Borehole Water Pollution and its Implication on Health on the Rural Communities of Malawi

J.B. Chimphamba[1], and O.L. Phiri[2]

[1] Department of Geography and Earth Sciences, Chancellor College, University of Malawi.
email: *jameschimphamba@cc.ac.mw*

[2] Regional Water Development Offices (S), Ministry of Irrigation and Water Development

Abstract
This study analyzed borehole water quality data collected by the Water Section of the Ministry of Irrigation and Water Development since 1980s. This study was done in order to verify the rightness of the public view that borehole water is synonymous to potable water. The study analyzed water quality data of 5,324 boreholes occurring throughout Malawi. The objective of the study was to determine the extent to which borehole water salts such as: fluorides, nitrates, iron and chlorides are occurring above the concentrations recommended as safe limit of drinking water by the World Health Organization (WHO). The study observes that of the 27,913 boreholes in Malawi, only 5,324 boreholes had been tested for water quality representing about 19.1% of the total boreholes. Of these 1,676 boreholes had chemical concentration above those recommended by WHO for safe limit of drinking water, representing 31.5% of the water quality tested boreholes. The study observed that: 567 boreholes had iron, 142 boreholes had fluorides, 81 boreholes had chlorides and 19 had nitrates above those recommended by WHO for safe limits for drinking water respectively. The implication of these findings is that a large number of rural communities in Malawi are continuously ingesting borehole water that has adverse levels of chemical toxicity. The detrimental impacts on human health of such toxicity may require many years of exposure before their impacts are recognized and by that time many rural communities would already have adversely been affected.

Key words: *Borehole water, chemical toxicity, rural communities, ingestion*

1. Introduction

Water supply is one of the fundamental requirements for human life. The quality of water drawn by households is an important aspect of domestic supplies that influences public health (Howard and Bartram, 2003). It has been estimated that 2.6 million (37%) of Malawians use boreholes as their main source of drinking water (Pritchard, **et al** 2008). In Malawi boreholes are viewed as supplying potable water (Malawi Government, 1999). However a number of reports on borehole water pollution have surfaced. Ndolo (2002) reported chemical contamination of lead and hardness in shallow wells of Phalula and Balaka. Pritchard, **et al** (2008) observed borehole water fluoride concentration of up to 9mg/l in Kumkwawa Village in Balaka, and toxic levels of sulphates in Chikwawa and Balaka. Sibale **et al** (1998) also reported high level of fluoride concentration in Machinga while Msonda **et al** (2007) has observed extensive fluoride toxicity in boreholes in the area of Senior Traditional Authority Mazengera around Nathanje area in Lilongwe District. The number of chemical toxicity concentration of borehole water in Malawi is increasingly becoming numerous (Msonda **et al**, (2007). It is the objective of this study to indicate the geochemical hazard of borehole water so as to better inform the policy and the public domain about the distribution and health risks of borehole water pollution across Malawi.

2. Materials and Methods

Analysis of borehole water quality is an on-going process of the Water Section of the Department of Water Development in Malawi. Water quality is being analyzed in its three administrative laboratories located in the regional cities of Blantyre, Lilongwe and Mzuzu. The methods used in determination of chemical parameters are based on the Association of Official Analytical Chemists, Maryland, USA; the 17th Edition, of Association of the Official American Chemists (AOAC) and the American Public Health Association (APHA) Standard methods for the examination of water and waste water (APHA, 1989; AOAC, 1990).

3. Results

The results of the borehole water quality data analysis has been presented in: table 1 and 2 showing borehole water pollution for districts of Malawi and the first ten districts with the highest concentration of water pollution respectively; while their spatial distribution is presented in figure 1.

Table 1: Borehole water pollution for districts of Malawi

District	Number of boreholes with chemical toxicity above the recommended safe limit for drinking water of the World Health Organization (WHO)					
	Fluoride WHO (1.5g/l)	Chlorides WHO (600g/l)	Iron WHO (1mg/l)	Nitrates WHO (50mg/l)	Sulphates WHO (250mg/l)	pH WHO (6.5-8.5)
Blantyre	3	2	3	0	0	0
Balaka	2	0	1	0	0	5
Chinkwawa	3	12	11	2	1	3
Chiradzulu	0	0	2	0	0	0
Machinga	4	5	5	0	12	33
Mangochi	63	19	30	1	25	195
Mulanje	3	-	2	0	2	2
Neno	1	-	1	0	0	1
Nsanje	2	3	5	0	1	6
Ntcheu	13	0	14	5	5	17
Phalombe	0	0	1	1	0	0
Thyolo	0	0	6	1	2	5
Zomba	0	0	6	0	1	5
Nkhotakota	7	0	34	1	2	28
Dedza	2	0	32	4	5	96
Dowa	1	0	23	1	26	23
Kasungu	0	4	25	0	5	13
Lilongwe	3	1	96	0	19	85
Mchinji	0	1	28	0	0	13
Ntchisi	0	1	19	0	2	3
Salima	4	2	45	1	36	11
Chitipa	0	0	3	0	0	1

Karonga	23	0	133	1	2	36
Mzimba	1	32	24	1	3	25
Nkhatabay	2	0	14	0	0	109
Rumphi	2	2	4	0	1	2
Likoma	-	-	-	-	-	-
National total	**139**	**84**	**567**	**19**	**150**	**717**
Total number of boreholes with contaminants is 1676						

Out of 5, 324 boreholes that has so far been tested for: fluorides, chlorides, iron, nitrates, chlorides, sulphates, and pH, about 1, 676 boreholes have concentration of these salts above those recommended by the World Health Organization for safe limit of drinking water(see table 1). Mangochi District has the highest number of boreholes with fluoride and chlorides water concentration, while Karonga District of iron, Dedza District of nitrates, Salima District of sulphates and Nkhatabay District of pH (table 2). It should be noted that these numbers does not give a full picture of the rate of borehole water pollution since the number of borehole tested for water quality differs markedly between districts. On the other hand figure 1 show the spatial distribution of borehole water pollution. For each salt a symbol has been assign to indicate whether pollution level in borehole water is above WHO or above those recommended by Ministry of Water Development for safe limit of drinking water.

Table 2: The first ten boreholes with the highest levels of concentration of water pollution

Chemical Parameter	**The first ten highest level of concentration of borehole water contaminants**									
Fluorides	1	2	3	4	5	6	7	8	9	10
Concentration (mg/l)	9.6	9.2	8.6	8.2	7.0	6.6	6.4	4.4	4.0	2.0
Borehole Name	Mwambuli Village	Kayuni Village	Nsanama	Kaluli Village	Imfya Village	Mtondo Village	Kapote Village	Misili Village	Nathenje	Chimutu Village
District	Karonga	Karonga	Machinga	Karonga	Mangochi	Dowa	Karonga	Chikhwawa	Lilongwe	Liongwe
Chlorides	1	2	3	4	5	6	7	8	9	10
Concentration (mg/l)	6037	5283	5183	5133	2690	2056	1778	1522	1230	1175
Borehole name	Nchalo Township	Bindula Village	Nyenyezi School	Masunduko Village	Nqumayo Village	Nankamba	Kumwenda Village	Thoma	Bowe	Nkope Village
District	Chinkhwawa	Machinga	Machinga	Machinga	mzimba	Mangochi	Mzimba	Mangochi	Rumphi	Mangochi
Iron	1	2	3	4	5	6	7	8	9	10
Concentration (mg/l)	95.78	76.07	60.69	33.5	27.9	18.6	17.7	10.5	9.11	7.25
Borehole name	Ngimira	Ngosi	Mwambelo	Zila Village	Mulwa Village	Mwalala	Maganga Village	Kayuni	Solomoni	Mwandira
District	Karonga	Karonga	Karonga	Nkhatabay	Karonga	Salima	Salima	Karonga	Salima	Mzimba
Nitrates	1	2	3	4	5	6	7	8	9	10
Concentration (mg/l)	524	282	197	196	129	114	114	83.5	69	64
Borehole name	Limeyo-Jere	Muhiyo	Gumbi	Mpoola	Kasumbu	Kasulo	Nkungula	Sitolo	Biwi	Siliya
District	Mzimba	Phalombe	Ntcheu	Ntcheu	Dedza	Dedza	Dedza	Dedza	Dedza	Ntcheu
Sulphates	1	2	3	4	5	6	7	8	9	10

Concentration (mg/l)	7,650	3,900	3,370	3,340	3,000	2,941	2,708	1,837	1676	1349
Borehole name	Ulande School	Moto	Mangumbi	Mberekete	Chowe	Sosola	Mduwa	Mandala	Malapa	Nqumayo Village
District	Mangochi	Dedza	Mangochi	Dowa	Mangochi	Salima	Mchinji	Dowa	Salima	Mzimba
pH	1	2	3	4	5	6	7	8	9	10
Concentration (mg/l)	4.4	4.4	4.5	5.5	5.8	9.9	9.56			
	8.9	8.8	8.7							
Borehole name	Kane-kakuti	Mbayo	Cheyethu	Mtuwa	Balaka School	Bwanali	Kajaliza	Ngasale	Mayera	Chowe
District	Mangochi	Dowa	Nkhatabay	Mchinji	Balaka	Kasungu	Mzimba	Machinga	Machinga	Machinga

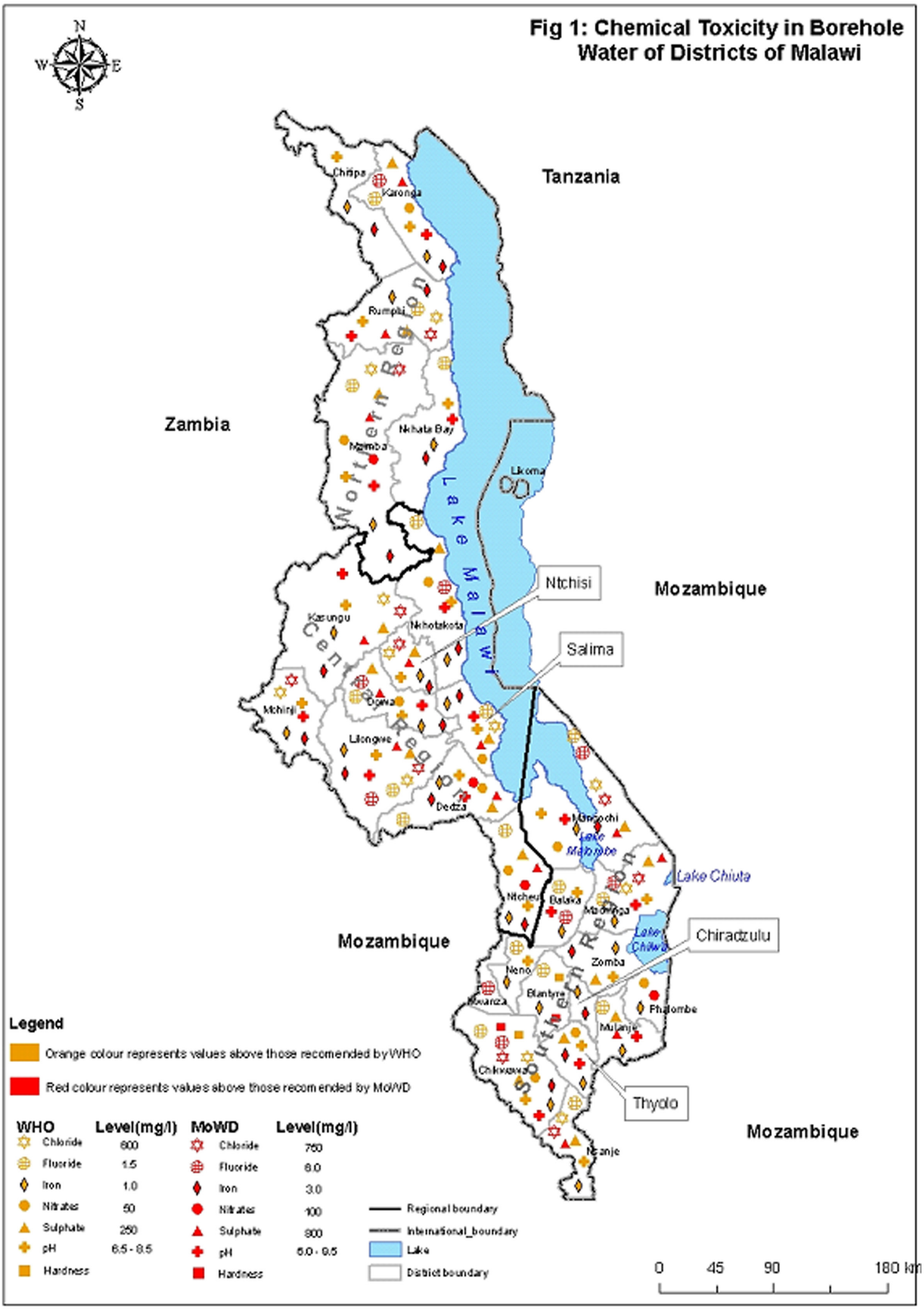

Fig 1: Chemical Toxicity in Borehole Water of Districts of Malawi
N
W
E
S
Tanzania
Zambia
Mozambique
Mozambique
Mozambique
Lake Malawi
Chitipa
Karonga
Rumphi
Nkhata Bay
Mzimba
Likoma
Northern Region
Central Region
Southern Region
Ntchisi
Salima
Kasungu
Nkhotakota
Dowa
Mchinji
Lilongwe
Dedza
Mangochi
Lake Malombe
Lake Chiuta
Ntcheu
Balaka
Machinga
Lake Chilwa
Chiradzulu
Zomba
Neno
Mwanza
Blantyre
Phalombe
Mulanje
Chikwawa
Thyolo
Nsanje
Legend
Orange colour represents values above those recomended by WHO
Red colour represents values above those recomended by MoWD
WHO
Level(mg/l)
Chloride 600
Fluoride 1.5
Iron 1.0
Nitrates 50
Sulphate 250
pH 6.5 - 8.5
Hardness
MoWD
Level(mg/l)
Chloride 750
Fluoride 6.0
Iron 3.0
Nitrates 100
Sulphate 800
pH 6.0 - 9.5
Hardness
Regional boundary
International_boundary
Lake
District boundary
0 45 90 180 km

4. Discussion

4.1 Occurrence of borehole water pollution and its implication to health

This study indicates that 1676 boreholes (see table 1) in Malawi have Fluorides, Nitrates, Iron, Chlorides, Sulphates and pH above the recommended safe limit for drinking water by WHO with some boreholes having more than one of these salts. Fig. 1 has been prepared to give a preliminary picture of the geochemical hazard of borehole water pollution based on data of 5,245 boreholes that have so far been tested for water quality. The study shows that almost all the districts in Malawi have borehole water pollution of at least three salts above the recommended level for safe drinking water according to WHO recommendation. The implication for this is that a large number of rural populations are continuously ingesting water that could have negative impacts to their health.

Studies have reported that Fluorides concentrations of <0.5mg/l in drinking water leads to dental carries while fluorides content of between 0.5 and 1.5 mg/l promotes dental health (WHO, 1984). Fluoride content of 1.5-4mg/l in drinking water leads to dental fluorosis while concentrations of >4mg leads to dental, skeletal and crippling fluorosis (Msonda, **et al** 2007; and Ndolo, 2002). Other studies have shown that the effects of fluorides could go beyond the mottling of the teeth and cause mental retardation in children (Mullenix, **et al** 1995). Mullenix **et al** (1995) further observed that fluoride accumulation in important regions of the brain, especially the hippocampus, was found to increase as the drinking water fluoride levels increased. This study observes that there are more than 139 boreholes in Malawi with fluorides concentration above 1.5g/l and up to 9.6g/l. This means that rural communities are at risk to suffering from dental fluorosis, sketletal and crippling fluorosis and mental retardation since they continuous ingest borehole water with high levels of fluorides concentration.

WHO iron concentration for safe limit of drinking water is 1mg/l and has reported that the average lethal dose of iron intake is 200-250mg/l(WHO, 1996).. However, death have been reported for ingestion of iron toxicity of as low dosage as 40mg/l (Fisch **et al** 1975). This study observes that there are 567 boreholes with iron concentration above 1mg/l with the highest borehole having 95.6mg/l (see table 1and 2). This implies that some villages in Malawi are subjected to continuous ingestion of iron concentration that could lead to death.

On the other hand continuous ingestion of water with high nitrates concentration could also lead to death. Wilkes University , (2008) observes that drinking water with high concentration of nitrates could lead to transformation of nitrates into nitrite in the digestive system which oxidizes iron in the hemoglobin of the red blood cells to form methemoglobin. Methemoglobin lacks the oxygen-carrying ability of the hemoglobin and creates the condition known as methemoglobinemia or “blue baby syndrome” leading to death (Wilkes University, 2008). Children under the age of one year , pregnant and lactating mothers are most vulnerable to methemoglobinemia. This study observes that rural communities in Malawi are continuously ingesting borehole water from nineteen boreholes which have nitrates concentration of above 50mg/l to as high as 524mg/l. This means that children, pregnant and lactating mothers are at risk of methemoglobinemia.

In conclusion this study observes that some rural communities in Malawi are continuously ingesting borehole water that is above the recommended level for safe drinking water by WHO. This situation could have long-term adverse impacts on health of such population. Malawi should therefore consider testing of water quality of all its boreholes so as to produce a comprehensive geochemical hazard database. It should also consider monitoring the impacts of continuous ingestion of such borehole water by its population and put in place policy framework that would curtail this predicament.

Acknowledgements

We are most grateful for the Malawi National Commission for UNESCO for provision of funds that enabled us to carryout this study. Our thanks also go to the Water Quality Section of the Department of Water

Development for making available data on borehole water quality. We would also like to thanks Associate Professor Maurice Monjelezi of the Department of Chemistry at Chancellor College for retrieving the water quality data from access files. We would also like to thank Messrs Jonathan Gwaligwali and Makwenda Namoto both of the Department of Geography and Earth Sciences of Chancellor College for map work and compilation of the borehole water quality data.

References

AOAC (1990). Official Methods of Analysis, 15th Edition, Association of Official Analytical Chemists, Arlinton.

American Public Health Association (APHA), 1989. Standard Methods for examination of water and wastewater, nineteenth ed. American Health Association (APHA), Washington Dc.

Cheng Y X, IQ of children in area of high fluorine content, *Chinese Journal of Control of Endemic Diseases*, Supplement 1991.

Dallman. P. R., (1990). Present knowledge in nutrition, 6th ed. Washington Dc. International Life Science Institute

Fisch R. O. et al. Potential toxicity of iron overload in successive generations of rats. *American journal of clinical nutrition*, 1975, 28:136-139.

Howard, G., and Bartram, J. (2003). Domestic water quality service level and health. World Health Organization. Geneva, Switzerland.

Malawi Government (1999). Water Resources Management Policies and Strategies. Ministry of water development. Lilongwe, Malawi.

Mullenix, P, J., Denbesten, P, K., Schunior, A., Kernan, W, J., (1995). Neurotoxicity of sodium fluoride in rats, *Neurotoxicology Teratology*, 17(2):169-177.

Msonda, K, W, M., Masamba,W,R,L., Fabiano, E.(2007).A study of fluorides groundwater occurrence in Nathenje, Lilongwe, Malawi . *Physics and Chemistry of the Earth*, 32(2007) 1178-1184

Ndolo, V., (2002). Examination of water availability, access and quality in drought-prone areas in Balaka District Malawi. MSc thesis. University of Malawi, Chancellor College, Zomba

Prichard, M., Mkandawire, t., O'Neill, J.G., (2008). Groundwater Quality in Rural villages: A case study: Malawi 2006-2007. Leads Metropolitan University, U.K

Sibale,F,K, Chidothi, C., Tsakala, E.,(1998). Oral health status among the 12 and 15 year old school pupils in Machinga District, Malawi.

Wilkes University (2008). Nitrates and Nitrites in Drinking Water. Center for Environmental Quality, Environmental Engineering and Earth Sciences.

WHO 1996 (1996). Guidelines for drinking water quality: volume 2. Recommendations, 3rd ed. World Health Organization, Geneva, Switzerland.