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FLUORIDE OCCURRENCE IN DOMESTIC WATER SUPPLY SOURCES IN TANZANIA: A CASE OF MERU DISTRICT ARUSHA REGION

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ABSTRACT

Surface and ground water are the major sources of water supply in Meru district. Most of the people in Meru rural areas depend on surface water in rivers and ground water shallow and deep wells and springs for house hold activities. The presence of fluoride in high concentrations in drinking water or cooking water causes severe health problems to the people. Distribution of fluoride concentrations in Meru district domestic water sources was studied by referencing the location of water sources using Extrex 20 garmin hand held GPS instrument. Fluoride concentrations were measured using Metrohm Ag/AgCl reference electrode connected to a Metrohm potentiometer (826 pH/Ion Meter) in a laboratory. Fluoride concentrations were found to range between 0.76 and 1103 mg/L. Around 69% of 146 samples collected had fluoride concentrations above 1.5 mg/L which is the WHO recommended standard while 47% of the samples had fluoride concentrations exceeding 4.0 mg/L as recommended by the Tanzania Bureau of Standards. The results indicate that, residences in five wards of Meru district namely Kikatiti, King'ori, Leguruki, Maji ya Chai, and Ngarenanyuki are exposed to high levels of fluoride posing risk of dental and skeletal fluorosis. Generally, the study observed that most of the ground and surface water resources in Meru district are contaminated with high fluoride concentration and therefore waters from most sources in the areas (wards) need to be defluoridated to be potable.

Keywords: Dental fluorosis, Ground water fluoride, Skeletal fluorosis, Fluoride distribution map, Surface water fluoride.

INTRODUCTION

Fluoride is generally found in the environment in natural surroundings such as soils, rocks, ground water and surface water sources (Mjengera 2002) and these are the major sources of fluoride occurrence in drinking water. Sources of fluoride ions in soils and rocks are fluorites (fluorspar) (CaF_2), topaz ($Al_2(FOH)_2SiO_4$) and its mineral compounds in soils and rocks occurring as a result of volcanic activities (Singano 2000). The occurrence of fluoride in Tanzania was recognized nationally as early as 1950 whereby most of the ground water and surface waters along the rift valley and slopes of the volcanic mountains of Kilimanjaro and Meru were documented (Figure 1). The report on groundwater-quality problems in Tanzania indicate that fluoride is most severe and widespread in the rift valley zones in northern and south-western Tanzania, associated with volcanic activity (British Geological Survey 2000). It was also reported by Gumbo and Mkongo (1995) that fluoride in ground water exceeded the WHO (1.5 mg/L) and TBS (4.0 mg/L) guidelines in the regions of Singida, Arusha, Mara, Kilimanjaro, Manyara, Mwanza and Shinyanga.

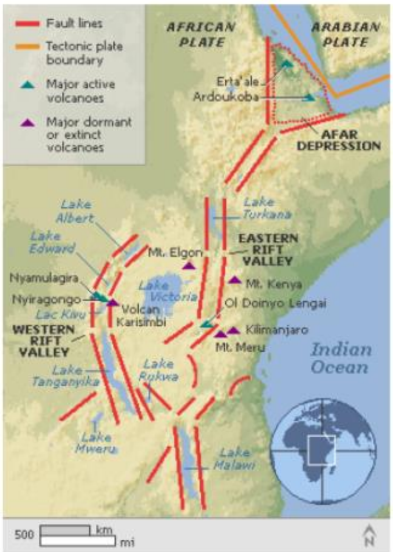

Figure 1: The Rift Valley (Pittalis 2010)

Fluorides are mainly found in ground water when derived by the solvent action on rocks and soil of the earth's crust. Fluoride in drinking water cannot be detected by taste, sight or smell.

The accurate information through water quality analysis, scientific study on fluoride ions distribution in surface and groundwater and geochemical knowledge with spatial information on geology is necessary to understand the cause, type and level of fluoride ions distribution (Manivannan et al. 2012). Fluoride is considered as an essential element that prevents dental caries (WHO 1993). However, when fluoride exceeds desirable limits in drinking water, it could cause problems to human health. Fluoride has been identified as a cause of dental and skeletal fluorosis (WHO 2006, Peter 2009, Onyango et al. 2009, Rango et al. 2010, Maliyekkal et al. 2010). The World Health Organization set a guideline value of 1.5 mg/L as tolerable upper limit (WHO 2006, 2011) while Tanzania Bureau of Standards (TBS) set the maximum concentration to 4.0 mg/L. At concentrations below 1.5 mg/L, fluoride in drinking water is known to prevent dental caries by strengthening the teeth enamel. However, drinking water which has a fluoride concentration higher than this may lead to injurious effects on humans as indicated in Table 1.

Table 1: Fluoride concentration levels effect on human health (Thole 2013)

Level of fluoride in water (mg/L)	Effect on human health
0.0-0.5	Limited growth and fertility, dental caries
0.5-1.5	Promote dental health, prevents tooth decay
1.5-4.0	Dental fluorosis (mottling of teeth)
4.0-10.0	Dental fluorosis, skeletal fluorosis (pain in back and neck bones)
>10	Crippling fluorosis

The problem of fluoride in areas with volcanic activity were reported by Maria and Laura (2015) who said that fluoride is commonly associated with volcanic activity and fumarolic gases, as magma ascend and decompressed their volatile species into gases. Active volcanoes emit a variety of gases, including H_2O, CO_2, SO_2, HCl, NH_3, H_2S, HF and few other constituents (Maria and Laura 2015). The emitted gases interact rapidly with the ash particles of the volcanic plume and form thin salt coatings. These materials are composed of relatively soluble sulphate and halide salts mixed with sparing soluble fluorine compound such as CaF_2, AlF_3, and $Ca_5(PO_4)_3F$ (Delmelle et al. 2007). As a result, the water in contact with volcanic ash deposits usually contains high concentrations of fluorides (Maria and Laura 2015).

This study aimed at mapping data of the fluoride concentrations of different water sources in Meru district community, which is known to be endemic in dental and skeletal fluorosis. Currently, the only available means of defluoridation include bone char filters distributed to some of the study area communities done at point of use, which was developed at Ngurdoto Research Station. The recently developed nanofilters developed at Nelson Mandela University by Dr. Askwar Hilonga (Jewell C 2015) are currently used to filter bottled water sold by Gongali Model Co. LTD. Only few rural people are able to access these technologies leaving large population using fluoride water for domestic use. The availability of data showing fluoride concentration in waters of the study area is a tool to other researchers to deal with fluoride problem. Alternatively, measures could be put in place to deploy means of defluoridation of water in those severely affected areas to ensure residents are not at risks of using water with high levels of fluoride.

MATERIALS AND METHODS

Study Area

Arusha region is among the regions highly affected by fluoride as reported by Gumbo and Mkongo (1995), and Pittalis (2010). The region is situated in northern Tanzania (Figure 2) and it is noted to fall along a fluoride belt which roughly follows the East African rift valley system (Figure 1). The chemical constituents of ground water streams are mainly affected by the geology of the area. The dominant rocks are mainly cenozoic volcanic with most alluvial deposit (Ghiglieri et al. 2008). Some rivers and streams in the fluoride belt have higher concentrations of fluoride as a result of the alkaline volcanism which is widespread throughout the East Africa Rift Valley System (Tekle-Haimanot et al. 2006, Jaroslav and Annukka 2007). The topography of Meru is dominated by the volcanic cone of mount Meru whose slopes cover most of the study area.

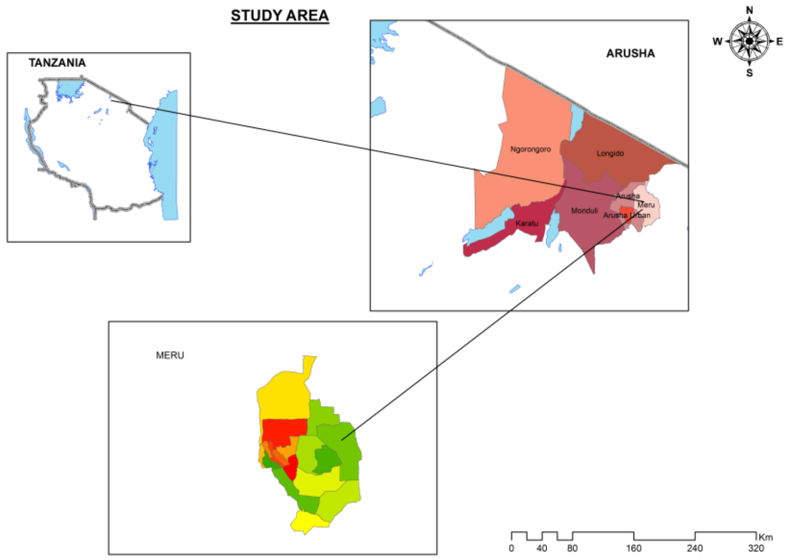

Figure 2: Location of Meru District in Arusha Region as Developed by Arch GIS in this study

This work mapped the fluoride concentrations in domestic water sources from different communities in Meru district which is known to be endemic in dental and skeletal fluorosis. Distribution of fluoride in domestic waters may be used to delineate areas where residents have high chances of developing dental and skeletal fluorosis due to excessively high concentrations of fluoride. The result can be used by planners in water distribution and researchers to develop alternative solutions to alleviate the excessive water flourotic problem in Meru district.

Water samples collection

Water samples from 146 different locations in Meru district (Figure 3) were collected from various domestic water sources. These sources were rivers, deep wells (more than 15 m deep), shallow wells (less than 15 m deep), springs, reservoirs and lakes. These were the major water source accessible by the domestic communities during the study period. Since the samples were taken from domestic water supply sources, some villages had many bore holes while other villages had few water supply sources. Also, some of the wards in Meru district are covered by forest and National Park whereby no people are living in those areas. Samples were collected in clean 500 ml polyethylene bottles which were rinsed by water to be sampled, before sampling. Bottles with sampled water were tightly sealed and labelled in the field. The sample bottles were kept at ambient temperature (18 to 25^{o}C) while transporting them to laboratory for fluoride concentration measurement. There was no preservative added during sampling and transportation. Standard analytical methods (APHA 1989, HACH 1997) were used to quantify the concentration of fluoride ions presence. A 5 ml sample solution was mixed with 5 ml CDTA-TISAB and the fluoride concentrations were measured using ion selective electrode (ISE) technique as described by Thole et al. (2012). Every sample was analysed twice and the average was taken as the concentration of the sample.

Sampled locations were documented using a hand held global positioning system (GPS), Garmin extrex 20. The fluoride distribution map of the study area, Figure 3, was created by using ArcMap 10.2.2 software. The sources considered were those for domestic uses, so the distances between the sites depended on the location of the villages and households with water sources therefore the distances between the sites are not regular.

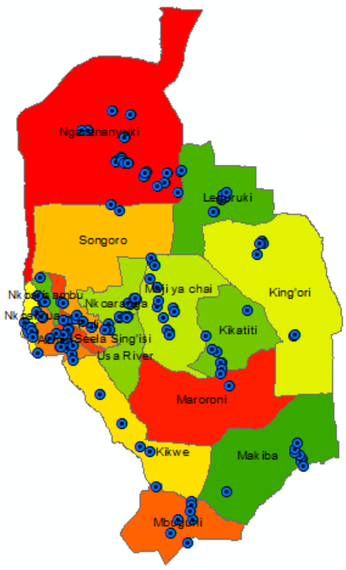

Figure 3: Position of fluoride water sampled areas in Meru district

RESULTS AND DISCUSSION

Water sources in relation to Fluoride concentration

Table 2 summarizes the distribution of fluoride concentration in some water sources of Meru district. Fluoride content in domestic surface and ground water sources ranged from 0.76 to 40 mg/L while the permissible level of fluoride for portable water is 1.5 mg/L as per WHO limit and 4.0 mg/L as per Tanzania Bureau of Standards (TBS) limit. Table 2 further shows that, wards with high fluoride concentrations in most of their water sources were Kikatiti, King'ori, Leguruki, Maji ya Chai and Ngarenanyuki and wards with fluoride concentrations in most of their water sources below 10 mg/L are Akheri, Kikwe, Makiba, Mbuguni, Nkoanrua, Nkoaranga, Nkoarisambu, Poli, Seela Sing'isi and Usa River.

Table 2: Some water quality parameters for water sampled from domestic sources (Sampled in January and February, 2015)

No.	Wards	Location	Site	Source	Latitude	Longitude	Elevation (m)	Well Depth (m)	EC (µS/cm)	TDS (mg/L)	F (mg/L)
1	Akheri	Akeri	Sebala B	Spring	-3.35281	36.77155	1451		227	124.85	1.2
2	Akheri	Akeri	Sebala A	Spring	-3.35448	36.7728	1435		237	130.35	1.1
3	Akheri	Nguruma	Saibala	spring	-3.3528	36.77152	1439		233	127.05	1.3
4	Akheri	Duluti	Duluti	Lake	-3.38306	36.7896	1273		456	240.9	3.3
5	Akheri	Lita	Lita (Kitchen)	Deep well	-3.38379	36.7973	1260		344	187.55	1.4
6	Akheri	Lita	Tengeru Spring No 2	Spring	-3.39025	36.8017	1221		370	202.95	1.4
7	Akheri	Cdti	Dp Nork Shop	Deep well	-3.38106	36.80235	1261		328	178.75	1.3
8	Akheri	Sing'isi	Kwa Soja	Spring	-3.37444	36.79583	1260		198	89.1	1.3
9	Akheri	Sing'isi	Kwa Soja	Spring	-3.37444	36.79583	1260		180	81	1.2
10	Akheri	Patandi	Malala	Spring	-3.37124	36.79275	1279		173	77.85	1.2
11	Akheri	Patandi	Gema	Spring	-3.37144	36.79278	1281		244	109.8	1.3
12	Akheri	Patandi	Meru Hospital	Deep well	-3.37017	36.78645	1307		287	129.15	1.2
13	Akheri	Patandi	Tengeru Fathers	Deep well	-3.37424	36.7803	1331		402	238	1.2
14	Akheri	Patandi	Tengeru Fathers	Deep well	-3.37434	36.7804	1333		582	316	11
15	Akheri	Akheri	Lake Duluti (Tengeru)	Lake	-3.3825	36.7913	1250		472		2.6
16	Kikatiti	Kikatiti	Kwa Pendaeli(Diwani)	Shallow well	-3.38786	36.94342	1093	12	1395	1395	22
17	Kikatiti	Kikatiti	Ngira (Kwa Ngira)	Shallow well	-3.37193	36.93262	1143	>10	283.5	383.5	2.7
18	Kikatiti	Kikatiti	Kisima Cha Iddi	Shallow well	-3.38565	36.93892	1100	5	1030	1030	22
19	Kikatiti	Kikatiti	Mnadani/Sokoni(Kwa Pendaeli)	Shallow well	-3.39826	36.9475	1072	10	1065	1065	29

No.	Wards	Location	Site	Source	Latitude	Longitude	Elevation (m)	Well Depth (m)	EC (µS/cm)	TDS (mg/L)	F (mg/L)
20	Kikatiti	Kikatiti	Mnadani Kwa Lomnyaki	Shallow well	-3.39801	36.94705	1074	8	1070	1070	30
21	Kikatiti	Kikatiti	Mnadani Kwa Lotegerwaki	Shallow well	-3.39789	36.94702	1074	8	1050	1050	30
22	Kikatiti	Nasholi	Nasholi Sec School	Shallow well	-3.40425	36.94805	1055	9	1215	1215	31
23	Kikatiti	Nasholi	Mlimani Kwa Dickson Paul	Shallow well	-3.40897	36.94669	1046	8	890	890	8.3
24	Kikatiti	Kwa Samaria	Maroroni Pr/School	Deep well	-3.34668	36.97329	984	150	1485	742	11
25	Kikwe	Lita	Tengeru Spring No 1	Spring	-3.39613	36.80241	1231		332	187.55	1.3
26	Kikwe	Kikwe	Uduma	Deep well	-3.42883	36.82952	1095	70	970	516.45	6.5
27	Kikwe	Maweni	Maziwa	Deep well	-3.45815	36.85021	1027	46	1187	651.2	12
28	Kikwe	Karangai	Mtowi	Deep well	-3.47977	36.86823	986	48	1001	519.75	2.4
29	Kikwe	Karangai	Miembeni	Deep well	-3.51939	36.88343	956	60	454	261.25	1.7
30	Kikwe	Kwa Ugoro	Maroroni	Deep well	-3.48542	36.87774	979	80	1027	513.5	7.3
31	King'ori	Malula King'ori	Kisima Cha Zefania	Shallow well	-3.37256	37.01865	940	15	202.5	202.5	0.89
32	King'ori	Malulu	Kisima Cha John Swai	Shallow well	-3.3713	37.01929	940	12	709	709	18
33	King'ori	King'ori	Shoroyandeke	Spring	-3.27967	36.98704	1179		1095	1095	15
34	King'ori	King'ori	Joel Kaaya Kisima	Shallow well	-3.28139	36.98792	1172	13	1040	1040	32

No.	Wards	Location	Site	Source	Latitude	Longitude	Elevation (m)	Well Depth (m)	EC (µS/cm)	TDS (mg/L)	F (mg/L)
35	King'ori	King'ori	Chemchem Ya Barnaba	Shallow well	-3.28143	36.9855	1165		1075	1075	26
36	King'ori	King'ori	Kisima Cha Mama Shirima	Shallow well	-3.28218	36.98512	1172		1150	1150	17
37	King'ori	King'ori	Kisima Cha Solomoni	Shallow well	-3.2919	36.98191	1147	11	538	538	7.9
38	Leguruki	Leguruki Madukani	Kisima Cha Elipokea	Shallow well	-3.25092	36.94123	1377	15	422	422	11
39	Leguruki	Leguruki Madukani	Kwa Ndellilio	Shallow well	-3.25052	36.93947	1376	<3	522	523	6
40	Leguruki	Mbaaseni	Kwa Kemishua	Shallow well	-3.23836	36.94794	1376		653	653	1.1
41	Leguruki	Mbaaseni	Kwa Sarakikya	Shallow well	-3.23695	36.94965	1371	<3	801	801	9.8
42	Leguruki	Mbaaseni	Kwa Barakaeli Ayo	Shallow well	-3.2368	36.95099	1373	8	1165	1165	17
43	Leguruki	Shistoni	Shistoni Pr/School	Shallow well	-3.23351	36.94954	1373	<4	1070	1070	23
44	Leguruki	Shistoni	Nosingili	Dam	-3.23153	36.95277	1354		2170	2170	38
45	Leguruki	Leguruki	Lake Tulisia Arusha	Lake	-3.2118	36.9076	1445		31400		974.9
46	Leguruki	Leguruki	Big Momella Lake	Lake	-3.2098	36.9084			38000		1103.7
47	Leguruki	Leguruki	Small Momella Lake	Lake	-3.22203	36.89155			8710		212
48	Maji ya Chai	Imbaseny	Imbaseny Peace School	Deep well	-3.36809	36.89621	1202	48	1800	900	0.09
49	Maji ya Chai	Imbaseny	Sokoni	Shallow well	-3.36556	36.89482	1201	8.5	1758	879	13
50	Maji ya Chai	Imbaseny	Chemchem	Spring	-3.35382	36.89053	1225		1117	558	8.2

No.	Wards	Location	Site	Source	Latitude	Longitude	Elevation (m)	Well Depth (m)	EC (µS/cm)	TDS (mg/L)	F (mg/L)
51	Maji ya Chai	Imbaseny	Shuleni	Deep well	-3.34401	36.88441	1267	60	1078	539	7.6
52	Maji ya Chai	Imbaseny	Kwamnegro Ucc	Deep well	-3.33719	36.88647	1213	70	1155	577.5	5.4
53	Maji ya Chai	Imbaseny	Tangini-A	Spring	-3.3451	36.90067	1275		874	437	9.8
54	Maji ya Chai	Imbaseny	Tangini-B	Spring	-3.3478	36.90131	1264		951	475	11
55	Maji ya Chai	Imbaseny	Tangini-C	Shallow well	-3.34841	36.90188	1266	10	993	496.5	11
56	Maji ya Chai	Maji ya Chai	Expresso Tea Water source Arusha NP	River	-3.29911	36.88051			2270		37.5
57	Maji ya Chai	Maji ya Chai	Maji ya Chai River Arusha NP	River	-3.29605	36.8793			921		21.9
58	Maji ya Chai	Maji ya Chai	Maji ya Chai River Arusha NP-Bridge	River	-3.30298	36.88258			922		22.8
59	Maji ya Chai	Maji ya Chai	maji ya Chai River at the village	River	-3.37082	36.89703	1185		995		18.6
60	Maji ya Chai	Maji ya Chai	Defluoridation Station Tap (Maji ya chai at source)	River	-3.32488	36.88445			907		20.2
61	Maji ya Chai	Maji ya Chai	Colobus Mountain Lodge Water tap	River	-3.31562	36.87745			609		17.1
62	Makiba	Makiba	Mabatini	Deep well	-3.52466	36.95242	925	50	676	376.2	3.1
63	Makiba	Majengo-Kati	Uduma-A	Deep well	-3.49248	37.02672	892	28	809	404.5	4.8
64	Makiba	Majengo-Kati	Uduma-B	Deep well	-3.49494	37.02523	894	30	424	212	4.2

No.	Wards	Location	Site	Source	Latitude	Longitude	Elevation (m)	Well Depth (m)	EC (µS/cm)	TDS (mg/L)	F (mg/L)
65	Makiba	Majengo-Kati	Uduma-C	Deep well	-3.4994	37.02731	896	70	503	251	2.2
66	Makiba	Majengo-Kati	Kati-A	Deep well	-3.48908	37.02409	891	36	5530	2765	1.5
67	Makiba	Majengo-Kati	Kati-B	Deep well	-3.48568	37.01904	891	33	5220	2610	11
68	Makiba	Majengo-Kati	Kati-C	Deep well	-3.48299	37.01957	894	25	4670	2335	8.5
69	Makiba	Majengo-Kati	Rumala	Deep well	-3.47665	37.02162	888	28	2560	1280	2.5
70	Maroroni	Kwa Samaria	Kijenge	Deep well	-3.42102	36.95523	1028	70	2300	1150	20
71	Mbuguni	Mbuguni	Amec	Deep well	-3.55142	36.91921	942	64	387	217.25	2.7
72	Mbuguni	Kikuletwa	Shamima Intake	River	-3.53335	36.91764	950		342	190.85	3.2
73	Mbuguni	Kikuletwa	Mnazi Mmoja	Deep well	-3.53692	36.91798	941	60	538	290.95	4.8
74	Mbuguni	Kikuletwa	Stemm	Deep well	-3.54288	36.9175	944	87	450	252.45	15
75	Mbuguni	Kambi Ya Tanga Juu	Kazamayo	Deep well	-3.55152	36.90492	946	58	546	297.55	2.1
76	Mbuguni	Shambalai Bruka	Kati	Deep well	-3.56496	36.89828	945	100	536	295.35	2.1
77	Mbuguni	Shambalai	Tumaini	Deep well	-3.57405	36.91437	938	50	741	395.45	1.5
78	Ngarenanyuki	Ngarenanyuki Olkung'wado	Mandoke 1	Spring	-3.20089	36.84391	1497		438	248.05	5.2
79	Ngarenanyuki	Ngarenanyuki Olkung'wado	Mandoke 2	Spring	-3.20169	36.84463	1499		429	240.35	5.2
80	Ngarenanyuki	Ngarenanyuki Olkung'wado	Mandoke 3	Spring	-3.19684	36.84954	1468		770	424.05	12
81	Ngarenanyuki	Ngarenanyuki Olkung'wado	Mandoke 4	Spring	-3.198	36.85082	1476		1287	707.3	21

No.	Wards	Location	Site	Source	Latitude	Longitude	Elevation (m)	Well Depth (m)	EC (µS/cm)	TDS (mg/L)	F (mg/L)
82	Ngarenanyuki	Ngarenanyuki Olkung'wado	Nasura 1	Spring	-3.20053	36.85015	1489		388	234.85	9.5
83	Ngarenanyuki	Ngarenanyuki Olkung'wado	Nasura 2 Kwa Andrea	Spring	-3.20321	36.85243	1489		1848	1111.2	31
84	Ngarenanyuki	Ngarenanyuki Olkung'wado	Ngarenanyuki	River	-3.20266	36.85678	1489		1852	1149.6	30
85	Ngarenanyuki	Ngarenanyuki Olkung'wado	Nasura Water Source	spring	-3.21665	36.8721	1516		346	243.65	3.9
86	Ngarenanyuki	Ngarenanyuki Olkung'wado	Ngujawi A	spring	-3.216	36.87218	1506		1771	1086	26
87	Ngarenanyuki	Ngarenanyuki Olkung'wado	Sekedo	spring	-3.21173	36.87397	1497		1835	1212	29
88	Ngarenanyuki	Ngarenanyuki Olkung'wado	Ngujawi B	spring	-3.21244	36.8729	1499		2020	1290	25
89	Ngarenanyuki	Ngarenanyuki Olkung'wado	Bulebule B	spring	-3.17749	36.85318	1454		945	586.3	9.5

No.	Wards	Location	Site	Source	Latitude	Longitude	Elevation (m)	Well Depth (m)	EC (µS/cm)	TDS (mg/L)	F (mg/L)
90	Ngarenanyuki	Ngarenanyuki Olkung'wado	Bulebule A	spring	-3.1776	36.85306	1452		724	429	7.2
91	Ngarenanyuki	Uwiro	Ngali Maji	spring	-3.15511	36.859	1429		851	515.9	7.6
92	Ngarenanyuki	Uwiro	Ngarenanyuki Pr/School Dp	spring	-3.15247	36.84129	1478		869	392.15	4.7
93	Ngarenanyuki	Kisimiri	Kismiri Chini	spring	-3.17044	36.81693	1613		649	179.3	5.6
94	Ngarenanyuki	Kisimiri	Kismiri Juu	spring	-3.17097	36.81117	1663		330	194.7	1.5
95	Ngarenanyuki	Ngarenanyuki	Lake Lekandiro	Lake	-3.21255	36.8948	1469		9230		199.3
96	Ngarenanyuki	Ngarenanyuki	Lake Rishaten Arusha	Lake	-3.23163	36.83917			28900		897.7
97	Ngarenanyuki	Ngarenanyuki	Small spring near headquarter Arusha NP	River	-3.24367	36.83916	1694		908		10.2
98	Ngarenanyuki	Ngarenanyuki	Kusare raw water	Deep well	-3.22545	36.8853					
99	Nkoanrua	Nkoarua	Mfulonyi	Spring	-3.34869	36.76672	1482		173.9	95.65	0.92
100	Nkoanrua	Filonyi	Camatec A	spring	-3.33318	36.76793	1586		160	93.72	0.81
101	Nkoanrua	Filonyi	Camatec B	spring	-3.33272	36.76775	1585		162	90.53	0.66
102	Nkoanrua	Filonyi	Malala	River	-3.3325	36.76791	1585		136	76.18	2.2
103	Nkoanrua	Ambureni	Ngwaimare	Spring	-3.35905	36.7558	1451		209	124	1.1
104	Nkoanrua	Ambureni	Petro Akyoo	Spring	-3.364	36.75856	1425		232	137	1.7

No.	Wards	Location	Site	Source	Latitude	Longitude	Elevation (m)	Well Depth (m)	EC (µS/cm)	TDS (mg/L)	F (mg/L)
105	Nkoanrua	Ambureni	Uronyi Mzee Seeo	Spring	-3.36789	36.75935	1383		247	144	2.2
106	Nkoanrua	Ambureni	Lekuta	Spring	-3.36421	36.76149	1415		250	147	2
107	Nkoanrua	Ambureni	Lemteri	Spring	-3.36892	36.76375	1373		244	144	1.4
108	Nkoanrua	Ambureni	Kwa Pailoti	Spring	-3.36715	36.762	1394		257	145	2.1
109	Nkoanrua	Ambureni	Kwa Laizer	Spring	-3.3736	36.76317	1349		254	145	1.6
110	Nkoanrua	Shambarai	Machumba	Spring	-3.38834	36.7682	1277		260	157	0.93
111	Nkoaranga	Ndulumanga	Ndulumanga A	Spring	-3.35465	36.8479	1195		248	136.4	1.3
112	Nkoaranga	Ndulumanga	Ndulumanga B	Spring	-3.35357	36.84851	1220		250	137.5	1.3
113	Nkoaranga	USA	Sangananu 1	Spring	-3.34111	36.8588	1255		194.2	106.81	1.5
114	Nkoaranga	USA	Sangananu 2	Spring	-3.33925	36.86167	1270		189.1	104.01	1.7
115	Nkoaranga	Nkoanekoli	Nkoanikole1	Spring	-3.34034	36.85592	1276		219	120.45	1.2
116	Nkoaranga	Nkoanekoli	Muralikoka2	Spring	-3.33606	36.86441	1277		328	180.4	5
117	Nkoaranga	Nkoanekoli	Usa River	River	-3.33545	36.86257	1270		232	127.6	3
118	Nkoaranga	Nkoanekoli	Mraakare	River	-3.33565	36.86317	1275		304	167.2	4.9
119	Nkoaranga	Nshupu	Ngaresero Lodge	spring	-3.35969	36.83775	1235		185.9	114.95	1.6
120	Nkoaranga	Nshupu	Nak I	spring	-3.36589	36.83671	1205		199.6	116.05	1.6
121	Nkoaranga	Nshupu	Nak II	spring	-3.36633	36.83761	1224		209	116.6	1.6
122	Nkoaranga	Nshupu	Nak III	spring	-3.36561	36.83869	1205		206	116.05	1.7
123	Nkoarisambu	Mfulonyi	Kumu	Spring	-3.33834	36.77346	1539		152.7	83.99	0.74
124	Nkoarisambu	Mfulonyi	Mfulonyi	Spring	-3.33834	36.77461	1543		150.6	82.83	0.66
125	Nkoarisambu	Mfulonyi	Mfulonyi	Spring	-3.33881	36.77557	1523		155.6	85.58	0.71
126	Nkoarisambu	Mburu Kuku	Masee	Spring	-3.31503	36.77085	1873		116	70.35	0.86
127	Poli	Poli	Mitateni	Spring	-3.35595	36.80382	1297		245	134.75	2.2
128	Poli	Poli	Makilele	Spring	-3.35542	36.80437	1308		265	145.75	1.8

No.	Wards	Location	Site	Source	Latitude	Longitude	Elevation (m)	Well Depth (m)	EC (µS/cm)	TDS (mg/L)	F (mg/L)
129	Poli	Poli	Kuluwo	Spring	-3.3549	36.8054	1310		268	147.4	1.7
130	Poli	Poli	Kivulini	Spring	-3.3519	36.80667	1306		254	139.7	0.82
131	Poli	Ndatu	Nkura	Spring	-3.35775	36.81234	1274		279	153.45	0.87
132	Poli	Ndatu	Karamu	Spring	-3.36393	36.82047	1210		289	158.95	1.3
133	Poli	Nshupu	Nak 1v	spring	-3.3663	36.83518	1207		215	119.35	1.7
134	Poli	Nshupu	Nak V	spring	-3.36628	36.83405	1216		217	120.45	1.7
135	Seela Sig'isi	Poli	Uriro	Spring	-3.33921	36.7905	1499		177.4	97.57	1.5
136	Seela Sig'isi	Poli	Nasa	Spring	-3.33945	36.79296	1489		170.1	93.56	1.1
137	Seela Sig'isi	Sing'isi	Kimath	Spring	-3.35834	36.79654	1341		207	93.15	1.6
138	Seela Sig'isi	Sing'isi	Mavinuni Bridge	River	-3.35688	36.79362	1341		163	73.35	1.5
139	Seela Sig'isi	Sing'isi	Seti	Spring	-3.36529	36.79794	1295		185	83.25	1.6
140	Seela Sig'isi	Sing'isi	Kimafie	Spring	-3.36452	36.79818	1281		178	80.1	1.3
141	Seela Sig'isi	Sing'isi	Tito	Spring	-3.36634	36.79798	1285		190	85.5	1.2
142	Seela Sig'isi	Sing'isi	Metengoi	Spring	-3.37074	36.79625	1271		207	93.15	1.3
143	Songoro	Songoro	Rest House Arusha NP	River	-3.24957	36.84855	1698		1545		19.4
144	Usa River	Magadilisha 1	Chemchem 1	Spring	-3.35355	36.8561	1222		249	136.95	1.2
145	Usa River	Magadilisha 2	Chemchem 2	Spring	-3.35355	36.85355	1224		246	135.3	1.3
146	Usa River	Magadilisha 3	Chemchem 3	Spring	-3.35474	36.85498	1215		246	135.3	1.2

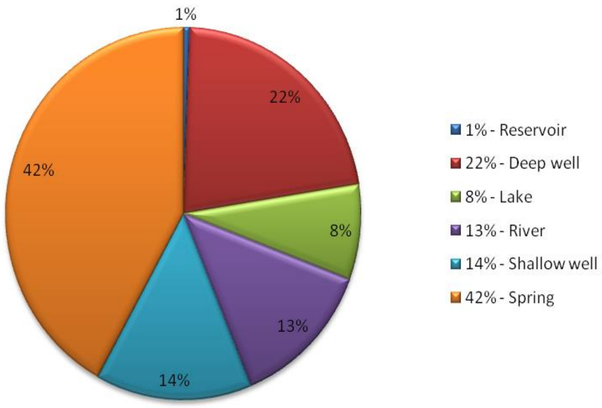

Figure 4: Sampled domestic water source types in Meru district

Figure 4 shows the types of domestic water sources available in the study area. Springs are the main source of water followed by deep wells, shallow wells and rivers.

Most of the domestic water sources of Meru district are affected by high fluoride content. About 69% of the samples taken from these sources had fluoride levels greater than 1.5 mg/L while about 47% had a fluoride level value greater than 4 mg/L (Figure 5). This shows that if the fluoride limit for Tanzania was set to 1.5 mg/L, more water sources in fluorotic rural areas would have been abandoned due to fluoride levels and hence increase water supply shortage in the district (Ghiglieri et al. 2008). Despite the fact that, fluoride concentration of 4 mg/L is not health for consumption the Government of Tanzania deliberately advised to set that level so that people could at least have sources of water rather than none while means are been worked out to solve the problem. Actually in 1974 the Temporal fluoride concentration allowed in Tanzania was set at 8 mg/L (British Geological survey 2002). The problem of high level of fluoride concentration was also observed by Gumbo and Mkongo (1995) who studied water defluoridation for rural fluoride affected communities in Tanzania.

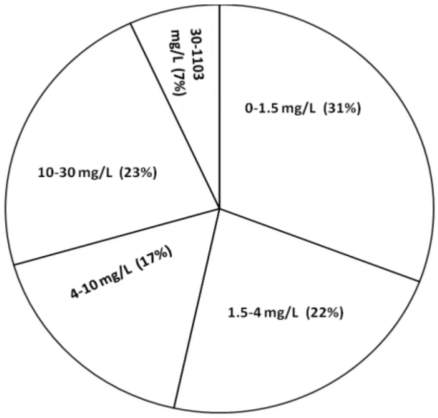

Figure 5: Ranges of fluoride concentrations in the sampled water from the study area

The variations in fluoride concentration in various water sources observed can be explained in geological point of view. Fluoride concentrations are affected by the geology of the area in the case of ground water, rivers and streams. Giogio et al. (2008) described the geology of Meru to be dominated mainly with rocks of Cenozoic volcanic with most alluvial deposits. Cenozoic rock is characterized by alkaline volcanic rocks, which are associated with higher quantities of soluble fluoride in ground water (Ghiglier et al. 2012). Geological studies conducted by researchers indicate that, some rivers and streams in the fluoride belt have higher concentrations of fluoride as a result of the alkaline volcanism which is widespread throughout the East Africa Rift Valley system (Tekle-Haimanot et al. 2006, Jaroslav and Annukka 2007). The topography of Meru is dominated by the volcanic cone of mount Meru whose slopes cover most of the area. The fluoride levels of the Rift Valley system ground water have been shown to vary from place to place (Tekle-Haimanot et al. 2006), depending on the influence exerted by local geology and climatic variation. Bedrock aquifers in alkaline magmatic rocks and metamorphic rocks are associated with fluoride contaminated groundwater (Banks et al. 1995, Dowgiallo 2000, Botha and van Rooy 2001, Shanker et al. 2003). Generally, fluoride builds up in ground water resulting from a prolonged contact of water with rocks rich in fluoride (Frengstad et al. 2001, Carrillo-Rivera et al. 2002). Thus, the variation in concentration of fluoride at different locations and at different depth is due to existence of different rock formations in different locations and at different depth.

Population and range of fluoride concentration

Table 3 provides population and range of fluoride concentration in each ward of the study area. From Table 3 it is clear that, wards highly affected with fluoride concentration have about 40% of the total population of the study area. Although in some wards the number of samples collected is not sufficient for a conclusive declaration of an impact, at least in most cases the study area shows a likely hood of high risk of health problems associated with high levels of fluoride associated with water supply sources. The profile of high levels of fluoride concentration in water in Meru district can be associated to the appearance of the teeth of the people living in the wards.

Several literatures (Pittalis 2010, Johansen ES 2013) linked the Meru district with dental and crippling fluorosis.

Table 3 : Meru District population and fluoride concentration range in water

Serial No	Ward	Population (Number)	No. of Samples	Range of Fluoride Conc. in (mg/L)
1	Akheri	13,699	15	1.1-11
2	Kikatiti	16,755	9	2.7-31
3	Kikwe	10,795	6	1.3-12
4	King'ori	23,280	7	7.9-32
5	Leguruki	17,636	7	6.0-38
6	Maji ya Chai	29,313	14	5.4-37.5
7	Makiba	11,874	8	1.5-11
8	Maroroni	14,103	1	20
9	Mbuguni	16,130	7	1.5-15
10	Ngarenanyuki	20,379	19	3.3-31
11	Nkoanrua	18,520	12	0.66-2.2
12	Nkoaranga	13,929	12	1.2-5.0
13	Nkoarisambu	7,359	4	0.66-0.86
14	Poli	9,507	8	0.82-2.2
15	Seela Sing'isi	10,109	8	1.1-1.6
16	Songoro	11,319	1	19.4
17	Usa River	23,437	3	1.2-1.3
	TOTAL	**268,144**		

Source: Population data are from Tanzania population census 2012

Variability of Fluoride concentration with depth

Figure 6 shows variability of fluoride concentration with well depth for the 41 wells in the study area. It appears there is a trend of low fluoride concentration with well's depth higher than 45 to 100 m. Apparently no studies have been conducted to depict the details of variation of well water fluoride concentration with rocks/soil features variation with depth, surrounding rock/soil and depth of the well. Therefore, no comparative studies to compare with the findings in this study.

The findings can be explained from the fact that, fluoride distribution in Meru district is a result of presence of rock (Ghiglieri et al. 2012) containing fluoride resulting from volcanic magma of Mt. Meru which spread over wide range of the area. As years pass by fluoride is dissolving from the rocks and spread into the soil. The extent of concentration with depth depends on the flow mechanism (with flowing streams, penetration through the soil or by other means). Due to different strata characteristics formed by the emitted magma (Ghiglier et al. 2010) there is no even distribution of fluoride on the surface, and underground waters because of different mechanism involved in the transportation of dissolved fluoride from the initial sources. The recorded fluoride concentration of 1104 mg/L in Big Momela lake lying within Arusha National park to the east of Mt. Meru is an indication that run off waters with dissolved fluoride may be a major mechanism of distribution of fluoride from the volcanic rocks. This lake is in Leguruki ward and is not very far from the Mount Meru volcanic cone and collects water from streams originating from mount Meru. It therefore follows that the high fluoride concentration at low depth is contributed by the presence of volcanic magma which contains high level of fluoride concentration while at deeper depth water is drawn from the depth at the original soil stratum which is beyond the volcanic magma.

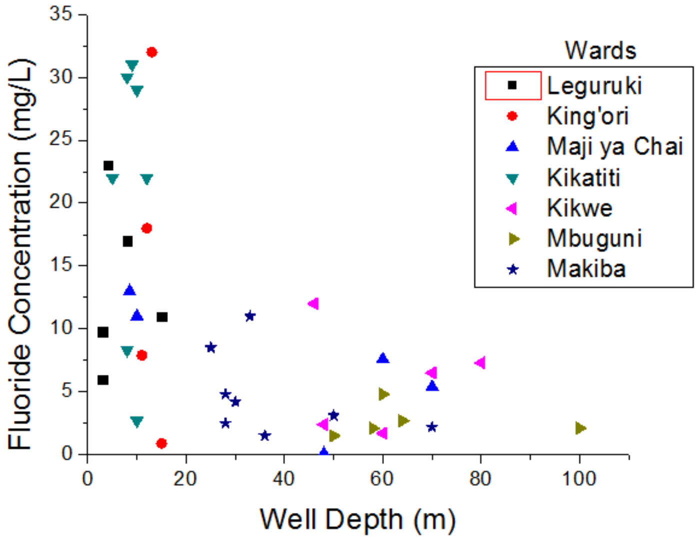

Figure 6: Variability of fluoride concentration with the depth of wells

CONCLUSION

From this study it has been observed that 40% of the population in the study area uses water sources with high fluoride concentrations and therefore they are at high risk of developing dental and skeletal fluorosis. Most of the water from the sources in the areas needs to be defluoridated to be potable. This work has developed useful information on fluoride concentration profile for the domestic water sources available in the Meru district. The results may be used for planning how to provide potable water for the residents of Meru district.

As mentioned above, fluoride in groundwater in the rift valley zones at northern and south-western Tanzania is associated with volcanic activity. In volcanic areas, drinking water sources often have inputs from geothermal activity related to volcanic or hydrothermal processes. Aqueous reservoirs (e.g., Big Momela Lake) in volcanic belt are affected by high fluoride concentrations. Other minerals like mica, apatite and fluorites formed as a result of volcanism are responsible for the release of elevated concentrations of fluoride to natural waters. Meru district falls in northern Tanzania rift valley therefore it suffers with the fluoride concentration problem in their water sources. Therefore, water supplier for the communities of Meru district have to pay attention to the levels of fluoride in water sources to be used to prevent skeletal and dental fluorosis to its people.

It was also observed from this study that, wells with deep depth i.e. > 50 m were found to have water aquifer with low fluoride concentration. But a detailed research by drilling more observation boreholes at different locations with different depths is required to be done in order to justify this observation. Drilling deep boreholes might be a solution to fluoride problems if another study on fluoride concentration in deep boreholes is conducted throughout Meru district and establish that the observation is valid for most places.

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