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Public Water Supply and Sanitation Authorities for Strategic Sustainable Domestic Water Management. A Case of Iringa Region In Tanzania

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Abstract: Water supply is a mandatory service for the majority from respective legal public water utilities, and its sustainability reflects implementations of best management strategies at a local level. The objectives of this study were (i) to assess current approaches used in water quality and quantity management and (ii) propose a sustainable domestic water management strategy. This was achieved through secondary water data trends, on-site water quality assessments, visits of water supply and sanitation authorities, and assessment of their performances. It was observed that water supplied in rural-based authorities was quite different from that supplied in an urban setting as far as quality and quantity are concerned; urban-based supplies are more affordable to users than rural ones. A new strategy on water management is presented for sustainable water supply; it is based on controlling groundwater abstractions and preference of surface water in public water supplies. Rural water supply management must learn several practices realized in urban supplies for the betterment of services for the majority of the users.

Keywords: community-owned water supply organization (COWSO); domestic water management strategy; water quality; water quantity; water supply and sanitation authority (WSSA)

1. Introduction

Globally, water is considered to be conserved by the hydrological cycle [1,2] and covers 75% of the planet earth, in which only 2.5% is freshwater [3]. The freshwater portion under the conservation concept is rather diminishing, i.e., 80% of wastewater is globally not treated, and only 10% is treated efficiently [4], due to increased demand through global population growth over time [5,6]. Major sectors that are essential for economic growth are agriculture, industries, and domestic water supplies [7,8]. Apart from stable ice-locked water and paleo-groundwater, freshwater flows and their interactions within the hydrologic cycle do not guarantee availability at their origin points, i.e., uneven distribution [9,10]; consequently, freshwater becomes scarce [2,11–13] and a common good [14] where businesses intervene [15–17]. While all countries are trying to account for the freshwater sustainability dilemma [18–23], international policies favor virtual water exploitation as all countries are relatively economically interdependent [24–27].

Like other countries, Tanzania is also facing a similar situation [28], where the agricultural sector is the backbone of the country's economy [29–33], supporting 80% of Tanzanians' occupations and 95% of food [34–36]. Freshwater use has been given first priority for basic human needs under domestic water supply [37], and the environment receives second priority, but other sectors,

including agriculture, are periodically given other priorities based on their real-time socioeconomic significance [38]. Even with firsthand prioritization of water for domestic use, many Tanzanians receive limited freshwater due to poor water resource management [39,40]. While many water sources used for domestic water supply become insufficient due to poor management, it has been a common practice to seek alternative water sources to supplement the existing ones. This idea threatens the second water priority of the environment over domestic favor, leaving agriculture, together with other sectors, to experience the worst scenario. Many successful water supply projects are utilizing fresh surface water sources over gravity-driven water supply, but when this option is not available in other communities, the pumping of either available ground or surface water sources is preferred. Unfortunately, the cost for supplied, treated, and electrically pumped water is unbearable to low-income individuals residing in rural settings [41].

Water quality is another criterion for freshwater source suitability in domestic use. Currently, groundwater is largely preferred over surface water due to a general perceived good water quality [42,43], regardless of the potential existence of chemical pollutants [44–47]. Since much effort is devoted to fresh surface waters, no attention in Tanzania laws and policies on the promotion and regulation of groundwater use have been effectively emphasized [48]. Thus, it has become a common practice where those who can afford to drill have legal and illegal access to groundwater, irrespective of critical issues, such as compromising aquifer composition and content leading to groundwater pollution, as well as overexploitation that mismatches recharge rates [49]. Since surface and ground waters are greatly interrelated [50], it is meaningless to solely put efforts on surface water source management. Furthermore, it has been evident that groundwater is greatly advocated for agricultural practices [51–54], which makes freshwater vulnerable to pollution and overexploitation, as contrasted from the water resource use priorities by [38].

Rainwater harvesting is a mature technology used for sustaining agricultural activities [55], but due to an increased freshwater crisis, it is currently receiving a lot of credit as a potential alternative and as a management strategy for sustainable water supply [56–58]. However, since it is not available to all places during the entire rainy season and due to the fact that it is vulnerable to pollution [59], it cannot reliably and exclusively be preferred in all areas with freshwater demands. Hence different management approaches that can supplement it and other sectors in a sustainable manner must be explored and implemented accordingly.

This paper explores public water supply and sanitation authorities as a management strategy for freshwater resources. The management concept is clearly addressed in terms of water quality and quantity aspects using the Iringa region in Tanzania as a case study. It is anticipated that, when this option is taken into consideration by relevant regulatory bodies under respective policies and regulations, it will be a potential preference in the toolbox towards better management of freshwater resources for integrating sectors and enable them to operate sustainably.

2. Materials and Methods

2.1. Study Area

This section provides an overview description of the Iringa region (Figure 1), which is located between 7.77° S and 35.69° E of Tanzania's southern highland zones. Dodoma and Singida regions are surrounding the northern part, Njombe (formerly being part of the Iringa region) in the south, Morogoro in the east, and Mbeya to the west. Iringa, with an area of about 36,000 km^2 has four administrative districts, i.e., Iringa Municipal, Iringa Rural, Mufindi, and Kilolo, with a total population of about 151,000. Water demands in the region are extremely high due to agricultural activities being dominant and accounting for 85% of the region's gross domestic product (GDP). Water scarcity in this region with many water resources has attracted many research studies and water supply project developments. The availability of newly developed water supply projects under several funders was the reason for its case study suitability. Furthermore, most localized water projects (at community

level) with at least chlorination treatment practices are available in the region and account for its exclusive study area suitability that reflects future implications on clean and safe water provision for all. This reflected an operational and functional performance reality that relates to the potential opportunities for water management strategies in Tanzania.
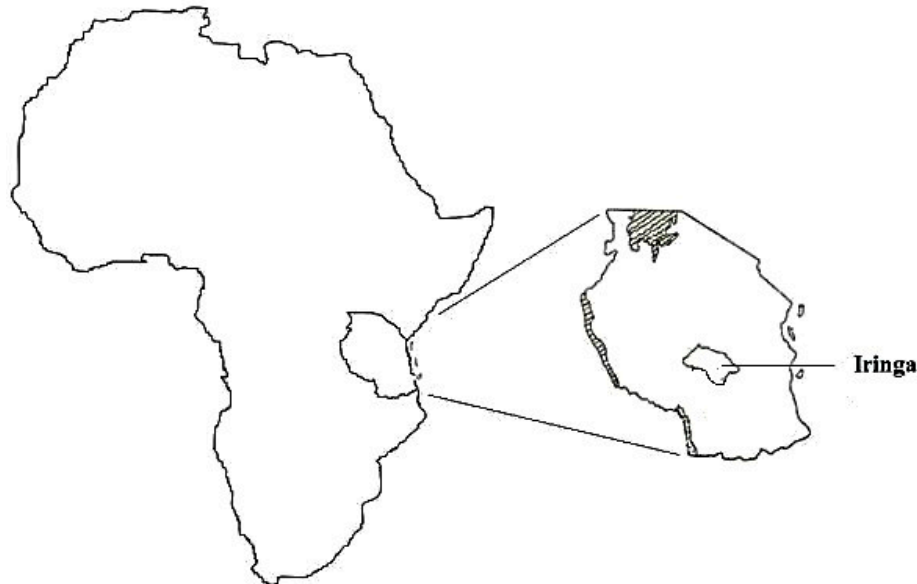
Figure 1. A Sketch map showing the Locality of the Iringa region (Modified from [60]).

2.2. Water Quality

2.2.1. Water Quality Assessment—Heavy Metals

Sixteen (16) heavy metals i.e., aluminium, arsenic, barium, cadmium, chromium, cobalt, copper, iron, lead, manganese, mercury, molybdenum, nickel, selenium, silver, and zinc were analyzed by an inductively coupled plasma (ICP) in raw and treated water samples from Little Ruaha River, which is the major source of public water supply in Iringa Municipality. Other samples analyzed were from Kibwabwa Borehole and Kitwiru spring, which altogether supplement the Iringa Urban Water Supply and Sanitation Authority (IRUWASA) supply. All water quality samples were collected, preserved, and analyzed according to the standard method for the examination of water and wastewater [61].

2.2.2. Water Quality Trends

Secondary data from Iringa Water Quality Laboratory (IWQL) database were used to study the long-term (2015 to 2018) behavior of surface (rivers, streams, dams, ponds, wetlands, and wastewaters) and ground (deep wells, shallow wells, and springs) water qualities across the Iringa region. These data were mostly based on monthly and quarterly water quality monitoring programmes, although semi-annual and annual monitoring programmes were also considered. All data within the study period were entered in an excel spreadsheet and manipulated for comments using "IF" function to provide the complying and noncomplying status of all considered water sources. Unlike complying samples, where only the "complies" status was provided by the function, noncomplying comments were further identified by a respective out of range parameter. Noncomplying physico-chemical and microbial parameters were used for trend analysis, whereas parameters that consistently complied with available national guidelines [62] for the trend period were not considered. Seasonal variations (dry and wet) were also taken into consideration for the entire trend. Trend analysis was realized from yearly plots of nonqualifying water quality parameters for the considered period.

2.2.3. Water Quality Perception

During site visits, ten (10) people from the management and technical part of the Water Supply and Sanitation Authority (WSSA) staff, including public kiosk operators, as well as twenty (20) people from the majority of water users were formally requested to provide their water quality perception based on daily water use experience from each of the eleven (11) visited WSSAs. The following questionnaires were restricted to three hundred and thirty (330) participants: (i) What do you consider as an indicator for quality water? (ii) Is it worth to treat polluted water for domestic uses? (iii) How do you feel about using chlorinated water? Comments were noted concerning available treatment practices and seasonal variation issues. Data were analyzed using an excel spreadsheet with the help of a word analyzer programme during coding of observed responses for statistical treatment.

2.3. Water Quantity

Assessment of WSSA Current Practices

Study area visits were implemented over 11 WSSAs (one municipal/urban, three small town/district, and seven rural-based community owned water supply organizations—COWSO), where information regarding population served, treatment practices, number of meters/private connections, water use tariffs, and payment modalities (e.g., flat rate or as per quantity consumed) were captured in relation to water management strategies.

3. Results and Discussion

3.1. Limitation of the Study

Several observations were noted to have a potential influence on this study; they included using secondary water quality data from a competent laboratory. Here, qualification and disqualification of water samples were based on East African potable water standards, which could be different from other country's guidelines. Furthermore, the case study is characterized by many surface water sources, whereas other regions with drought dominance may lack representations, especially in the water quality section, which can be characterized in a different manner than the one presented herein. The heavy metal assessment was done only at the urban-based water supply authority due to analytical cost implications; rural-based supplies were not accomplished in this case and could have established another compelling relationship. Rural based supplies selected in this study were based on recently developed projects (≤1 year), which could have presented unique information compared to old projects that still operate at the same level and locality; their selection was also a function of availability of a treatment practice, i.e., chlorination.

3.2. Quality Aspect

3.2.1. Water Testing

Privately Owned Water Sources

The concept behind WSSA as a water resource management strategy extends itself to quality issues that strictly define the suitability of any secured freshwater source for domestic use. Currently, all WSSAs in Tanzania are legally established and recognized by [63] as an amendment of [64], which continues to address internal and external requirements on regular water quality monitoring. Thus, water supplied by these entities is of known quality, which is accountable for public health protection. In urban settings, water supplies are perceived to be relatively expensive compared to rural areas, which is due to multi-step treatment expenses of polluted surface water sources from rivers and streams. Individuals and institutions that are financially sound tend to opt for user permits over deep groundwater sources as they are economically feasible to operate once established. Furthermore,

their quality is observed to be superior when compared to treated surface water supplies, which are believed to contain residual treatment chemicals that could affect people's health. The majorities with limited financial capacities are also interested in shallow groundwater sources; fortunately, [65] has a free of permit room for individuals utilizing groundwater within a few meters deep. Individuals and institutions located far from WSSA networks usually secure their permitted water from nearby running surface waters, and/or groundwater abstractions. However, almost all of these privately owned water sources are not tested and or monitored for water quality status in their entire operational periods; in rare cases, a water test is realized only when it is a regulatory requirement that is accompanied by an inspection from a compliance body.

What is urged here is that water quality tests are too technical and very expensive among privately owned water users. Furthermore, Tanzania's government has only sixteen (16) regional water laboratories for this task; thus, it becomes even more expensive to arrange the necessary logistics for remote and on-site testing, including transport and technical staff per diem [66]. The following are technical suggestions, based on water quality assessment experience, towards alleviating unnecessary setbacks, and thus, facilitating convenient and smooth water testing means for all privately owned water sources:

○ Water samplings are greatly emphasized at sources or intakes rather than existing domestic points. It takes a long time to visit remote surface water source intakes for the same water available near residential or easily accessible areas. Besides, it presents increased cost (e.g., per diem) to the technical staff during monitoring sessions, which private water source owners find higher than the analysis cost. Thus, samples shall only be taken at point of use, and for a new source, the closest downstream point shall be preferred as its quality would be a representative of the source intake to a large extent, unless a point source of pollution is identified to interfere.

○ Water sampling and preservation prior to laboratory conveyance for microbial assessment shall be taken by private water source owners using guidelines presented by [67]. Glass bottles that require an autoclave for sterilization can be replaced by locally sold bottled water, as their cleanliness is assured by good manufacturing practices and regular factory and market monitoring by legal Tanzania quality regulatory bodies.

○ Water quality testing laboratories should be simpler and less costly through the concept presented by [68], where electric conductivity (EC) shall be the basis of omitting unnecessary chemical parameters that could only increase analytical expenses, which is a burden and one of the critical reasons as to why the majority do not prefer water testing.

Publicly Owned Water Sources

While WSSAs are strictly obliged to test and monitor their water quality supplies, rural-based WSSAs with limited financial and analytical technical capabilities are experiencing a similar scenario comparable to that of privately owned water sources. Thus, solutions presented for privately owned water sources on enhancing regular water quality testing following proposed cost-effective sampling in 3.2.1.1 above can be adopted here. Unlike privately owned water sources, WSSA legal water quality compliances are required for reporting to the respective regulatory authority, i.e., The Energy and Water Utilities Regulatory Authority (EWURA). The current paradigm of respective WSSAs to directly report on EWURA is questioned based on regular EWURA monitoring programs, the results of which are quite different from regularly reported trends by most WSSAs [69]. There are possible incidences where results are directly entered over online platforms, even without realizing any water quality monitoring programme. In order to avoid this, analytical results shall be directly entered by a respective water quality laboratory that executed the analytical task, and the same should be declared if not done. Furthermore, since compliance is an issue here, WSSAs implementing the proposed privately owned water sources sampling option shall be accompanied by another legally accountable and nearby available qualified staff (e.g., regional, district, and/or town environmental/water engineers, scientists, and technicians).

Currently, most WSSAs are implementing chlorination practices to publicly supplied water as a safeguard step against endemic diseases following recent cholera outbreaks throughout the country [70,71]. However, majority citizens utilizing such treated water are complaining about this new chemical that has been added to their historically pristine domestic water, and they claim it to be unbearable to use (see Figure 2). Complaints observed include bad water taste, that it is believed to have been established for birth control by destroying male reproductive systems, and carcinogenic upon prolonged use. The main reason arises from all WSSAs (except IRUWASA) having only taken the chlorination step towards treatment, and the fact that gravity-based water supplies have an uncontrolled water flow rate, thus, manual chlorine set doses becomes sporadically unstable. Higher flows are noted at night and morning with relative clear waters, whereas low flows are noted during the day and evening, with higher turbidities (mostly due to involvement of water for agricultural activities upstream). Thus, chlorine demand dramatically changes in response to these changes, thereby exposing domestic water users to extreme events of high and low chlorine doses. With these constraints, many WSSAs are unofficially opting to reduce chlorine set doses, while others prefer not to use it at all for the sake of political issues and the majority of water users' reactions. Thus, the aims of establishing chlorination treatments are compromised, and a sustainable solution is urgently required on this matter.
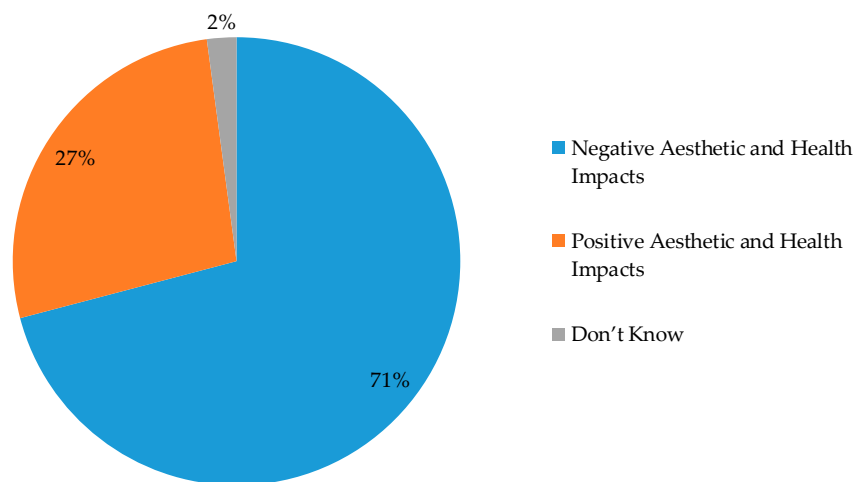
**Figure 2.** Water quality analysis by perception.

3.2.2. Water Quality Trends

In all water quality trend plots (Figures 3–6), groundwater is observed to have a lesser number of samples and, hence, a low number of nonqualifying parameters compared to surface waters. Limited groundwater samples are attributed to privately owned boreholes that are negligibly tested for water quality; the few groundwater sources noted are due to regulatory requirement assessments over several private companies that usually require compliance confirmation to their accrediting organizations. Parameters noted to exceed in groundwater sources were mostly the same for surface water sources, although several unique parameters existed for each source. While the wet season was observed to have a dilution effect on groundwater sources by presenting less nonqualifying parameters, as contrasted by their dry season statistics, surface water sources are characterized by high nonqualifying parameters during the wet season due to interaction with mostly terrestrial rain surface run-off. Useful information obtainable from these plots includes:

i. Microbial quality: Most groundwater sources present limited microbial pollution in both seasons, but surface water sources guarantee microbial contamination in both seasons. Current water quality practices are emphasizing efforts to assess microbial quality in new and developed sources, and while these parameters require strict analytical precautions, it can be concluded

that they are of no importance to their analysis in surface water sources (unless it intends to assess a microbial treatment practice efficiency), but rather significant in groundwater sources. Many water supply projects are constantly established based on funds and funder's availability. Hence, when surface water sources are preferred, efforts on microbial assessment should be avoided, and treatment practices should be a mandatory part of the project infrastructure. State monitoring programmes that realize on-site water quality assessment can omit microbial analysis in untreated surface water sources/supplies as it increases complications, while the reality is always valid for this source category being vulnerable and containing contaminants.

ii.   The trend shows the dominance of certain parameters in either surface or groundwater sources. Since regional water quality laboratories are focusing on their legal sphere of services and the fact that they aim to be accredited, it can be concluded that such laboratories better focus on accrediting respective nonqualifying parameters as a basic criterion. Furthermore, heavy metal assessments can be preferred over most qualifying parameters when there is a limited analytical scope coverage window.
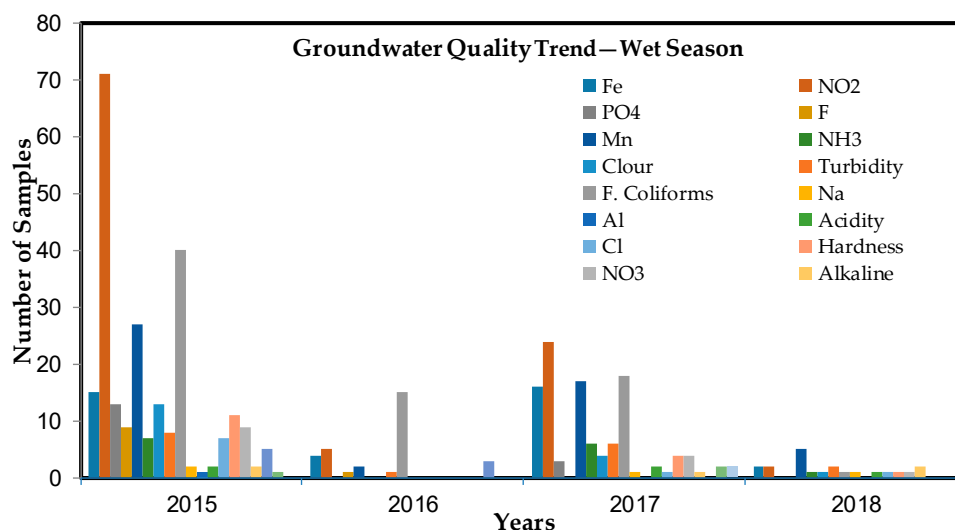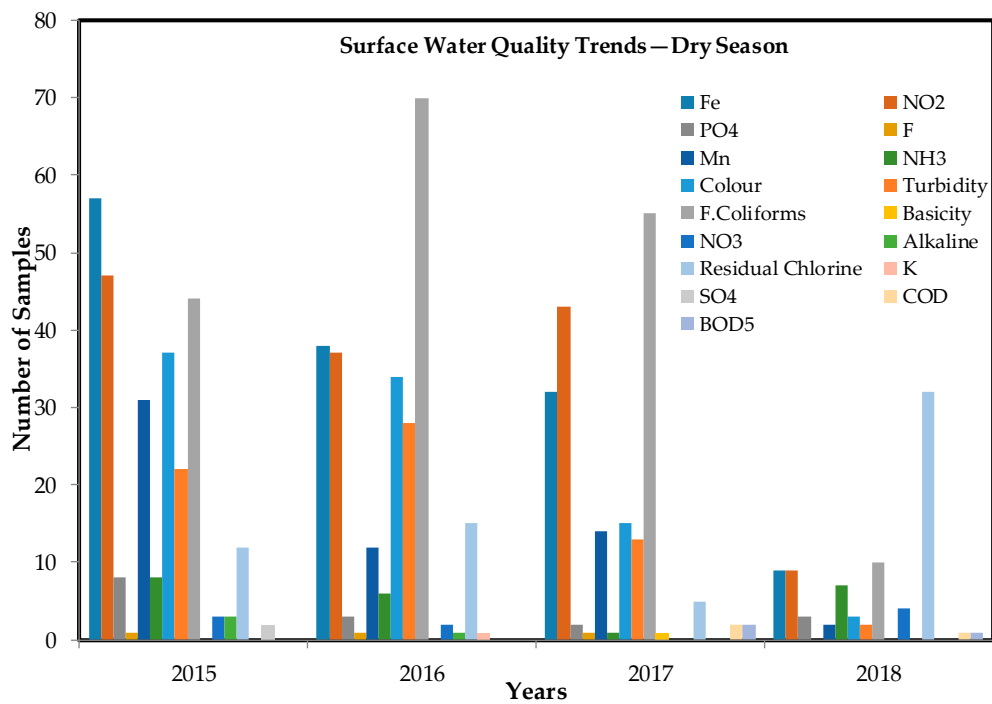

Figure 3. Groundwater quality variations during wet season from 2015 to 2018 (number of nonqualifying parameters, *n* = 19).
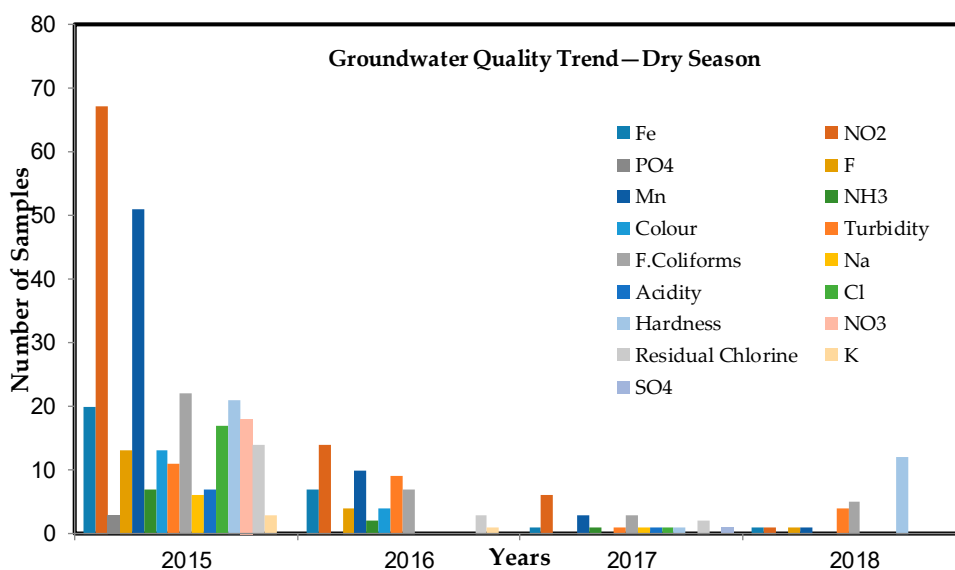
Figure 4. Groundwater quality variations during dry season from 2015 to 2018 (number of nonqualifying parameters, *n* = 17).
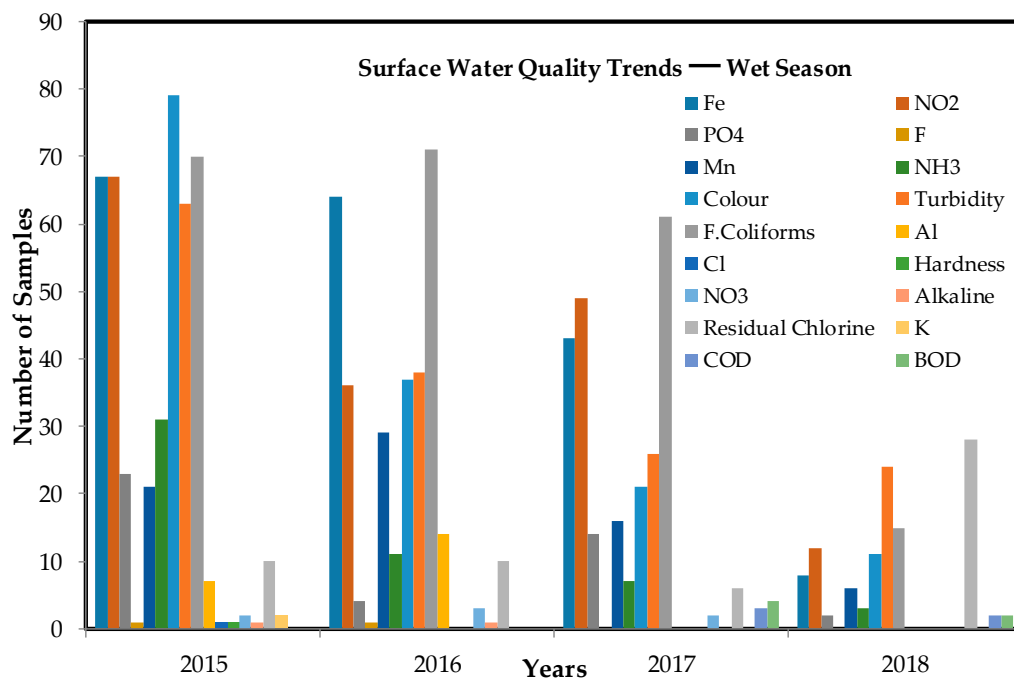
Figure 5. Surface water wuality variations during wet season from 2015 to 2018 (number of nonqualifying parameters, *n* = 18).

Figure 6. Surface water quality variations during dry season from 2015 to 2018 (number of nonqualifying parameters, *n* = 17).

3.2.3. Water Quality Remediation Practices

Heavy Metal Issues

Irrespective of any domestic water source origin (ground or surface; public or private), good quality is a prerequisite criterion due to its suitability conformity. Heavy metals are encountered in environmental settings due to their geological conservation; thus, groundwater sources are vulnerable to a large extent. On the other hand, human development has encouraged heavy metal contamination in water sources in a number of ways, these include (i) fertilizer application in irrigation water that interacts with aquifers or becomes transported downstream where domestic applications are realized, (ii) rainwater harvesting through various roof materials, and (iii) corrosion of metallic-based water supply networks [72]. The Ministry of Water [67] demonstrated the significance of assessing heavy metals due to their increasing impacts on public health [73–75]. Similar to other chemical pollutants, heavy metals are bioaccumulated in body tissues and will present their effect at chronic levels [76]. Table 1 shows the status of heavy metals in different sources based on IRUWASA-tested water sources.

Table 1. Heavy metal concentration (mg/L) in different water sources supplied by IRUWASA.

S/N	Parameter	Raw Water at Little Ruaha River	Borehole at Kibwabwa	Springwater at Kitwiru	Treated Water *
1	Aluminium	0.000	0.000	0.000	0.004
2	Arsenic	0.000	0.000	0.000	0.000
3	Barium	1.000	0.000	1.000	0.000
4	Cadmium	0.010	0.000	0.030	0.010
5	Chromium	0.000	0.000	0.000	0.000
6	Cobalt	0.410	0.000	0.320	0.000
7	Copper	0.000	0.010	0.000	0.010
8	Iron	0.100	0.010	0.030	0.020
9	Lead	0.002	0.000	0.004	0.000
10	Manganese	0.025	0.007	0.045	0.000
11	Mercury	0.001	0.000	0.000	0.000
12	Molybdenum	0.010	0.090	0.050	0.010
13	Nickel	0.000	0.034	0.147	0.000
14	Selenium	0.005	0.001	0.042	0.000
15	Silver	0.020	0.000	0.000	0.000
16	Zinc	0.050	0.000	0.030	0.000

* Treated water is a blend of (i) treated Little Ruaha River water, 85%, (ii) springwater, 14%, and (iii) borehole water, 1%.

Heavy metal results with 0.000 mg/L concentration were implied to be below the analytical detection limit. The concentration of heavy metals followed the order of raw water from Little Ruaha river > spring water > borehole >>>> treated water. Since the high volume of treated Little Ruaha raw water contributes much to final blended water, it was observed that treatment practices employed to eliminate higher river water turbidities (coagulation–flocculation and sedimentation) were also responsible for concurrent elimination of heavy metals [77]. Thus, it can be noted that, while IRUWASA is struggling with turbidity elimination using flocculants, they also realize heavy metal remediation from the same water. Furthermore, when this water (85%) was mixed with that of spring (14%) and borehole (1%), which contained higher levels of several heavy metals, it resulted in an overall dilution effect and the new blended water was characterized with less to no detectable heavy metal content. While it has been observed as a curse for many WSSAs in Tanzania to encounter very turbid raw water sources, it is now an advantage, as making this water clear makes it free from heavy metals, too.

Disinfection By-Products (DBPs) Issues

Chlorination is a mandatory treatment stage for many water supply schemes in Tanzania, regardless of any pretreatment means, such as water clarification from high turbidity values. Even in advanced treatment practices that involve turbid water clarification prior to chlorination, organic flocculant residuals play a vital role in the formation of DPBs [78]. However, with such an observation, many remediation approaches are suggested for combating DBP issues: membrane technique is an excellent [79], two-stage or standard treatment, contrasted by rapid [80] in WSSA implementing clarification processes that reduce DBP levels. However, the common and affordable method is household boiling of treated water meant for drinking (Table 2).

Table 2. DBPs (regulated trihalomethanes, THMs) remediation by boiling drinking water.

S/N	DBP Species	Efficiency (%)	Reference
1	Chloroform (TCM)	69–97	[81–83]
2	Bromodichloromethane (BDCM)	68–98	[81–83]
3	Dibromochloromethane (DBCM)	51–100	[81–83]
4	Bromoform (TBM)	40–100	[81–83]
5	Sum of 4 THMs (THM4)	40–98	[81–83]

A variation on DPB decrease efficiency was attributed to different boiling appliances in all experiments within five minutes. Useful information in these observations is that, while the state recommends chlorination practices to all public water supplies in favor of preventing endemic disease eruption, individuals can avoid any potential health impact (especially for children and pregnancy) due to DBPs by boiling such water meant for drinking.

3.3. Quantity Aspect

Available water resources (ground and surface) experience deteriorating trends, which threatens their reliability because (i) flows across rivers and streams have shifted from continuous to seasonal, and are characterized by rapid drying; (ii) springs that present declined discharges due to dry up affect water resource availability; (iii) groundwater from boreholes have diminished discharges and recharge rates; and (iii) wetlands become overexploited and severely polluted. Climate change, coupled with global overpopulation, is the main reason for observed water resource behaviors [84–86].

3.3.1. Groundwater

Tanzania has more than 47 known private groundwater drilling companies [87] that competitively provide relatively affordable services compared to the government Drilling and Dam Construction Agency—DDCA. While DDCA has a remarkable record of this service (Table 3), it can be concluded that groundwater has been adversely exploited under the operation of these companies that stick to profit maximization. In this case, groundwater quantification and, hence, accountability as a water resource becomes poorly managed. Water use permits that are legally granted by a country's water boards have not been successful, as most private companies and clients on drilling normally find this step a setback. Therefore, the many boreholes reported to have been drilled are not reflective of the reality, and many water users are abstracting groundwater without any plausible use control. The government of Tanzania, through the ministry of water, should consider the identification of such illegal drilled boreholes and account for them in available water sources and revenue channels for the promotion of equitable water utilization among the country's dwellers.

Table 3. Boreholes and their yields from 1999 to 2015 (modified from [88]).

Financial Year	Successful Borehole	Average Yield per Borehole per Day (m³/d)	Total Yield per Day (×10³ m³/d)
1998/1999	427	163.44	69.8
1999/2000	503	120.24	60.5
2000/2001	352	179.04	63
2001/2002	331	140.88	46.6
2002/2003	358	123.12	44.1
2003/2004	417	136.32	56.8
2004/2005	423	123.45	52.2
2005/2006	401	150	60.2
2006/2007	401	242.13	97.1
2007/2008	419	228	95.5
2008/2009	380	133.8	50.8
2009/2010	254	142.10	36.1
2010/2011	219	102.00	22.3
2011/2012	226	249.3	56.3
2012/2013	205	137.66	28.2
2013/2014	116	142.95	16.6
2014/2015	285	166.85	47.6
Total	**5717**	**2681.28**	**903.7**

For the past 17 years (1999 to 2015), DDCA was able to accomplish 5700 boreholes in Tanzania with an average of 86% success rate, capable of providing 903,700 m³/d yields. It was declared that 27 L to 200 L per capita per day (0.027 m³/d to 0.2 m³/d) are required for drinking, sanitation, cooking, and bathing [89]. Currently, there are about 61,000,000 Tanzanians [90], whom altogether would require a total of 1,647,000 to 12,200,000 m³/d freshwater. Thus, an average of 6,923,500 m³/d freshwater is required to sustain the current daily demand. As of 2005, the Ministry of Water had a database of 9242 drilled boreholes [91], in which DDCA contributed 2811 (30.4%), since private drilling companies are preferred by individuals due to their affordability (which is also suspected to affect the quality of the work). Thus, at least each year, a total of 1320 boreholes are accomplished (even though [91] determined an annual requirement of at least 1600 boreholes drilling). Using such an estimation for the period of 1999 to 2018, at least 26,406 boreholes are available in Tanzania. In fact, as of 2009, private enterprises contributed about 9000 boreholes from Dar es Salaam city alone [92]. Since boreholes are drilled to operate for 20 years to 50 years [93], then a total of 4,174,060 m³/d is obtainable and capable of satisfying more than 60% of current freshwater demands for all Tanzanians. This estimate excludes shallow wells and unreported boreholes, which significantly contribute to the water supply sector; in this case, 25% reported as a contribution of boreholes in the domestic water supply [94] is rather due to poor management of abstracted groundwater.

During site visits, many hotels, lodges, and guest houses were characterized by the possession of boreholes as a secondary water source, i.e., in addition to the one supplied by WSSAs; however, such groundwater sources were significantly preferred over public water supplies, as they could meet customer requirements at an affordable cost. It was observed that individual guests were utilizing more water under the claim that they pay for it. Thus, groundwater resources are inequitably accessed by many Tanzanians in the business intervention model. Furthermore, since only WSSAs are legally permitted to realize water supplies, many individuals with private wells are unofficially doing the same under civilian support. The worst scenario arises from the government's (Ministry of Water) recent statement over an intention for the authorization of free groundwater access for household use. Thus, it contradicts WSSAs and water basin supply businesses/fraud and revenue collection, respectively [48]. In fact, the majority preferred groundwater due to clarity issues, as WSSAs utilizing surface water sources are facing significantly inadequate supply and poor quality (e.g., very turbid water during rainy seasons; chemical residuals from treatment practices).

Thus, this paper suggests that no permits on groundwater abstraction shall be a setback in drilled and ongoing drilling business, but for each borehole there should be water abstraction control and charges by means of metering; well owners shall then not be prohibited from selling their water, but only the agreed price must be used and collected by the governmental control body (e.g., Basin Water Boards and WSSAs based on their legal spheres of influence). The same should be done to bottled water companies that maximize their profit on this common good. Groundwater abstraction for irrigation shall be exempted due to the fate of irrigation waters [95] and the significance of agriculture to the country's economy, unless aquifers get compromised in a defective manner that threatens domestic water supplies.

3.3.2. Surface Water

Generally, Table 4 shows that rural water supplies are costly compared to urban-based WSSA services. Furthermore, while public domestic point connections are aimed at serving many people at an affordable cost, the opposite is observed due to most points having higher or comparable costs to those of private-based points. These observations were attributed by many rural-based WSSAs ensuring the availability of funds for sustainable water supply operations; hence, relatively higher tariffs were to be subjected to the large public-oriented community. In fact, private connections are much preferred as their revenues are exclusively collected by WSSA management, whereas public connection requires a public kiosk operator who must receive a 20% to 50% share of the collected tariff.

Table 4. Water supply and sanitation authority (WSSA)/community-owned water supply organization (COWSO)'s current practices (as of April 2019).

S/N	WSSA/COWSO	Source	Supply Mode	Treatment Practices	Population Served	Connection		Tariff (TShs/m^3)	
						Public	Private	Public	Private
1	IIRUWASA—(M)	R, BH, and Sp	P	F, SF, C, and B	138,000	128	24,553	1000	1685–2035
2	Kilolo—(D)	St	G and P	C	28,000	70	724	1000	485
3	Mafinga—Smt	St and Sp	G and P	C	72,000	1	3768	500	790-930
4	Ilula—Smt	St	G	C	40,700	56	1186	1500–2500 1000^{FR}	500–600 5000^{FR}
5	Magubike—(R)	R	G	C	15,000	62	187	1500	1500
6	Ifunda—(R)	Sp	P	C	6000	20	5	2500	2000
7	Kidabaga—(R)	R	P	C	2300	13	40	2500	2500
8	Ng'uruhe—(R)	St	G	C	2900	48	78	2000^{FR}	5000^{FR}
9	Ihimbo—(R)	St	G	C	2700	18	66	1000	5000
10	Mgama—(R)	St	G	C	1000	17	110	1000^{FR}	1667^{FR}
11	Irindi—(R)	St	G	C	2400	16	27	1000	5000

M—municipal, (D)—district, Smt—small town, (R)—rural, R—river, BH—borehole, Sp—spring, St—stream, P—pumping, G—gravity, F—flocculation, SF—sand filtration, C—chlorination, B—blending, FR—flat rate tariff payment per household on a monthly basis (i.e., not TShs/m^3).

Water supply through pumping modes in rural areas had a higher tariff compared to rural gravity-based water supplies; in these WSSAs, water management is improved and financial collections reflect operation and maintenance expenses. On the other hand, gravity-based water supplies are facing difficulties in financial collections, as the majority of public water users take water for granted, and believe that operating costs are far lower than the current tariff. Hence, management of rural gravity-based water supplies become deprived and threaten the sustainability of these projects. Such management practices are further related to water loss in most parts of the supply network from these highly numbered gravity water supplies, causing loss of permitted water quantities for abstraction and subjecting downstream users to water scarcity vulnerabilities; the situation becomes worse in flat rate tariff-oriented WSSAs, where water management is extremely poor. Water treatment and supply modes presented by urban WSSA are relatively advanced and characterized by the highest operation costs, and yet the supplied water for town dwellers is relatively cheap compared to rural settings, so a lesson can be learned here and propagated in all rural-based WSSAs for effective safe water provision at an affordable cost.

Socioeconomically, an affordable tariff should consider good practices from mutual or integrated stakeholders' participation. It should include an application of water resources protection and enforceable pollution prevention environmental laws, backed up with quality management approaches [96]. To support such WSSAs in managerial and technical operating areas and tariff regulations, regulatory authorities that exercise multiple factors before authorization of a proposed tariff [97] should be employed. This should also reflect underlying circumstances in the consideration of water quality and quantity, and their associated treatment and supply modalities.

4. Conclusions

Generally, results show that the water supply sector in terms of quality and a quantity aspects is poorly addressed in regards to sustainable domestic water concepts. Systematic analytical approaches from this study suggest that water resources should be centralized to state governing bodies in terms of supply for surface and groundwater among all citizens. This will be achieved through policies, rules, and regulations under respective ministries, so that only public water supply and sanitation authorities are allowed to control domestic water provisions. In order to achieve this, the following will be put into consideration for the implementation of WSSAs as a national strategy for sustainable domestic water management:

○ Groundwater abstraction should be controlled through metering and, hence, charging a reasonable tariff that will consider owners of invested well infrastructure, who shall be permitted to sell such water to neighbors to enhance service, while controlling abstraction charges by respective WSSAs.

○ Treatment of turbid surface water sources should be preferred as the process concurrently eliminates heavy metals in the final water; furthermore, other polluted sources can be subjected to blending practices using treated water to reach acceptable final contaminant limits prior to supply.

○ Water quality assessment can be enhanced among private water source owners if water sampling is done by such an owner using a simplified procedure presented to them and a relevant state sampling protocol.

○ Rural-based WSSAs/COWSOs must learn and implement best practices from urban WSSAs who, irrespective of higher operation and maintenance expenses, still provide water to urban communities at relatively low tariff cost compared to rural water suppliers.

○ The diversity of water quality laboratories should be eliminated in order to improve management and minimize operations expenses while maximizing analytical capabilities. Only three to five fully furnished water laboratories are satisfactory in the country. This is possible if offices at regional and or district levels are established to facilitate in situ analysis of nonpreservable parameters and sample preservations for transportation to such designated laboratories.

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