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Fluoride Levels in Borehole Water: The Case of Chiradzulu District in Malawi

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Aims: The objective of this study was to determine the levels of fluoride in borehole water samples.
Study Design: The total of eight samples were collected from five villages in Chiradzulu and transported in cooler ice-bath to the laboratory for the analysis.
Place and Duration of Study: The study was conducted in the Department of Chemistry and Chemical Engineering Laboratories, at University of Malawi in the month of June.
Methodology: The ion selective electrode technique was used to assess fluoride levels. Physicochemical water parameters were measured with multi-meters.

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Results: The results obtained ranged from 2.26 to 3.08 mg/L, 136 to 561 mg/L, 261-1212 µs/cm and 6.27 to 6.97, for Fluorides, TDS, conductivity and pH, respectively. Levels of fluorides exceeded permissible limits for borehole water established by WHO and were below the standards for MBS

Conclusion: The results attained in the scope of the study support coloration of teeth observed amongst individuals in study communities, helping to understand that groundwater is not suitable for consumption. Therefore, the study provides recommendation for urgent implementation of defluoridation measures to provide clean and safe water for the existing community members.

Keywords: Fluorides; mineral elements; groundwater; irrigation; defluoridation.

1. INTRODUCTION

Water is regarded as the most important resource on earth as it ensures the existence of life. Every living organism requires this precious resource for cellular tissue respiration and metabolic processes [1]. The need for clean and safe drinking water resources keeps rising due to rapid population growth, urbanization and industrialization [2]. Water of good quality and accepted standards is required for domestic usage, agricultural irrigation, recreation and industrial manufacturing applications, among others [3]–[5]. Most people residing in remote areas in Sub-Saharan African countries depend on borehole water resource for domestic use as it is considered the safest and the cleanest. In Malawi, just like most African nations, many people residing in rural areas do not have access to portable water. As a result, they resort to ground and surface water resources for drinking and other domestic purposes [6]. However, several chemical pollutants have been detected in groundwater sources. This threatens the well-being of water users as they are associated with various health effects. Several studies have reported high levels of ions including arsenic, cadmium, lead, mercury, nitrates, nutrients, microbes and fluorides [7]. The presence of these ions in groundwater sources is influenced by mineral dissolutions, deposits and rock layer depending on the geology of a particular area [8]. High levels of fluoride in ground water sources is influenced by numerous factors. Some of them include; high levels of fluorine in aquifers, high water pH, poor groundwater flow rate and semi-arid climate that enhances evaporation [9]. However, anthropogenic activities such as irrigation and agriculture have also been documented as the major contributors to the presence of mineral elements, heavy metals and fluorides in water, among others [10].

Fluorides in drinking water at minimal concentration of 0.5 mg/L is responsible for the development of healthy teeth and bones especially in children [11,12]. However, high levels of fluorides in drinking water resources is hazardous to human health and can induce numerous serious health problems such as dental and skeletal fluorosis [13]. Fluorosis has become a serious health concern having affected more than twenty nations in Africa and Asia as the most affected continents [14]. Furthermore, recent studies have indicated that intake of fluorides surpassing required doses can cause metabolic physiological related illnesses such as reproductive system and central nervous system failure and the impairment of soft tissues [14]. It is therefore very significant to monitor levels of fluorides in water resources in order to overcome its associated health implications when consumed in amounts exceeding permissible limits [15].

Studies conducted in some parts of the western Ghana have shown that groundwater from different boreholes in some locations exceeded 1.5 mg/L permissible fluoride standard limit established by World Health Organization (WHO) and health experts suggested complete shutdown of such particular boreholes to escape dental fluorosis related cases [16]. In another study done in rural areas of South Africa indicated that fifty percent of the primary school leaners had brown teeth due to consumption of borehole water with high amounts of fluorides [17]. Malawi is among the African countries that lie to the East of African Rift Valley system which is known to be rich with high level doses of fluorides [18].

This study therefore aimed at assessing the levels of fluorides in groundwater samples which were collected in selected villages in Chiradzulu District in the Southern Region of Malawi. Chiradzulu District was opted for the study because it is among the districts which were recently heavily affected by Cyclone Freddy and most of the surface water sources were greatly

compromised due to the aftermath of the catastrophe. Furthermore, most of the people within the community have teeth discoloration condition since they are dependent on borehole water for drinking and other domestic purposes due to the absence of clean tap water. Therefore, this justifies the need to assess the levels of the fluorides in the groundwater used by the populations within the surrounding communities.

2. METHODS AND MATERIALS

2.1 Study Area

The study was conducted in Chiradzulu District in the Southern Region of Malawi. The samples were collected in five selected villages namely: Njenjema, Mukowa, Chikaika, Chimombo and Kanyepa as shown in Fig. 1. Geographically, the area comprises two adjacent hills and the River Thumbwe. The hills are Chitembere and Mwananyama. Thumbwe River flows within the vicinity and it is not sufficient to provide clean adequate water resource to the communities. The water is not be safe for drinking and domestic purposes due to massive pollution resulting from poor waste management. This implies that inhabitants of the area rely much on the ground water resource for their daily activities.

2.2 Sample Collection

The samples used in the study were collected in winter season in the month of July 2023. A total of eight samples from separate boreholes were collected for analysis. On each point, the samples were collected in triplicate in 500 mL pre-cleaned plastic bottles. The samples were collected from boreholes and after collection, the samples were placed in cooler box with ice bath and transported to public institution, The University of Malawi, Chemistry and Chemical Engineering Laboratory where analysis was performed. Onsite measurements such as electrical conductivity, pH, TDS, and temperature were carried out and recorded instantly using multi-meter and the results were appropriately recorded in the data book.

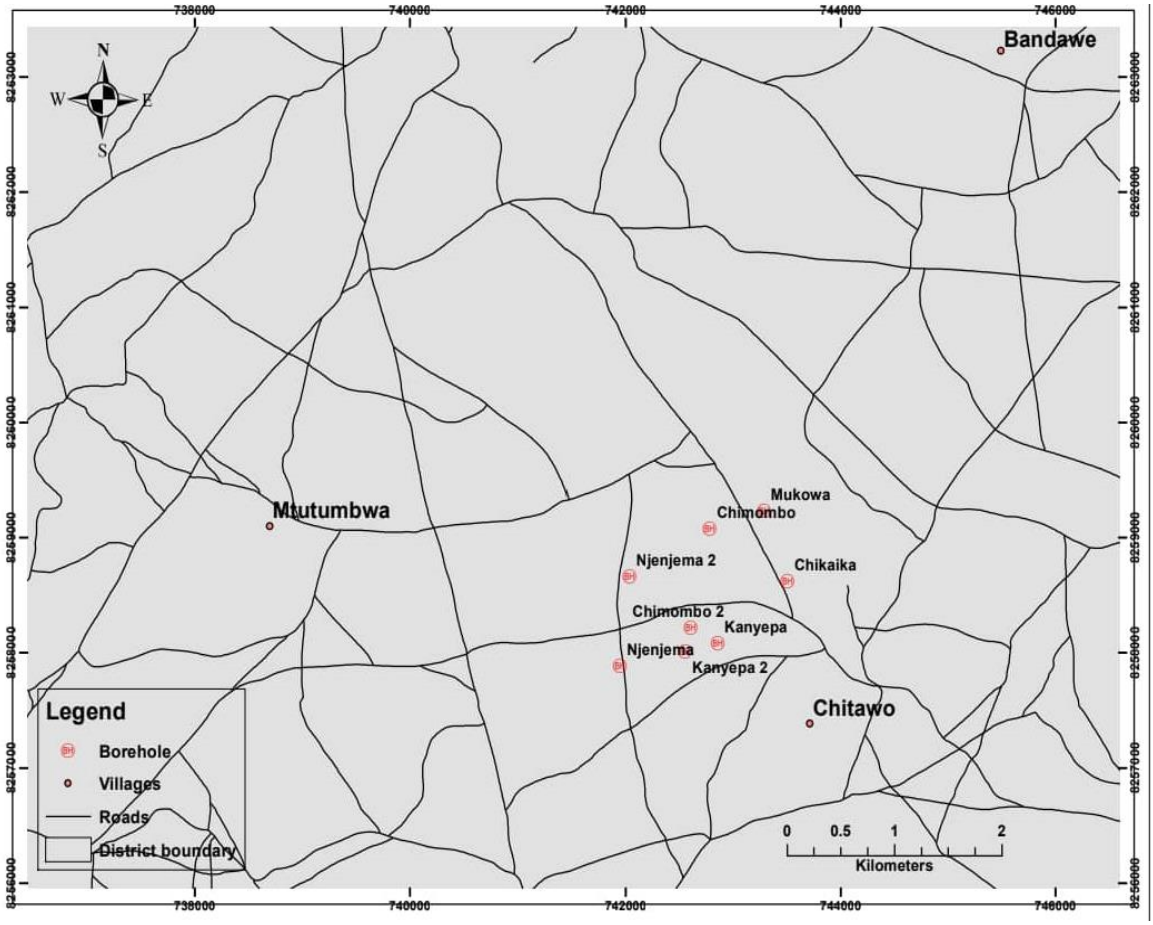

Fig. 1. Map of Chiradzulu showing water sample collection points

2.3 Fluoride Determination

Dissolved Fluoride concentrations in borehole water was determined using ion selective electrode method connected to ion meter with TISAB at the temperature of 298 K. The accuracy of the method was verified and calibrated with different concentrations followed by deionized water. The fluoride solution of 100 mg L^{-1} was prepared by dissolving 2.219 g of NaF in 1 L of distilled water. Standard solutions of different concentrations (0.5, 1, 1.5 and 2) were prepared by dilution of the stock solution. The prepared resulting concentrations were used to validate the workability of the methodology.

3. RESULTS AND DISCUSSION

The outcome of the fluoride levels for the tested water samples which were collected from boreholes in different villages within the study areas are presented in Table 1. The realized concentrations of the fluorides ranged from 2.26 to 3.08 mg/L. The highest levels of fluorides were realized at two separate boreholes thus; Chimombo BH 1 and Kanyepa BH 1 registering the concentration of 3.08 mg/L, whilst the lowest value of fluoride level was recorded at 2.26 mg/L for the underground water collected from Kanyepa BH 2. The obtained results in the study are low compared to Malawian regulatory borehole drinking standard established by the Malawi Bureau of Standards (MBS). However, despite that fluorides were within accepted limits for MBS, the attained concentrations exceeded set limits for underground drinking water established by WHO which is at 1.5 mg/L. These results are similar to those reported by other Malawian researchers and elsewhere who have worked on assessment of borehole water quality in different parts of Malawi. Most of these studies have reported and indicated that water from the underground sources contained high levels of Fluoride and is not safe for human consumption by residents in those areas where the study was undertaken [2,5,6,10,19,20].

The present study has recorded physicochemical parameter results which are presented in the Table 1. Temperature of the water samples ranged from 18-20 0C, it has been observed that there was no variation in the values amongst sample collection points. These findings support the previous studies reported in literature by other scholars [10]. The attained values of pH realized in the study ranged from 6.27 to 6.97, the results were within the recommended limits defined by both WHO and MBS. These results are in line with other studies that have assessed the pH values of groundwater samples conducted elsewhere [21-23]. Turbidity results achieved in the study ranged from 2.08 to 2.71 NTU, the overall results were within accepted levels described by MBS. The outcomes from this investigation support previous similar findings found in the literature [10,24,25]. Furthermore, Electrical conductivity ranged from 261-1212 µs/cm with Kanyepa BH 2 and BH 1, registering the lowest and highest readings, respectively. However, the results were within accepted levels provided by MBS and WHO for underground water resources. The results support the findings reported by other researchers who also aimed at assessing the

Table 1. Showing physicochemical parameters of borehole water samples

Location	Temp (°C)	pH	Turbidity (NTU)	EC (µs/cm)	TDS (mg/L)	Fluorides (mg/L)
Njenjema						
BH 1	20	6.91	2.35	385	395	2.83
BH 2	19	6.96	2.71	708	330	2.87
Mukowa						
BH 1	19	6.88	2.43	598	283	2.73
Chikaika						
BH 1	20	6.97	2.61	708	421	3.02
Chimombo						
BH 1	20	6.85	2.30	1070	490	3.08
BH 2	20	6.92	2.08	878	395	3.04
Kanyepa						
BH 1	18	6.86	2.50	1212	561	3.08
BH 2	19	6.27	2.71	261	136	2.26
MBS		6.0-9.50	25	3500	2000	6.00
WHO		6.5-8.50	-	1500	1000	1.50

groundwater quality for human usage [26]–[28]. The outcome for total dissolved solids observed in this study ranged between 136 to 561 mg/L. The levels of attained falls within the recommended set by both MBS and WHO for borehole water. Other, previous investigators have reported similar results, showing that fluoride contamination in borehole water is a big challenge in most developing countries [10,29,30].

4. CONCLUSION

The present study has shown that tested water samples collected from different underground points within the study area were within the recommended permissible limits for borehole water resource except for fluoride levels which exceeded the acceptable limits defined by WHO. This explains that the teeth discoloration observed amongst the inhabitants in the studied communities could be associated with the presence of large amounts of fluoride in the borehole water used for drinking. It is recommended that low cost defluoridation treatment technologies such as the use of ceramic filters and AlOOH units should be implemented before the water can be used for drinking and other domestic purposes to safeguard the healthy welfare of the people in the communities.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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