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Seasonal Drinking Water Quality Monitoring for the Community Wellbeing in the Eastern Rwanda

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Abstract

The rapid population growth, climate change and inappropriate natural resources use and management are predominantly limiting the community's access to safe drinking water. This record is high in poor regions compared to developed countries due to lack of awareness and/or financial capabilities. The objective of this study was to compare changes on drinking water quality during dry and rain seasons for the quality management and community wellness. The measured heavy metals were Calcium, Iron, Manganese, Copper, Aluminium and Zinc between July 2016 and February 2017 in the Eastern province of Rwanda. The samples were collected from three sites randomly selected among the water sources available in the study area. The monthly water samples were analysed in the laboratory of the water treatment plants neighbouring each sampling site. The results showed higher values of heavy metals during the rainy season than that in dry season. The mean of Manganese (0.25, 0.25 and 0.19 mg/L) at all sampling sites exceeded the drinking water guidelines (0.1 mg/L) of the World Health Organization. In addition, it was noted that the mean of Iron (0.35 mg/L) and Aluminium (0.95 mg/L) at Nyagatare site was higher than the WHO standards, 0.3 and 0.1 mg/L for the Iron and Aluminium, respectively. Thus, to ensure safe drinking water, it is good to initiate the rain harvest, agroforestry and bench terraces approaches to minimize the runoff, envisage appropriate wastes and wastewater management, and to approach and involve the community in managing water sources.

Keywords

Drinking Water Quality, Heavy Metals, Water Sources, Eastern Rwanda

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1. Introduction

The access to safe drinking water is limited by various factors, especially the global warming, rapid human population growth, limited political and partnership willingness and community involvement, inappropriate wastes and wastewater management, housing style as well as the geographical location of the water sources [1-4]. These factors gradually limited access to safe drinking water from around 2.6 billion people in 1990 to 600 million people drinking water from unprotected sources in 2015 [5-7]. Although the problem is experienced worldwide, it heavily impacts on poor countries with high stress of water quality pollution and poor waste management compared to developed countries [8-11]. In addition, there is still huge inequality in accessing safe drinking water, and most of communities with limited access live in rural areas of the Sub-Saharan Africa [12-15]. Previous reports [10, 16-18] highlighted that the consumption of polluted surface and ground water may increase the number of non-carcinogenic and carcinogenic health effects due to high level of heavy metals concentration in the water.

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However, this is mainly recorded in poor countries where local community directly consume water from farm well, springs as wells as rainwater without prior treatment [12, 19]. In addition, industrial wastes and other anthropogenic inputs, particularly in highly populated areas greatly pollute water quality, due to limited financial capabilities and poor infrastructure, and this consequently, affects the health of water consumers who directly take water from its sources [20-23]. In Rwanda, there are abundant water sources, of the total area, lakes occupy about 128,190 ha, rivers seize approximately 7,260 ha, while 77,000 ha are occupied by marshlands along with about 22,300 springs [24-26]. The Government understands the role of water in community welfare and set out management measures, such as water treatment plants, buffer zones for a certain distance from water sources before any type of land use, integrated water resources management, etc., for sustainable use and management [21, 27, 28]. These initiatives led to increasing the proportion of people accessing safe drinking water from 23 to 54 percent in 1990 and 2015, respectively [29, 30].

Previous water quality related studies have been specific and considered seasonal water quality, to evaluate the changes on water quality per season [19, 31, 32] and such reports have been of great importance in indicating when much precautions on water quality management should be prioritized. Nevertheless, in Rwanda, previous studies [21, 33-35] have been case studies, on heavy metals or physico-chemical parameters measurement without considering seasonal changes. In defiance of water quality management policies suggested, there is still pollution likelihood primarily caused by rapid population growth, inappropriate land use and management, industrialization and urbanization, which may rise in future. Thus, this calls for urgent attention of policy makers and the community in understanding the role of water and to envisage appropriate protection measures for present and future benefits.

Furthermore, population growth, inappropriate human settlements and poor urban and industrial wastes and wastewater management, the cost of travelling to piped water, poor sewage systems, common use of public latrines and septic tanks along with the rainfall patterns facilitating easy loading of sediments and other pollutants into waters are among the key drivers to water pollution in Rwanda [33, 34, 36, 37]. Therefore, seasonal water quality assessment in Rwanda can be a good source of information for water resources managers, environmental health officers and the whole community, as far as much will be provided in terms of the period when strong policies are required for the water quality management between the rainy and dry seasons. Therefore, the objective of this study is to compare the status of drinking water quality between the dry and rainy seasons and suggest appropriate management policies.

2. Materials and Methods

2.1. Description of the Study Area

The Eastern Province of Rwanda occupies a total surface of 9,813Km^2 and is divided into seven districts namely: Bugesera, Gatsibo, Kayonza, Kirehe, Ngoma, Nyagatare and Rwamagana. The province is bordered by Uganda in North, Tanzania in East, Republic of Burundi in South, while in the West; it is bordered by the City of Kigali, Northern and Southern Provinces. The Eastern province is recognized by its richness in both surface and ground water resources and low rainfall frequency and intensity compared to other parts of the country [38, 39].

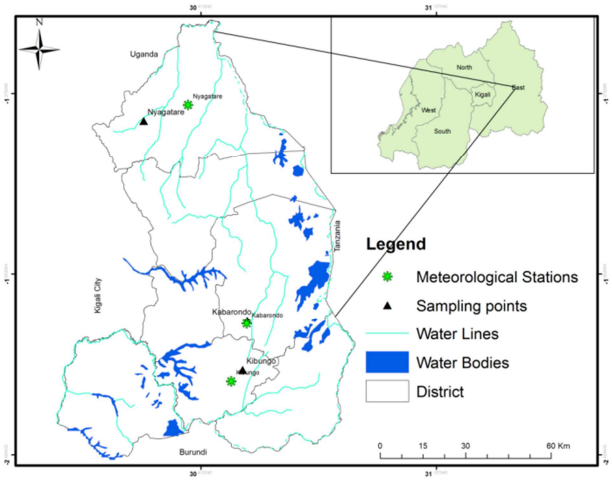

Figure 1. Map indicating the location of the study area, it water sources and the sampling sites.

2.2. Collection and Analysis of Water Samples

This study considered three sampling sites (Figure 1) collected from the Kabarondo, Nyagatare and Kibungo sites. This study used monthly collected water samples from July 2016 to February 2017. The authors conducted an extensive monthly water quality monitoring by measuring the concentration of heavy metals namely: Calcium (Ca), Iron (Fe), Manganese (Mn), Copper (Cu), Aluminium (Al), and Zinc (Zn). These heavy metals were sampled from three water sources randomly selected among the water sources (springs) available within and used for drinking water sources by the population of the study area.

The water samples were collected by using a Van Dorn Bottle water Sampler and analysed with standards methods, the common methods employed while measuring the physicochemical and heavy metals in water sources [40, 41]. After water samples collection, the analysis was carried out

in the laboratory of the water treatment plants neighbouring the sampling sites. The authors chose to analyse untreated water immediately after collection, due to the fact that, the water treatment plants whose laboratories were used, are the ones used while treating water for further consumption with use of some chemicals and/or other products/processes, which would confuse the study's objective.

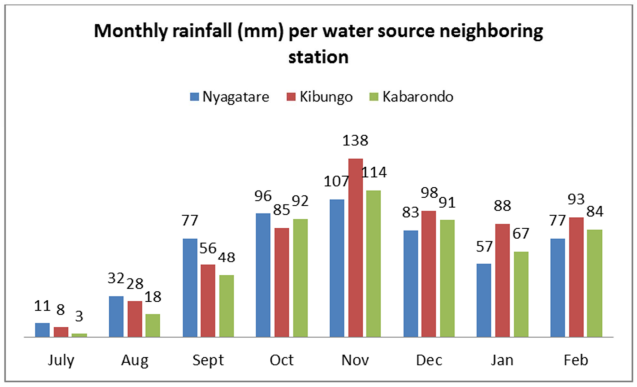

Figure 2. Monthly maximum rainfall (mm) recorded at the meteorological stations neighbouring with the water sampling sites indicates high rainfall between September and February. While within almost all months considered by this study, the Kibungo meteorological station recorded high monthly rainfall compared to other stations.

Moreover, seasonal water quality was carried out, due to the fact that, the country is almost steep and hilly, and the protected land with radical terraces, to minimize the direct sediments and other wastes runoff into waters is reported to be at low pace [42, 43]. This expresses that, water sources directly receive rainwater from uphill with all sediments and/or other pollutants. Therefore, the authors measured heavy metals during the rainy season (between late September 2016 and February 2017) and dry season (July and August 2016), and every month's maximum rainfall was considered (Figure 2), to identify seasonal changes on water quality. Furthermore, the sample analysed were compared with the drinking water guidelines of the World Health Organization (WHO), to evaluate the quality of drinking water sources in the eastern province of Rwanda.

3. Results

The results as illustrated in Table 1 below indicated gradual increase of the values of heavy metals, particularly during the rainy season (between September 2016 and February 2017) compared to the values registered during the dry season (July-August 2016).

Table 1. Monthly Heavy metals measured at sampling sites.

				Nyagatare		
	Ca	**Fe**	**Mn**	**Cu**	**Al**	**Zn**
July 2016	6.4	0.29	0.02	0.08	0.03	0.04
August 2016	13.66	0.28	0.02	0.39	0.004	0.34
September 2016	14	0.035	0.39	0.93	0.01	0.17
October 2016	12	0.14	0.21	0.02	0.06	0.4
November 2016	24	0.69	0.22	0.25	0.21	0.2
December 2016	32	0.72	0.63	0.42	0.18	0.28
January 2017	29	0.45	0.43	0.83	39	0.17
February 2017	31.2	0.23	0.08	0.71	0.11	0.04
				Kabarondo		
July 2016	16.2	0.12	0.052	0.49	0.022	0.06
August 2016	16.6	0.09	0.027	0.41	0.022	
September 2016	16.6	0.11	0.027	0.41	0.022	0.05
October 2016	15.8	0.11	0.031	0.53	0.024	0.05
November 2016	14.4	0.19	0.58	0.57	0.25	0.06
December 2016	27.6	0.13	0.39	0.48	0.19	0.5
January 2017	32	0.12	0.69	0.49	0.3	0.9
February 2017	29.2	0.17	0.3	0.57	0.04	0.6
				Kibungo		
July 2016	18.4	0.12	0.058	0.52	0.024	0.07
August 2016	17.6	0.12	0.042	0.47	0.025	0.12
September 2016	15.8	0.19	0.045	0.52	0.029	0.05
October 2016	17.6	0.23	0.066	0.56	0.028	0.06
November 2016	27.6	0.12	0.57	0.56	0.32	0.07
December 2016	35.2	0.24	0.68	0.74	0.29	0.09
January 2017	20	0.18	0.056	0.54	0.03	0.102
February 2017	18.4	0.27	0.05	0.56	0.05	0.07

Ca: Calicium, Fe: Iron, Mn: Manganese, Al: Aluminium, Zn: Zinc and all heavy metals were measures in milligram per litre.

The above results illustrated in Table 1 express that water pollution was accelerated by the rainfall, which effortlessly loaded sediments and other wastes into water bodies, and this in turn, facilitated and/or led to increasing the water pollution likelihood. In addition, high water pollution was registered in semi-urban areas (Nyagatare and Kabarondo sampling sites) than at Kibungo (a rural area).

4. Discussion

This study assessed the quality of drinking water sources by measuring heavy metals during both rainy and dry seasons in the eastern province of Rwanda. The drinking water quality monitoring is suggested [24, 44-46] to assess its quality status, explore and control its threatening factors to ensure the community's easy and equal access to safe drinking water. In addition, as long as the world human population growth, there is rising water demand, and to ensure satisfaction, numerous efforts have been consolidated, such as buffer zones policy, water purification, reduction of wastes and other pollutants loading into waters, wastewater treatment, highlighting the role of different stakeholders in managing water sources, etc. [47-51]. The eastern province of Rwanda is reported to have abundant water sources (Figure 1) associated with its rainfall despite its shortage compared to other provinces. These are the major sources for the drinking water, domestic and industrial uses in the eastern Rwanda [52].

Despites the water richness in Rwanda, its landscape (steep slope) exposes its natural resources specifically water and land at large risk of erosion, degradation and pollution [24, 36]. In addition, the country's high population density which grew from 294 to 482 people per Kilometre Square in 1990 and 2016, respectively, classifies Rwanda among countries with highest population density worldwide, and this is reported to negatively impact on its natural resources [53-55]. This is similar to the study area, the largely inhabited province in Rwanda, and expresses that the available water sources (Figure 1) are greatly exposed to pollution likelihood resulting on population growth and its daily socio-economic activities. Moreover, the findings of this study (Table 2), revealed that the drinking water sources are predominantly polluted by Iron, Aluminium and Manganese and their average concentrations exceeded the standards of the World Health Organization compared to their counterparts heavy metals measured. In addition, as far as some water sources are becoming polluted, this expresses that, in the future the pollution likelihood of the available water sources (Figure 1), may rise with effects on consumers, unless appropriated mechanisms are envisaged.

Table 2. Averaged heavy metals in comparison with WHO Standards.

Sampling Sites	Ca	Fe	Mn	Cu	Al	Zn
Nyagatare	20.28	0.35	0.25	0.45	0.95	0.2
Kabarondo	21.05	0.13	0.26	0.49	0.1	0.31
Kibungo	21.32	0.18	0.19	0.56	0.1	0.8
WHO Standards	80	0.3	0.1	1	0.2	3

Al: Aluminium; Fe: Iron; Mn: Manganese; Cu: Copper, Ca: calcium; Zn: Zinc and WHO: World Health Organization. Values in Bold are those exceeding the WHO Standards on Drinking Water Quality and all values are measured in milligram per Litre.

Moreover, with reference to the drinking water standards of the World Health Organization the results of this study (Table 2) indicated that the consumers are exposed to several risks. This is congruent with previous reports [21, 34, 56] on water quality management, which highlighted how water pollution affects human health mainly resulting on the wastes generated by industries, abattoirs, home uses and agricultural chemicals as well as the location of water bodies in the middles of mountains, where sediments easily load into waters. Although the proportion of people accessing and consuming safe water increased last years in Rwanda, with reference to the findings of this study (Tables 1 and 2), it is evident that there is still some people consuming unsafe water. This, as a result, is reported [57, 58] to likely impact on the community's livelihood, specifically pregnant women and children, who are subject to toxicity of the nervous system and cancer, liver, heart and pancreatic damage due to excess manganese and iron in water.

Furthermore, water resources are reported [56, 59, 60] to be largely polluted during the rainy season in urban areas, where sediments and other wastes easily load into waters. This was similar with the results of this study (Table 1) Nyagatare and Kabarondo (semi-urban areas) recorded increasing heavy metals during the rainy season than Kibungo (rural area). Therefore, under rapid human population growth, industrialization and urbanization, climate change, the pollution of drinking water sources may likely increase, with high probability during the rainy season in semi/urban areas than that in dry season and in rural areas, respectively. This expresses the fact that, the abundant water sources (Figure 1) are constantly exposed to pollution and the consumers 'health is at risk, but also the socio-economic and ecological costs resulting on this pollution may be harmful and expensive unless appropriate measures are regarded.

5. Conclusion

This study compared the drinking water quality between the rainy and dry seasons. The authors collected monthly water samples to evaluate the heavy metals concentration. Three sampling sites were randomly selected among water sources in the eastern province of Rwanda between July 2016 and February 2017. The results indicated that the mean of Iron, Manganese and Aluminium exceeded the drinking water guidelines of the World Health Organization. In addition, during the rainy season, the concentrations greatly raised than that in dry season, mainly in semi/urban areas than in rural area. This expresses that, urban water is heavily polluted compared to rural waters. Basing on the findings of this study, to ensure safe drinking water, it is suggested to (1) reduce the wastes loading into waters by harvesting the rain water and

using bench terraces and agroforestry to minimize the sediments and other pollutants runoff, mainly in semi/urban areas, (2) involve the community in, and strengthen its knowledge through education and training, on water resources management and (3) supervise the implementation of the buffer zones policy under execution in Rwanda.

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