Original Research Article

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

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 Chemistry Laboratories 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.
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 life existence. Every living organisms 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 use 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 usage as it is considered the most safe and clean. In Malawi, as to most of the African nations many people staying in rural areas do not have access to portable water and they resort to groundwater and surface water resources for domestic and drinking purposes [6]. However, several chemical pollutants have been detected in groundwater sources that threatens the well-being of water users as they are associated with health effects. Several studies have reported high levels of ions including arsenic, cadmium, lead, mercury, nitrates, nutrients, microbes and fluorides [7]. The presence of the 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 fluorides in ground water sources is influenced by numerous factors for instance, high levels of fluorine in aquifers, water with high pH, poor groundwater flow rates and arid and semi-arid climate that enhance evaporation [9]. However, anthropogenic activities such 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 health 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 problems such as dental and skeletal fluorosis [13]. Fluorosis is serious health issues which has affected more than twenty nations in Africa and Asia is the most affected continent [14]. Further, recent studies have also indicated that intake of fluorides surpassing required doses can cause metabolic physiological related illness for instance reproductive system and central nervous system failure and also impairment of soft tissues [14]. This implies that it is significant that the levels of fluorides in water resources should be monitored in order to overcome its associated health implications when consumed 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 standards established by World Health Organization (WHO) and health experts suggested complete shutdown of such particular boreholes to escape dental fluorosis related illness cases [16]. In another study which was done in rural areas in 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 amongst African countries that exists to East African Rift system described 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 Southern region of Malawi. Chiradzulu district was opted for the study since it is among the districts which were recently 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 domestic purposes and for drinking due to absence of tap clean 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. MATERIAL AND METHODS

2.1 Study Area

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

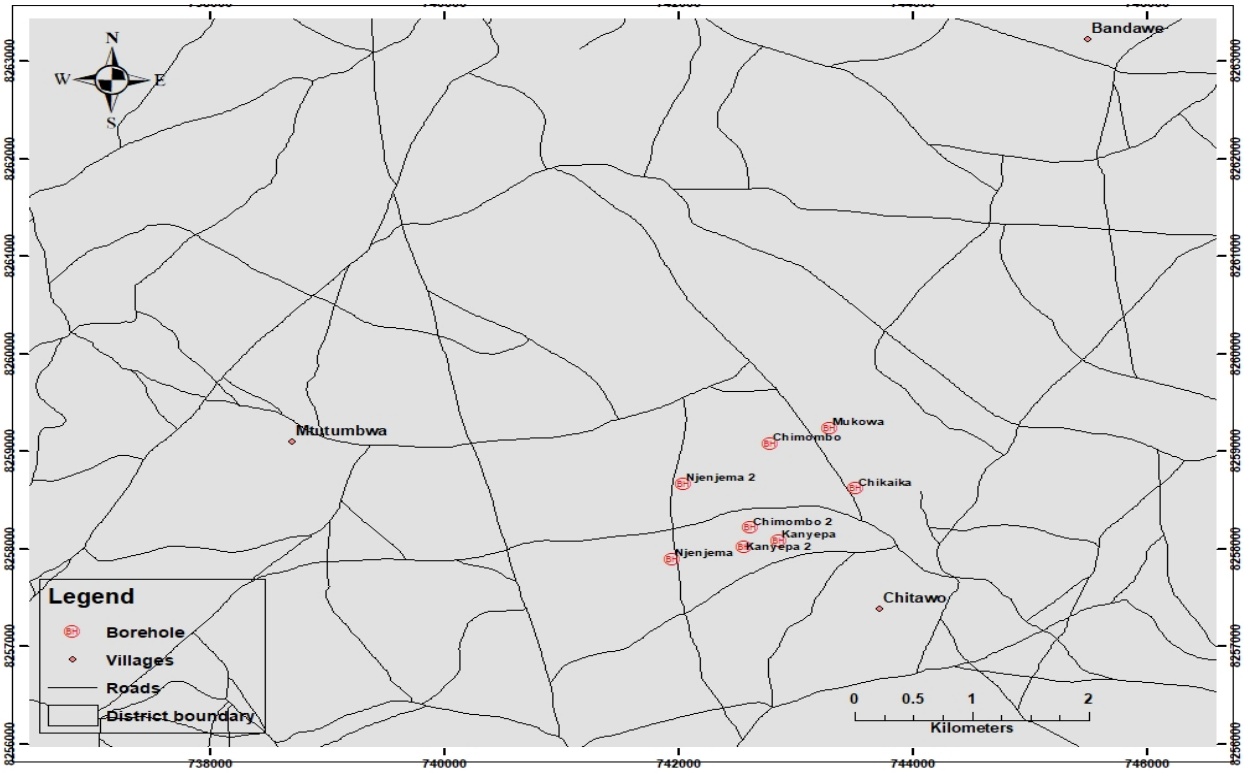

Figure 1. Map of Chiradzulu showing water sample collection points.

2.2 Sample Collection

The samples used in the study were collected in winter 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 the Chemistry Laboratory where analysis was performed. On site measurements, such as electrical conductivity, pH, TDS, and temperature were carried out and recorded instantly using multi-meter and results were appropriately recorded in the data book.

3. RESULTS AND DISCUSSION

The outcome of the fluoride levels for the tested water samples which were collected from the boreholes in the 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 levels 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 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 set 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 contain high levels of Fluorides and is not safe for human consumption amongst residents in those areas the study was undertaken [2], [5], [6], [10], [19], [20].

Table 1. Showing physicochemical parameters of borehole water samples.

Location	Temp (^{0} 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	-	15001000	1.50	

The present study has recorded physicochemical parameter results which are presented in the table 1. Temperature of the water samples ranged from 18-20 ^{0} C, it has been observed that there was no variation regarding the values amongst sample collection points. These findings support 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 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 1 and BH 2, 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 groundwater quality for human uses [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 [10], [29], [30].

4. CONCLUSION

The present study has shown that tested water samples collected from different underground points within study area were within the recommended permissible limits for borehole water resource except for fluoride levels which exceeded allowed limits defined by WHO. This suggest that the teeth discoloration observed amongst inhabitants in the communities could be associated with the presence of the fluorides in the borehole water used for drinking. It is recommended that low cost defluoridation treatment technologies should be implemented before the water can be used for domestic and drinking purposes to safe guard the health welfare of the community.

REFERENCES

[1] MM F, CK P, GNP. Assessment of the Impact of Groundwater Fluoride on Human Health: A Case Study of Makindu District in Kenya.J. Earth Sci. Clim. Change. 2017. 08:(04). 4–9. doi: 10.4172/2157-7617.1000396.

[2] Chidya RCG, Matamula s, Nakoma O, Chawinga CBJ. Evaluation of groundwater quality in rural-areas of northern Malawi : Case of Zombwe Extension Planning Area in Mzimba. Phys. Chem. Earth. 2016:1–8.

[3] Abiyu A, Yan D, Girma A, Song X, Wang H. Wastewater treatment potential of Moringa stenopetala over Moringa olifera as a natural coagulant , antimicrobial agent and heavy metal removals," *Cogent Environ. Sci.*, vol. 4, no. 1, pp. 1–13, 2018, doi: 10.1080/23311843.2018.1433507.

[4] Amoako J, Karikari AY, Ansa-Asare OD, Adu-Ofori E. Water quality characteristics of Densu River basin in south-east Ghana. Water Sci. Technol. 2010:61(6):1467–1477. doi: 10.2166/wst.2010.012.

[5] Monjerezi M, Ngongondo C. Quality of Groundwater Resources in Chikhwawa, Lower Shire Valley, Malawi. Water Qual. Expo Heal. 2012 (4)39–53. doi: 10.1007/s12403-012-0064-0.

[6] Vunain E, Nkhuzenje C, Mwatseteza J, Sajidu S. Groundwater Quality Assessment from Phalombe Plain , Malawi," ChemSearch. 2019.10:(1): 1–10.

[7] Onipe T, Edokpayi JN, Odiyo JO. Geochemical characterization and assessment of fluoride sources in groundwater of Siloam area, Limpopo Province, South Africa.Sci. Rep. 2021.1–19. doi: 10.1038/s41598-021-93385-4.

[8] Odiyo JO, Makungon R. Chemical and Microbial Quality of Groundwater in Siloam Village, Implications to Human Health and Sources of Contamination. Int. J. Environ. Res. Public Health. 2018 15:(317).doi: 10.3390/ijerph15020317.

[9] Odiyo JO, Makungo R. Fluoride concentrations in groundwater and impact on human health in Siloam Village, Limpopo Province, South Africa. Water SA. 2012 5:(38) 5:731–736.

[10] Mapoma T, Xie X, Zhang L, Tananga M, Maliro A, Chimutu D. Hydrochemical characteristics of rural community groundwater supply in Blantyre , southern Malawi.J. African Earth Sci.2016:114.

[11] Chicas SD, Omine K, Prabhakaran M, Sunitha TG, Sivasankar V. Ecotoxicology and Environmental Safety High fluoride in groundwater and associated non-carcinogenic risks at Tiruvannamalai region in Tamil Nadu, India.Ecotoxicol. Environ. Saf, vol. 2022:233:113335. doi: 10.1016/j.ecoenv.2022.113335.

[12] S. Priya, B. Chandra, R. Das, and S. Pran, "Results in Chemistry Exploring in situ Ni (II) complexation of pyrrole-benzimidazole ligands towards colorimetric sensing of fluoride ion in aqueous medium.Results Chem.2022:5.100927.doi: 10.1016/j.rechem.2023.100927.

[13] Aziz F, Din I, Khan F, Manan P, Sher A, Hakim S. Treatment of fluoride contaminated water using mango (Mangifera indica) leaves powder as an adsorbent. Curr. Res. Green Sustain. Chem. 2023:(6). doi: 10.1016/j.crgsc.2023.100359.

[14] Scheverin VN, Horst MF, Lassalle VL. Results in Engineering Novel hydroxyapatite-biomass nanocomposites for fluoride adsorption.Results Eng.2022:(16). doi: 10.1016/j.rineng.2022.100648.

[15] Opinya GN, Pameijer CH, Grön P. Simple defluoridation procedures for Kenyan borehole water. Community Dent. Oral Epidemiol. 1987:(15) 2:60–62.doi: 10.1111/j.1600-0528.1987.tb00482.x.

[16] Salifu A, Petrusevski B, Ghebremichael K, Buamah R, Amy G. Multivariate statistical analysis for fluoride

occurrence in groundwater in the Northern region of Ghana. J. Contam. Hydrol. 2012:140–141. doi: 10.1016/j.jconhyd.2012.08.002.

[17] Odiyo JO, Mathoni MM, Makungo R. Health Risks and Potential Sources of Contamination of Groundwater Used by Public Schools in Vhuronga 1, Limpopo Province , South Africa. *Int. J. Environ. Res. Public Health*. 2020:(17): 6912.

[18] Wanke H, Ueland JS, Hipondoka MHT, Spatial analysis of fluoride concentrations in drinking water and population at risk in Namibia. Water SA. 2017:(43) 3: 413–422.

[19] T. Mapoma, X. Xie, Y. Liu, F. Kawaye, and T. Kayira, "Hydrochemistry and quality of groundwater in alluvial aquifer of Karonga , Malawi. Environ. Earth Sci. 76, no. 335, 2017. doi: 10.1007/s12665-017-6653-2.

[20] Asiedu KD, Yidana SM. Water quality analysis of groundwater in crystalline basement rocks, Northern Ghana.Environ. Geol. 2009: (58): 989–997. doi: 10.1007/s00254-008-1578-4.

[21] Aziane N, Khaddari A, Ebn-touhami M, Zouahri A, Nassali H. Evaluation of groundwater suitability for irrigation in the coastal aquifer of Mnasra (Gharb, Morocco).Mediterr. J. Chem. 2020:(10) 2: 197–212.

[22] Bouderbala A. Assessment of Groundwater Quality and its Suitability for Agricultural Uses in the Nador Plain, North of Algeria.Water Qual Expo Heal.2015:4(7):445–457. doi: 10.1007/s12403-015-0160-z.

[23] Maher H, Moussadek R, El Moudane M, Ghanimi A. Effect of no tillage on the physico-chemical properties of soils of the El Koudia region, Rabat (Morocco). E3S Web Conf. 2019:(150):10.

[24] Chibuzo A, Okoro BC, Hippolitus O, Nwadike EC, Chima A. Assessment of Groundwater Quality in Selected Areas in Imo State in South Eastern Nigeria. J. Environ. Earth Sci.2014:4(9):52–59.

[25] Harold M, Xie X, Zhu Y, Banda G. Trace element geochemical evolution and groundwater origin in North Rukuru – Songwe alluvial aquifer of northern Malawi.Environ. Earth Sci. 2016:(75):877.doi: 10.1007/s12665-016-5682-6.

[26] Alfy MEL, Merkel B. Assessment of Human Impact on Quaternary Aquifers of Rafah Area, NE Sinai , Egypt. J. Ecol. Environ. Geol.2004: (12): 1–9.

[27] Mtoni Y, Chikira I Bakundukize C, Camp V, Martens K. Saltwater intrusion and nitrate pollution in the coastal aquifer of Dar es Salaam, Tanzania. Env. Earth Sci, 2013: (70): 1091–1111. doi: 10.1007/s12665-012-2197-7.

[28] Sefiani S, *et al.*Evaluation of groundwater quality and agricultural use under a semi-arid environment : case of agafay, western haouz, Morocco.Irrig. Drain.2019.

[29] Emeka C, Nweke B, Osere J, Ihunwo CK, Water Quality Index for the Assessment of Selected Borehole Water Quality in Rivers State. Eur. J. of Environment Earth Sci. 2020: 1(6):1–4.

[30] Chizoruo F, Alexander I, Opara I, Emeka C, Bridget A, Ibe O. Environmental risk assessment of the intake of contaminants in aquifers in the vicinity of a reclaimed waste dumpsite in Owerri municipal, Southeastern Nigeria. Appl. Water Sci. 2021: 11(24).