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Quality of drinking water used by communities in selected villages from Iringa rural, Kongwa and Mufindi districts, Tanzania

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Abstract

Drinking water quality was assessed in selected villages from Kongwa, Mufindi and Iringa rural districts between March and August 2020. Ten villages from three districts were involved in the study: Kongwa (4 villages), Iringa rural (3 villages), and Mufindi (3 villages). Methods used in data gathering were observation, in-situ, and ex-situ measurement of water parameters. A total of 150 samples were collected from different water sources (a bore hole, a well, a spring, and a river) and analyzed using standard methods. Results show that the minimum and maximum values of dissolved oxygen (DO), biochemical oxygen demand (BOD, pH, total dissolved solids (TDS), turbidity, calcium, magnesium, fluoride, nitrate, and hardness were 3.35-9.62, 0.52-1.93, 4.40-8.28, 13.0-2000 mg/L, 0.47–31.6 NTU, 0.41-1.32 mg/L, 0.25-1.35 mg/L, 0.02-1.02 mg/L, 1.30-167 mg/L, and 0.68-216 mg/L, respectively. TDS (2000 mg/L) and nitrate (167 mg/L) were significantly higher than WHO guideline values in some villages from different sources. Further results indicated that 3 out of 17 sampling sites had *Escherichia coli*, indicating fecal contamination. Higher levels of physical-chemical parameters and microbial contamination observed are of health concern and call for mitigation measures. The study recommends regular water testing, monitoring its quality, treating source points, and providing education to communities surrounding the water sources.

Keywords: Chemical, conductivity, dissolved solids, Escherichia coli, physical, pollution.

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1. Introduction

Human population in Africa has increased from 800 million in 2000 to 1.4 billion people in 2022. About 500 million people gained access to basic drinking water and 290 million to basic sanitation services (WHO/UNICEF, 2022). On the continent, however, 418 million people still lack even a basic level of drinking water service, 779 million lack basic sanitation services (including 208 million who still practice open defecation), and 839 million still lack basic hygiene services. In order for Africa to meet the Sustainable Development Goals (SDG) targets for water, sanitation, and hygiene, existing rates of development must be dramatically accelerated (UNICEF & WHO, 2019). This necessitates quick action on a continent where lack of access to clean water and inadequate sanitation and hygiene services can endanger peace and development.

Tanzania's water sector status is described by taking into consideration the existing situation of water resources management, water quality management, rural and urban services for sanitation and water supply, and the institutional capacity of the sector. According to the National Atlas for Water Resources (2019 Version), Tanzania is estimated to have water resources fit for human consumption amounting to an annual average of 126 BCM, of which 105 BCM are available as surface water and 21 BCM are available as ground water. Considering the population of Tanzania in 2022, the amount of water available per person per year is approximately 2,250 cubic meters. The amount is above the average of 1,700 cubic meters, which is the minimum internationally recommended amount per person per year below which the country is considered to be water stressed (UNICEF, 2022). This requirement is expected to increase to approximately 80 BCM per year by 2035. This indicates that the country has enough water resources for socio-economic development. However, due to increased catchment degradation, it is important to strengthen the management and development of water resources to avoid water stress.

Water quality in different water sources of Tanzania varies from one area to another. The variation is caused by the apparent geology and geography of the particular area, climatic conditions, and human activities (Lintern *et al.,* 2018; Edmond, *et. al.,* 2019). The presence of high levels of nitrogen and phosphorus in lakes and turbidity in rivers resulting from human activities is among the challenges facing surface water sources (Katonge *et al.,* 2019). In addition, high levels of salt, nitrate, fluoride, iron, and manganese are among the challenges for groundwater quality in some parts of the country. Similarly, the presence of high fluoride concentrations in the Rift Valley zone, including Arusha, Kilimanjaro, Manyara, Singida, and Shinyanga regions; salt in coastal areas of Dar es Salaam, Mtwara, Lindi, and Tanga regions; and the central zone in Dodoma and Singida regions, remain challenges. Despite the difficulties encountered in some parts of the country, water from various sources remains useful after being treated for specific uses, especially the drinking water supplied to community is of satisfactory quality. Drinking water quality is considered good if it does not have an excessive concentration of minerals, toxins, or disease-causing organisms such as *Escherichia coli* and *total coliform bacteria* (WHO, 2017b).

Several efforts have been in place in Tanzania to ensure water access and quality of water supplied in both urban and rural areas is not compromised. For example, in 1970s, Standards for water quality were developed in the country for both urban and rural places (Ministry of Water and Irrigation, 2011). The government also adopted drinking water quality standards from the WHO and the East African Community in 2016. Developed and implemented water, sanitation, and hygiene (WASH) projects and the Water Sector Development Program (WSDP) 2006–2025, which targeted a good quality of water supply to the community in rural areas reaching 85% by the year 2025. Water service providers to the community are also assigned responsibility of controlling the quality and safety of drinking water (Lwimbo et al., 2019; Mcheka, 2015). Despite the government's efforts, the level and variation of water quality in the country are little known. Kongwa, Iringa rural, and Mufindi districts are among districts affected by the government efforts of improving water access and quality. However, according to the Iringa District Council (2018), Kongwa District Council (2017, 2018), and Mufindi District Council (2018), the districts were reported to be prone to water contamination and deterioration of water quality, which continued to affect the health of people. While that is known, little has been reported on the condition of the domestic water quality in the districts, and human activities that can affect the water quality. It is from that background, the paper assessed the physical-chemical and microbiological drinking water quality, to identify the communities using questionable sources, and to offer potential remedies to lessen pollution issues in the study sites.

2. Materials and Methods

2.1 Study area and sampling location

This study was conducted in the sites of the big research project titled "Integrated Project on Right to WASH, Health, and Nutrition in Iringa and Central Tanzania", which was being implemented by the Italian NGO LVIA in collaboration with the University of Dodoma, Doctors with Africa CUAMM, Hydro Aid, MR&D, and UNICEF and AICS. Thus the study villages were selected purposeful based on the condition of the project funder, but also the study sites are among the areas reported to be prone to water contamination and deterioration of water quality, which continued to affect the health of people (Kongwa, Mufindi and Iringa rural council's reports (2018). The study sites characterized by differences in climatic conditions, geology, soil characteristics, topography, and anthropogenic activities features that are well documented on its influence to water quality (Roig, *et.al,* 2014; Lintern *et al.,* 2018; Edmond, *et. al.,* 2019). Based on that criteria, ten villages were involved in the study including Ugogoni, Hogoro, Mbande, and Chamkoloma (Kongwa district); Kaningombe, Luganga, and Magulirwa (Iringa Rural district), and Mabaoni, Mbalamaziwa, and Mapanda (Mufindi District) (Figure 1)

2.2 Sample determination

The following drinking water sources were identified as the most commonly used by the community: (A) bore holes, (B) wells, (C) springs, and (D) rivers, in proportions of 6 (35.3%), 2 (11.8%), and 3 (17.6%), respectively (Table 1). The leading water source types in the study area were bore holes and springs.

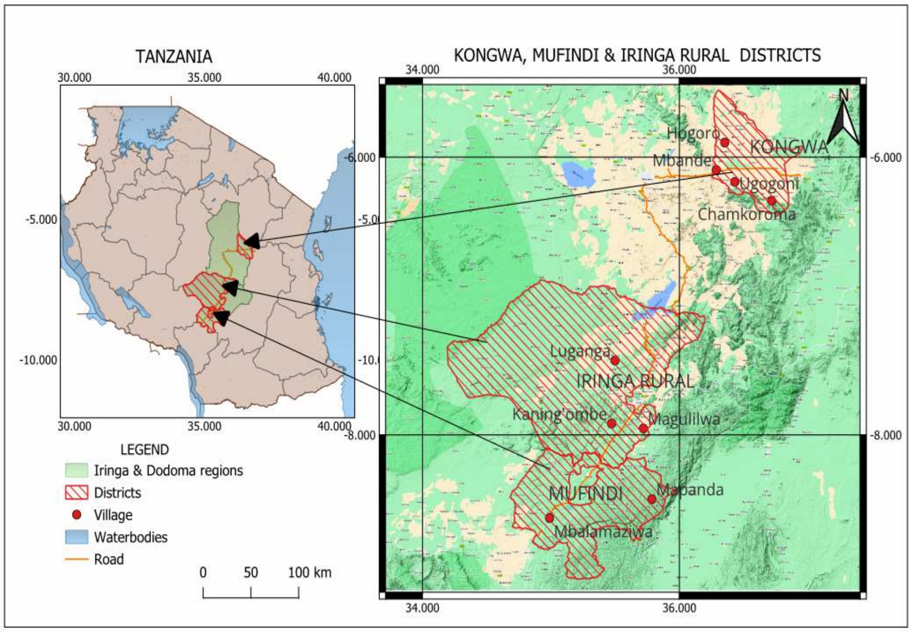
Table 1. Water sources types in selected villages

District	Village	Source type	Number of sites	Number of samples
Kongwa	Ugogoni	A	2	6
	Hogoro	A	2	6
	Mbande	A	4	12
	Chamkoloma	C	2	6

Table 1(cont'd). Water sources types in selected villages

District	Village	Source type	Number of sites	Number of samples
Iringa DC	Kaningombe	C	4	12
	Luganga	D	4	12
	Magulirwa	A, C	8	24
Mufindi	Mabaoni	B, D	8	24
	Mbalamaziwa	B, C	8	24
	Mapanda	A, C	8	24
		Total	50	150

Water source type A: Bore hole, B: Well, C: Spring and D: River
Source: Field data



. **Figure 1**: Map of the studied districts under S.A.N.I project

2.4 Water sampling

Water samples were collected in March and April, the period representing a wet season as well as July and August 2020 the period representing a dry season. First, the geographical coordinates of sampling points were determined using GPS. Second, physico-chemical parameters (turbidity, pH, DO, BOD, and TDS) were measured on site. Third, triplicate water samples for chemical parameters (calcium, potassium, fluoride, and nitrate) were collected by dipping a standard water sampler, biological characteristics were obtained in order to get a representative sample for each site. Water samples collected were completely filled in 0.25-liter standard sterilized bottles to ensure that the water did not freeze during transport. With a waterproof marker, each bottle was uniquely tagged with the location, date, sample number, collector's name, and the sort of analysis required. Cross-referencing was done between this data and the sample collection sheets and field diary. On-site ice was used to chill water sample bottles before they were sent to the lab for analysis in a cool box.

2.5 Direct observation

Direct physical observation was used in each sampling location for a specific water source, such as a bore hole, well, river, or spring. This entailed photographing various scenes of water sources and activities conducted around water sources in order to detect potential sources of contamination. An observation checklist tool was used to identify natural conditions such as climatic conditions, the geology and nature of the soil, and human activities. Direct physical observation was used in each sampling location for a specific water source, such as a bore hole, well, river, or spring. Furthermore, the effects of farming activities, livestock grazing, the handling, discharge of domestic and industrial wastes on the environment as well as other possible sources of contamination that affect water quality were observed.

2.6 Physical parameter analysis

Water samples were collected in each village from bore holes, wells, rivers, and spring sources and analyzed following the steps suggested by Balance and Bartram (1996), WHO (2007), and Yuncong & Migliaccio (2011) at the GST laboratory and UDOM laboratory. The WTW Photoflex Turb Set was used to test and record the physical parameters (turbidity, pH, TDS, and EC) while DO and BOD was measured by DO meter and BOD meter OxiDirect respectively in the field.

2.7 Chemical parameter analysis

Water samples were collected from wells, rivers, boreholes, and spring sources following the steps suggested by Robert (2012) and WHO (2017). Prior to sampling, each sampling container was thoroughly cleaned with distilled water and then with the desired water. The samples used to identify metallic elements (calcium and magnesium) were kept in 0.5 L plastic bottles that had been dosed with strong nitric acid to achieve a pH of 2. Samples for nitrate measurements were kept in 0.5 liter polyethylene bottles, where concentrated sulfuric acid was dosed to a pH of less than 2. Finally, samples for the other analyses (chloride and fluoride) were individually collected in 0.5 L plastic bottles. The samples were then immediately stored in ice boxes on membrane (except for tap samples, which were filtered onto a 0.2 and boreholes once in the laboratory) and analyzed. The photometer WTW Photoflex Turb Set was used to measure chloride, nitrate, calcium, and magnesium. Ionometer WTW pH/ION 340i was used to measure fluoride. Hardness was determined by the neutralization method.

2.8 Analyses of microbiological characteristics

The Most Probable Number (MPN) method was employed for microbial analysis (Odonkor and Ampofo, 2013) to detect the E. *coli* presence and total coliforms in each sample collected from boreholes, wells, rivers, and spring sources for each village. The MPN method was used to determine the approximate number of coliforms in water samples. MPN entails dilutions of water samples in lactose-containing broth tubes with a vial to tap gas. The tubes, in which the gas is produced, are then tested to verify the existence of coliforms (Alkhiry, 2020). Three sets of 3 to 5 tubes containing the same growth medium were prepared. Each set was given a specific amount of a sample, such as water and food for the microbes to cultivate. However, the added amount determined the expected bacterial concentration in the sample. Thereafter, each set was inoculated with an amount 10 times less than the previous set and incubated for 24 to 48 hours. After the incubation period, the presence or absence of bacterial growth in the tubes was observed, as well as a distinctive observable change, such as the production of gas were expected and recorded (Table 3).

2.9 Data Processing and Statistical Analyses

Data collected for this study came from different sources, the nature of a particular set of data determined the type of statistical or analysis technique to be used. Basic statistical parameters were used to analyze the data and assess how far the values for each parameter and each source category were dispersed.

3. Results

3.1. Physical parameters

The physical parameters analyzed were DO, BOD, pH, TDS, and turbidity, and the results are presented in Table 2. Most of the water sources had pH levels that were lower than or equal to neutral. Low pH values were typical of shallow wells, while boreholes, springs, and tap waters ranged from neutral to slightly basic values. The lowest and highest pH values (4.40 and 8.28) were observed in the H/H shallow well of Mabaoni village in Mufindi district and in the bore hole at Ugogoni village in Kongwa district, respectively (Table 2). In general bore holes had a relatively higher pH compared to other water sources.

DO was within the acceptable range (6.5 -8 mg/L) except for the majority of water sources at Ugogoni, Magulirwa and Mapanda villages that recorded minimum values. As for BOD all sources recorded values less than 2.0 mg/L High BOD levels indicate a higher level of organic pollution, which reduce the available oxygen in the water. As a result, the oxygen levels decrease, making it more difficult for aquatic organisms to survive. TDS levels were lowest (13 mg/L) and highest (2000 mg/L) in Mkumbulu spring of Mapanda village in Mufindi district and Bore hole of Old Tank at Mbande village in Kongwa district, respectively. The highest TDS recorded is beyond the accepted value (1000 mg/L). The flavor, smell, and appearance of drinking water are impacted by high TDS levels as this change water cloudy or discolored, which detracts its aesthetic attractiveness. The potential health effects of high TDS in water depend on the precise make-up of the dissolved materials in it. When ingested, contaminants including heavy metals, nitrates, and other dangerous compounds cause health hazards. These contaminants are found in water sources with high TDS levels pose negative health effects, particularly for people with excessive ingestion of some minerals, such sodium or fluoride. Turbidity measured a minimum of 0.47 NTU at old tank Mbande village in Kongwa district and a maximum of 31.6 NTU at Ilolo mpya Luganga village in Iringa district council. According to the WHO, acceptable turbidity limits is 5 NTU, water with turbidity below this level is often safe to drink. The relationship between BOD, DO, and TDS lies in their impact on water quality. High levels of TDS affect the taste and odor of drinking water. Elevated TDS levels were not directly influence BOD or DO, but indirectly affect them by interfering with the natural processes in the water body. Excessive TDS impact the solubility of oxygen, potentially reducing the availability of dissolved oxygen.

3.2 Chemical parameters

Calcium, magnesium, fluoride, nitrate, and hardness results are presented in Table 3. Findings indicate that the minimum value of calcium was 0.41 mg/L at Sokoni DP/Main Tap of Mabaoni Village in Mufindi District and a maximum value of 1.35 mg/L at Kibalali BH, Magulirwa Village in Iringa District Council. These values are within WHO standards (75 mg/L). Magnesium had its minimum value (0.25 mg/L) at Katulika Spring in Magulirwa village in Iringa district council and a maximum value (1.35 mg/L) at Kibalali BH in Mufindi district. The WHO recommends magnesium levels of 50 mg/L. Observed values are within accepted limits and thus have no detrimental effect on people. The minimum value of fluoride was 0.02 mg/L at the Ubenani bore hole, Hogoro village in Kongwa district, and a maximum value of 1.02 mg/L at Katulika Spring, Magulirwa village in Iringa district council are within WHO standards (1.5 mg/L). Nitrate levels recorded minimum and maximum values of 13 and 167 mg/L, respectively, in Mkumbulu spring of Mapanda village in Mufindi district and in Uvimbe DP at Mbalamaziwa village in Mufindi district. A minimum value of hardness of 0.68 mg/L was recorded at Katulika Spring, Magulirwa village in Iringa district council, and a maximum value of 2.16 mg/L at Kibalali BH in Mufindi district, the WHO defines acceptable magnesium levels as 100 mg/L.

3.3 Microbiological characteristics

Out of 17 villages surveyed, The MPN results have revealed presence of fecal contamination and *Escherichia coli* bacteria in some sampling stations from Chamkoloma, Mbande, and Ugogoni villages in Kongwa district (Table 5).

4. Discussions

4. 1. Physical parameters

DO and BOD give assurance on the safety and fitness of drinking water for human use. A sufficient level of dissolved oxygen is necessary to support the health of aquatic life, while low levels of BOD indicate a lower degree of organic pollution suggesting good water quality. Ugogoni, Magulirwa and Mapanda villages recorded minimum values of DO (3.35-3.80 mg/L) this suggest consumption by algae during decomposition process. Recorded values of BOD less than standard value (>2.0 mg/L) for all sources imply that water is not safe for drinking due to algae pollution observed in water samples collected from these sources. Algae pollution is a result of runoff from fertilizers applied to vegetable farms close to water sources in these villages. Higher pH levels (8.28) observed at Ugogoni village in Kongwa district could be the result of discharges from agricultural runoff of fertilizers and from limestone gravel rocks observed in the area. On the other hand, maximum values of TDS recorded (2000 mg/L in the bore hole of the old tank at Mbande village in Kongwa district are beyond the accepted value of 1000 mg/L). This is associated with the presence of salts in the soil that leached towards the water source. The maximum turbidity at Ilolo mpya Luganga village in Iringa district council is 31.6 NTU, which is higher than the WHO acceptable limit of 5 NTU and may have an effect on health. Turbid waters suggest microbiologically polluted and indirectly pose a health risk (Kisaka, 2018). High turbidity shield bacteria from the effects of disinfection, creating a significant chlorine demand and impairing the effectiveness of various disinfection methods (Jabeen et al., 2015).

4.2 Chemical parameters

Calcium, magnesium, and fluoride levels were within WHO standards and therefore cannot pose any health problems. High nitrate levels (167 mg/L) in Uvimbe DP at Mbalamaziwa village in Mufindi district had wastewater that has leaked from fertilized soil, and livestock feedlots from observed in the village. According to Ahuja (2013), Edmond *et al.* (2019), and Salustian *et al.* (2019), the possible source of the elevated nitrate in drinking water may is influenced by human and animal wastes through runoff or leaching, and the nature of the geology. Crop cultivation such as tomatoes, onions, okra, and spinach practiced near water sources and the upper slopes of the streams, shallow wells, and springs, have contributed to the leaching and runoff of nitrate into the water sources. The results are consistent with those of Lintern et al. (2018), who noted that an area's geology and soil characteristics can influence the nitrate concentration level in water. Furthermore, water with a high nitrate level, above acceptable health standards is considered to be of poor quality and not suitable for human consumption. Nitrate contamination may exacerbate the occurrence of waterborne diseases, which affect the health of the community as many solely depended on this water for domestic usage.

4.2 Biological parameters

Results for the microbial characteristic demonstrated minimal variation in the study area. Water consumed by a large community in some villages is considered suitable and free from bacterial contamination except from sources where *Escherichia coli* were detected as indicated in Table 5. Coliforms are a type of naturally occurring bacteria that are utilized as a sign of the presence of other, possibly dangerous bacteria. *Escherichia coli* detected in water sources from Chamkoloma, Mbande and Ugogoni villages indicate fecal contamination discharged from animal and human wastes.

Table 2: Results for physical parameters from different sampling sites (n=150)

Date	Region	District	Village/ Street	Sampling point	Water Source	DO (mg/L)	BOD (mg/L)	pH	TDS (mg/L)	Turbidity (NTU)
21/8/2020	Dodoma	Kongwa	Ugogoni	Ugogoni BH	Bore Hole	3.55	1.91	8.28	255	2.28
22/8/2020	Dodoma	Kongwa	Chamkoloma	Dispensary DP	Spring	5.00	1.00	7.84	50	7.84
23/8/2020	Dodoma	Kongwa	Mbande	Juhudi SW	Bore Hole	5.90	1.12	7.08	590	7.57
23/8/2020	Dodoma	Kongwa	Mbande	Old Tank	Bore Hole	6.20	1.03	6.96	2000	0.47
24/8/2020	Dodoma	Kongwa	Hogolo	Ubenani	Bore Hole	9.62	0.52	7.36	962	0.80
28/8/2020	Iringa	Iringa DC	Luganga	Sedmentation Facility	River	8.71	0.61	6.29	80	1.22
28/8/2020	Iringa	Iringa DC	Luganga	Ilolo Mpya	River	8.00	0.59	6.26	85	31.60
29/8/2020	Iringa	Iringa DC	Magulirwa	Kibalali BH	Bore Hole	3.35	1.18	5.60	29	4.82
29/8/2020	Iringa	Iringa DC	Magulirwa	Katulika Spring	Spring	3.80	1.15	6.30	132	7.40
30/8/2020	Iringa	Iringa DC	Kaning'ombe	Kasela Spring	Spring	7.46	0.86	6.88	57	1.26
30/8/2020	Iringa	Iringa DC	Kaning'ombe	Primary School tap	Spring	4.52	1.08	5.80	45	9.31
31/8/2020	Iringa	Mufindi	Mbalamaziwa	Uvambe DP	Spring	5.46	1.20	6.96	30	9.70
31/8/2020	Iringa	Mufindi	Mbalamaziwa	Mama Ted	Well	6.90	1.02	6.08	636	24.40
02/9/2020	Iringa	Mufindi	Mabaoni	Sokoni DP/Main tap	River	7.48	0.90	6.93	60	2.10
02/9/2020	Iringa	Mufindi	Mabaoni	H/H shallow well	Well	4.28	1.09	4.40	111	4.52
03/9/2020	Iringa	Mufindi	Mapanda	Mkumbulu spring	Spring	5.23	1.10	5.45	13	1.95
03/9/2020	Iringa	Mufindi	Mapanda	Kiwanjani P/S BH	Bore Hole	3.68	1.16	6.00	21	9.32
					Mean	5.832	1.031	6.498	303.294	7.445
					S.E	0.467	0.076	0.228	124.799	2.060
					S.D	1.927	0.312	0.941	514.561	8.492

Source: Field data

Table 3: Results for chemical parameters from different sampling sites (n=150)

Date	Region	District	Village/Street	Sampling Point	Water Source	Calcium mg/l	Magnesium mg/l	Floride mg/l	Nitrate mg/l	Hardness mg/l
21/8/2020	Dodoma	Kongwa	Ugogoni	Ugogoni BH	Bore Hole	0.81	0.48	0.3	14.8	1.29
22/8/2020	Dodoma	Kongwa	Chamkoloma	Dispensary -DP	Spring	0.71	0.43	0.21	15.5	1.14
23/8/2020	Dodoma	Kongwa	Mbande	Juhudi SW	Bore Hole	0.76	0.45	0.11	14.2	1.21
23/8/2020	Dodoma	Kongwa	Mbande	Old Tank	Bore Hole	1.16	0.69	0.07	14.2	1.85
24/8/2020	Dodoma	Kongwa	Hogolo	Ubenani	Bore Hole	1.3	0.77	0.02	15.5	2.07
28/8/2020	Iringa	Iringa DC	Luganga	Sedmentation facility	River	0.81	0.51	1.01	0.01	1.71
28/8/2020	Iringa	Iringa DC	Luganga	Ilolo Mpya	River	0.78	0.46	0.89	149	1.24
29/8/2020	Iringa	Iringa DC	Magulirwa	Kibalali BH	Bore Hole	1.35	0.81	0.77	130	2.16
29/8/2020	Iringa	Iringa DC	Magulirwa	Katulika Spring	Spring	0.43	0.25	1.02	151	0.68
30/8/2020	Iringa	Iringa DC	Kaning'ombe	Kasera Spring	Spring	1.2	0.71	0.93	138	1.91
30/8/2020	Iringa	Iringa DC	Kaning'ombe	Primary School tap	Spring	0.45	0.42	0.79	165	0.87
31/8/2020	Iringa	Mufindi	Mbalamaziwa	Uvambe DP	Spring	0.74	0.44	0.9	167	1.18
31/8/2020	Iringa	Mufindi	Mbalamaziwa	Mama Ted	Well	0.55	0.37	0.67	145	1.12
02/9/2020	Iringa	Mufindi	Mabaoni	Sokoni DP/Main tap	River	0.41	0.60	0.84	16.5	1.01
02/9/2020	Iringa	Mufindi	Mabaoni	H/H shallow well	Well	0.53	0.48	0.15	10.5	1.01
03/9/2020	Iringa	Mufindi	Mapanda	Mkumbulu spring	Spring	0.44	0.39	0.46	13	0.83
03/9/2020	Iringa	Mufindi	Mapanda	Kiwanjani P/S	Bore Hole	0.61	0.47	0.33	14.3	2.08
					Mean	0.767	0.513	0.557	69.029	1.374
					S.E	0.075	0.037	0.088	16.927	0.117
					S.D	0.311	0.152	0.364	69.793	0.4830

Source: Field data

Table 4: Microbial most probable number test results

Date	Region	District	Village/Street	Sampling point	Water Source	Presumptive test	*Erscherichia. coli* test	Fecal coliform test	Total coliform test	Remarks
21/8/2020	Dodoma	Kongwa	Ugogoni	Ugogoni BH	Borehole	+	+	+	+	E. coli, FC
22/8/2020	Dodoma	Kongwa	Chamkoloma	Dispensary -DP	Spring	+	+	+	+	E. coli, FC
23/8/2020	Dodoma	Kongwa	Mbande	Juhudi SW	Borehole	+	+	+	+	E. coli, FC
23/8/2020	Dodoma	Kongwa	Mbande	Old Tank	Borehole	-	-	-	-	NFC
24/8/2020	Dodoma	Kongwa	Hogolo	Ubenani	Borehole	-	-	-	-	NFC
28/8/2020	Iringa	Iringa DC	Luganga	Sedmentation facility	River	-	-	-	-	NFC
28/8/2020	Iringa	Iringa DC	Luganga	Ilolo Mpya	River	-	-	-	-	NFC
29/8/2020	Iringa	Iringa DC	Magulirwa	Kibalali BH	Borehole	-	-	-	-	NFC
29/8/2020	Iringa	Iringa DC	Magulirwa	Katulika Spring	Spring	-	-	-	-	NFC
30/8/2020	Iringa	Iringa DC	Kaning'ombe	Kasela Spring	Spring	-	-	-	-	NFC
30/8/2020	Iringa	Iringa DC	Kaning'ombe	Primary School tap	Spring	-	-	-	-	NFC
31/8/2020	Iringa	Mufindi	Mbalamaziwa	Uvambe DP	Spring	-	-	-	-	NFC
31/82020	Iringa	Mufindi	Mbalamaziwa	Mama Ted	Well	-	-	-	-	NFC
02/9/2020	Iringa	Mufindi	Mabaoni	Sokoni DP/Main tap	Ruaha river	-	-	-	-	NFC
02/9/2020	Iringa	Mufindi	Mabaoni	H/H shallow well	Well	-	-	-	-	NFC
02/9/2020	Iringa	Mufindi	Mapanda	Mkumbulu spring	Spring	-	-	-	-	NFC
03/9/2020	Iringa	Mufindi	Mapanda	Kiwanjani P/S BH	Bore hole	-	-	-	-	NFC

Key: (+) Positive, (-) Negative, FC: Fecal Contamination, NFC: No Fecal Contaminant
Source: Field data

Table 5. Status of water physical-chemical parameter in the three study districts

Parameter	Source category	N	Value ($\bar{x}$ +0.01)	Min	Max	WHO Guide value
pH	All	17	6.29	5.43	7.28	6.5–8.5
	A	6	6.88	5.60	8.28	6.5–8.5
	B	2	5.24	4.40	6.08	
	C	6	6.54	5.45	7.84	
	D	3	6.49	6.26	6.93	
Total dissolved solids (TDS) (mg/L)	All	17	286.45	51.25	713.25	300
	A	6	642.84	21	2000	300
	B	2	373.50	111	636	
	C	6	54.50	13	132	
	D	3	75.00	60	85	
Turbidity (NTU)	All	16	10.44	2.09	18.76	5.0
	A	6	4.21	0.47	9.320	22
	B	2	14.46	4.52	24.40	100
	C	6	6.24	1.26	9.70	60
	D	2	16.85	2.10	31.6	100
Calcium (mg/L)	All	17	0.72	0.50	0.98	75
	A	6	1.00	0.61	1.35	75
	B	2	0.54	0.53	0.55	
	C	6	0.66	0.43	1.20	
	D	3	067	0.41	0.81	
Magnesium (mg/L)	All	17	0.51	0.38	0.65	50
	A	6	0.64	0.45	0.81	50
	B	2	0.43	0.37	0.48	
	C	6	0.44	0.25	0.71	
	D	3	0.52	0.46	0.60	
Fluoride (mg/L)	All	17	0.58	0.31	0.87	1.50
	A	6	0.27	0.02	0.77	1.50
	B	2	0.41	0.15	0.67	
	C	6	0.72	0.21	1.02	
	D	3	0.91	0.84	1.01	
Nitrate (mg/L)	All	16	75.65	13.55	147.75	50.0
	A	6	33.83	14.2	130	50.0
	B	2	77.75	10.5	145	
	C	6	108.25	13	167	
	D	2	82.75	16.5	149	
Hardness (mg/L)	All	17	1.32	0.98	1.73	100
	A	6	1.78	1.21	2.16	
	B	2	1.07	1.01	1.12	
	C	6	1.10	0.68	1.91	
	D	3	1.32	1.01	1.71	

Water source type A: Bore hole B: Well, C: Spring and D: River
Source: Field data

5. Conclusions and recommendations

This study assessed the physical-chemical and microbiological quality of several sources of water that villagers use for drinking in Iringa rural, Kongwa, and Mufindi districts. The study provides baseline information on the quality of drinking water at the village level. With certain notable exceptions, drinking water sources have a good chemical quality when it comes to physical-chemical criteria in most study villages. However, some villages' recorded higher pH and nitrate levels, as well as turbidity and *Escherichia coli* identified have raised water quality concerns that are significant to exacerbate the occurrence of waterborne diseases, which affect the health of the local community. Due to that, we argue to address the observed water quality challenges, it is vital to encourage local community to harvest rain water as an alternative sources of domestic drinking water, ensure treatment or boiling of household drinking water to reduce microbial contaminations as well as to perform regular water testing, monitoring of water quality at the source, treating source points, and providing education about caring and protection of water sources to the communities surrounding the different water sources and water catchments areas at the village level.

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