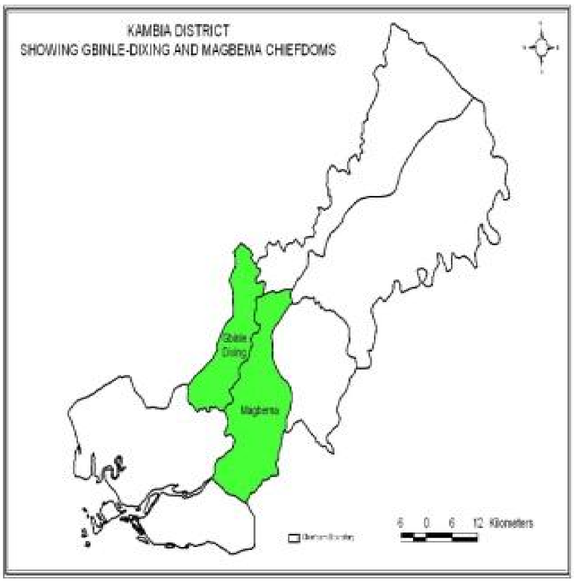
Water safety and security are usually taken for granted in rural and peri-urban communities where the practice of harnessing unconventional sources for drinking and other domestic use is still common place. The result of this study will help government and humanitarian agencies better understand the status of our drinking water sources in terms of safety and to use the recommendations as a guide to policy formulation and implementation in the water resources sector.

II. DESCRIPTION OF THE STUDY AREA

As shown in Fig. 1, the study area is located in Kambia District which lies within the interior and coastal plains of northern Sierra Leone and encompasses two chiefdoms: Gbinle Dixing Chiefdom to the north and Magbema Chiefdom to the south of Kambia Town where about 60 % of the water points are located. The area of study is approximately 432 km^2 and lies between latitudes $9^\circ\, 00'$ and $9^\circ\, 15'$ N, and between longitudes $12^\circ\, 53'$ and $13^\circ\, 02'$ W, comprising the Great Scarcies (Kolente) catchment in northwestern Sierra Leone.

Figure 1. (a) Map of Sierra Leone showing Kambia District; (b) Map of Kambia District showing the study area

(a)



(b)

Hydrogeological setting

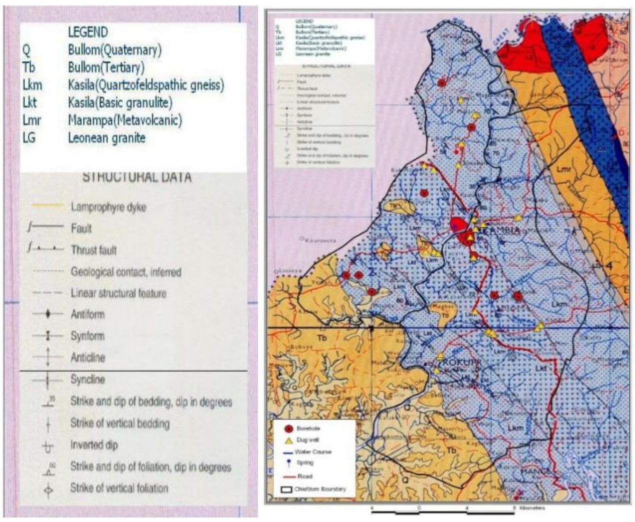
The study area is covered by a thick mantle of regolith formed by weathering of the underlying crystalline basement. The surface geology consists of high grade (amphibolite to granulite facies) metamorphic rocks occupying a belt roughly 25 km wide extending from the Guinea border in the north to the southern tip of Sierra Leone. A geological map of the area (Fig. 2) is adapted from the Geological Map of Sierra Leone (Keyser and Mansaray, 2004). The lithology consists of basic granulites, amphibolites, and basic and quartzo-feldspathic gneisses (Williams, 1988), which are in tectonic contact with and resting on an Archaean Basement comprising granitoids and migmatitic gneisses (Fig.2). The quartzofeldspathic and quartzose rocks have been interpreted (Vallance, 1975; Williams and Williams, 1976; Macfarlane et al., 1981) on the basis of their composition and association as being dominantly of sedimentary origin.

Deposits of Tertiary and Quaternary sediments occur within large depressions of the granulites as patches of fresh, poorly consolidated sands and clays (Culver and Williams, 1979a). The sediments possess dual permeability in that the sandstones are characterised by diffused and fissure flow while flow in the crystalline basement is largely fissure controlled. Recent sands and gravels transported by streams which sometimes contain fragments of bedrock are found on the surface and at shallow depths.

Thomas (2008) presents an overview of the Crystalline Basement Aquifer. The porosity of the weathered layer (regolith) is relatively high and contains a significant amount of water. However, because of the relatively high clay content derived from weathering of feldspars, its permeability is low, unlike the fresh and fractured bedrock which has high permeability (Barker, 2001). Barker (2001) suggests that as fractures do not constitute a significant volume of the rock, the fractured basement has a low porosity.

Taylor and Howard (1998; 1999b), note that fractures in crystalline bedrock are often discontinuous and the apparent low storativity suggests that sustained abstraction from this aquifer could only be possible due to leakage from the more porous overburden. Precipitation appears to be the principal factor controlling recharge into the aquifers. Butterworth et al. (1999) have shown that where the soil in weathered aquifers is freely draining, groundwater levels typically responded within a few days of major rainstorms.

Figure2. Geological map of the study area showingthe distribution of water points



III. METHODOLOGY

Protected dug wells used for drinking and other domestic use were selected for the study. River water is sometimes used for drinking and other domestic use. Thus, a sample of river water was collected and analysed for comparison. It was ensured that all sources were in use at the time of sampling. Bacteriological tests were conducted using a Delagua Water Quality Testing Kit. Groundwater samples were collected in special glass bottles that have been previously sterilized by heat treatment to eliminate any traces of micro-organisms. The bottles were filled completely with the water samples and the caps tightly screwed to prevent the entry of air. The water samples were put in petri dishes and left to incubate at a temperature of 44°C on a medium that allows the bacteria to reproduce and form colonies. The petri dishes were removed from the incubator chamber after 16 hours and the green and pink colonies were counted for faecal and non-faecal coliforms, respectively. The colonies counted are directly related to the bacteriological content of the water sample.

IV. RESULT

Table1 shows the number of faecal and non-faecal coliform bacteria found in the groundwaters. It is seen from the result that 73% of the sources including the river water contain faecal coliform bacteria, while those with non-faecal coliform represent 77%. The result also clearly indicates that in four of the sources (GBR-GD, KEB-GD, TAUII-GD, and GBE-GD) the number of faecal coliform bacteria are too numerous to count.

Table1. Bacteriological quality of shallow groundwater in Kambia District

No.	Water source	Well ID	Faecal coliform /100 ml of water	Non-Faecal coliform/100 ml of water
01	Banguru	BANII-GD	165	60
02	Mafari	MAF-GD	250	190
03	Rotifunk	ROT-GD	80	35
04	Balamuya	BALI-GD	Nil	5
05	Gbinleh River	GBR-GD	*TNTC	25
06	Kebeya	KEB-GD	*TNTC	20
07	Tauyia 1	TAUI-GD	15	90
08	Tauyia 2	TAUII-GD	*TNTC	5
09	Gberi	GBE-GD	*TNTC	75
10	Kambia CAR	KAMCAR-M	25	125
11	Kamba 2	KMBII-M	5	20
12	Kamba 3	KMBIII-M	135	TNTC
13	Magbema Market	MAGBMI-M	125	100
14	Magbema Market	MAGBMII-M	20	10
15	Magbema Market	MAGBP-M	Nil	150
16	Petifu	PET-M	10	Nil
17	Kapairon 1	KAPI-M	25	Nil
18	Kapairon 2	KAPII-M	Nil	Nil
19	Kambia PS	KAMII-M	70	10
20	Rokupr P	ROKII-M	Nil	Nil
21	Rokupr A	ROKIII-M	Nil	Nil
22	Magbema Market	MAGBS-M	Nil	20

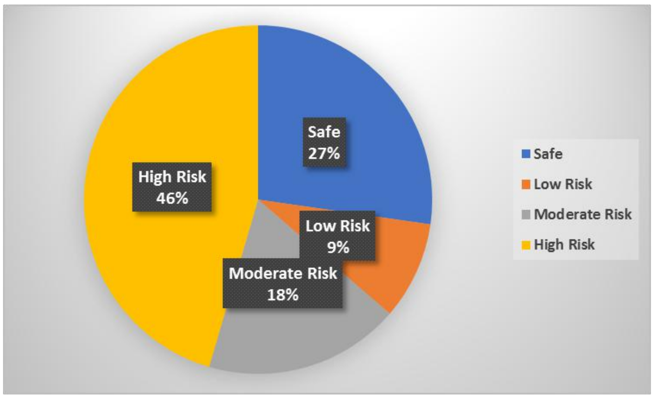
**TNTC = Too numerous to count*

The risk associated with the use of the groundwaters for drinking is presented in Table2. It is seen that 46% of the sources are deemed to be of high risk (Fig.3), with the content of coliform bacteria exceeding 60, suggesting that the sources are contaminated and therefore unfit to drink in their current states unless they are disinfected, preferably with chlorine solution.

Table2. Risk assessment of the groundwaters based on the content of faecal coliform bacteria

Content of faecal coliform bacteria	Risk Assessment	No. of sources
0	Safe	6
1 - 10	Low Risk	2
11 - 60	Moderate Risk	4
>60	High Risk	10

Figure3. Pie chart depicting the safety of the drinking sources



V. DISCUSSION

The result of water quality assessment clearly suggests that the groundwater sources used for drinking are contaminated by faecal coliform bacteria. Faecal coliform bacteria were found in 16 out of 22 sources, which represents 73% of all sources investigated. The content of non-faecal coliform bacteria is also very high in the groundwaters. The result shows that 17 out of 22 sources contain non-faecal coliform bacteria, representing 77% of all sources investigated. There is also good correlation between contents of faecal and non-faecal coliform bacteria. That is, most of the sources where faecal coliforms are found also contain non-faecal coliforms. Nearly half of the water samples tested (46%) are shown to be of high risk and only 27% may be considered safe.

There has been much speculation about the sources of faecal coliform bacteria in groundwaters in shallow wells in Sierra Leone (Thomas, 2008; Thomas, 2010, Thomas and Momoh, 2017). Although the close proximity of shallow wells to pit latrines could account for a high coliform count in the groundwaters, faecal matter entering the saturated zone, derived from open defecation seems to be the principal source of bacteriological contamination of groundwaters in shallow wells in the area and elsewhere in the country (Thomas and Momoh, 2017). More research has to be done to track travel paths of contaminants and the velocity of groundwater flow.

VI. CONCLUSION

This assessment has shown that the quality of groundwaters in the study area has been compromised by the presence of faecal and non-faecal coliform bacteria, which could be attributed to poor sanitation practices, exacerbated by poor hygiene in the affected areas. Where such drinking sources are shown to be contaminated the cheapest remedy is to disinfect the source by applying chlorine solution. The source(s) of contamination should be immediately ascertained and protective measures instituted to thwart the threat. The study has corroborated earlier findings of widespread contamination in shallow dugs wells in rural and peri-urban communities in the country.

VII. ACKNOWLEDGEMENT

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