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Research Article

Spatial-Temporal Dynamics in Potable Water Quality: A Case Study of Mizan-Aman Town, Southwest, Ethiopia

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Surface water is one of the sources of global potable water. However, the quality of surface water has been degrading due to an increase in human activities. Hence, the present study was conducted to evaluate the spatial and temporal variability in drinking water physico-chemical and bacteriological characteristics from the different sources in Mizan-Aman, Ethiopia. The physico-chemical characteristics of water at the Kosokol site were found to be statistically different ($p < 0.05$) from the other sites (Gacheb, Tsit, Reservoir 1, and Reservoir 2 sites). The dry and wet season temperature (27.1 and 23.8°C), turbidity (37.4 and 54.8 NTU), pH (7.6 and 8.1), biological oxygen demand (18.1 and 20.7 mg/l), phosphate (2.4 and 3.5 mg/l), and ammonia (2.2 and 4.8 mg/l) of the water were beyond the acceptable limit set for drinking water by both Ethiopian standards (temperature: <15°C; turbidity: 7 NTU; pH: 6.5–8.5; BOD: 10 mg/l; phosphate: 0.02 mg/l; and ammonia: 1.5 mg/l) and the WHO standards (temperature: <15°C; turbidity: 5 NT U; pH: 6.5–8.5; BOD: 5 mg/l; phosphate: 0.01 mg/l; and ammonia: 1.5 mg/l). The total coliform (366.5 and 494.3 CFU/100 ml) and fecal coliform (209.5 and 278.3 CFU/100 ml) contents of the water in the dry and wet seasons are beyond the acceptable limits for drinking water by Ethiopian standards (total and fecal coliform: 0) and the WHO standards (total and fecal coliform: 0). The physico-chemical and bacteriological characteristics of the water in the wet season were found significantly higher than those ($p < 0.05$) in the dry season. In general, the water quality changes on a spatial and temporal basis in the study area. Thus, it is important to encourage water quality management works at the upper source sites of the catchment. Furthermore, the city water authority should reinforce safeguarding treatment processes, continuous monitoring of water quality as well as risk assessment and management practices.

1. Introduction

Water is one of the major important elements for the survival of human being on the earth [1]. Humans need water for drinking, food, cooking, body and cloth washing, recreation, plant and animal production, environmental cleaning, industry, construction activities, etc. [2]. The water covers 72% of the earth; yet, 97% of the earth water is saline water in oceans and seas. The remaining 3% is fresh water captured majorly in glaciers and the rest hosted in the ground and surface water reservoir [3]. The surface and ground waters are sources of drinking water for more than 33% of the populations of the globe [3, 4]. However, the surface water quality worsens due to human activities and climatic changes [5, 6]. Currently, drinking water quality has been a major human health challenge in developing countries [7].

Water for human consumption must be free of contamination, safe, and adequate [8]. However, the surface water sources such as lakes, rivers, and open wells were open to the atmosphere and are subject to run off from the land. Hence, it can be easily contaminated by living and nonliving organisms, toxic elements, and chemical substances in concentrations large enough to affect health [9, 10]. Globally, 663 million people used unimproved drinking water sources in 2015 [11]. For example, at least 2 billion people use a drinking water source contaminated with feces in the world [12]. Similarly, in sub-Saharan Africa, half of the people are using unimproved drinking water sources [13].

Ethiopia is the water tower of Africa because of its many rivers and lakes that emanate from the Ethiopian highlands. However, the country has one of the lowest rates of coverage for improved water and sanitation in the world and sub-Saharan Africa. Nearly 42 million people lack access to safe drinking water, and 94 million people lack access to basic sanitation [14]. Urban residents draw their potable water from piped municipal suppliers after treatment of water from sources such as rivers, lakes, streams, ponds, reservoirs, springs, and wells [15, 16]. Since water from those sources are open to air and running on the surface of the soil, it dissolves naturally occurring minerals and can pick up many substances generated by human activities. For example, climate changes, agricultural land expansion, land degradation, increases in population, deforestation, and urbanization have led to the deterioration of the surface and subsurface water sources [17–20]. This leads to pollution because of a great variety of inorganic contaminants, pesticides, herbicides, and organic chemical contaminants [15, 21] and increases water treatment cost [18]. Incidentally, drinking water pollution increases exposure to waterborne diseases such as gastroenteritis, cholera, hepatitis, diarrhea, typhoid fever, and dysentery [22]. Ayaliew Werkneh et al. [23] reported that more than 80% of human diseases in Ethiopia are attributed to poor access to clean water and better sanitation. Also, diarrhea is the second killer of under five year's children in Ethiopia.

Mizan Teferi water treatment plant was constructed in 2006 to supply drinking water for Mizan Teferi, Aman, and surrounding areas. The upper Gacheb catchment is headwaters of Gacheb river, which is the source of water for the water treatment plant. However, the increase in human population and associated human activities has led to land degradation in the Gacheb catchment [24, 25]. For instance, land degradation was followed with an increase in sediment concentration, reservoir siltation, runoff, flood, and nutrient concentration and deterioration in reservoir water storage capacity and water quality in Ethiopia [26, 27]. Furthermore, the study reported that sedimentation resulted in the reduction of the reservoir depth from a design of 16 m in 1999 to 12 m in 2001. This in turn increased the treatment cost of water from 8,040 USD to 21,514 USD within two years of interval [28]. Despite high human pressure at the upper catchment, high rainfall, and waterborne diseases in the study area, no prior research has been conducted on the spatial and temporal-based water quality evaluation at the source sites of drinking water rivers in recent years. However, the spatial and temporal scale water quality evaluation at the watershed level is important for sustainable drinking water quality management and treatment cost reduction [6, 29–31]. Furthermore, it is important for understanding the anthropogenic impacts in river water, providing the basis for conservation and sustainable management of the natural resources at the catchment scale [26].

In addition, it will help provide baseline information for further monitoring and tracking of changes in water quality at the source and the reservoir. Thus, the study aimed at determining the spatial and temporal physico-chemical and bacteriological characteristics of source river sites of the Gacheb river drinking water treatment plant during the wet and dry seasons.

2. Materials and Methods

2.1. Description of the Study Area. The research was conducted at Gacheb catchment drinking water source rivers sites. The Gacheb catchment is a source of Kosokol, Tsit, and Gacheb rivers, which drain to the White Nile through the Gacheb and Baro-Akobo river system (Figure 1). The study area is located at 6°59′N and 35°34′E. The elevation of the study catchment ranges from 900 to 2700 m a.s.l. The rainfall pattern of these areas is characterized by a bimodal distribution with the small rainy season (March to June) and the main rainy season (July to November). The average air temperature ranges from 13 to 27°C [32]. In 2019, the total population of the Mizan-Aman town was 79,581 of which 40,678 were male and 38,903 were female [33].

2.2. Sampling Techniques and Sample Collection. A preliminary field visit was made using a topographic map and GPS to fully understand the land features, the tributary, rivers, and reservoir for locating the study area's representative water sampling points. The water samples were collected on January 10^{th} and July 17^{th}, 2020, corresponding to the dry and wet seasons in the study area. A total of 5 sites (Kosokol, Gacheb, Tsit, Reservoir 1, and Reservoir 2 sites) were selected intentionally based on their water contribution to the treatment plant, human activity on the upper reaches of rivers sites, and location in relation to water treatment (the source and reservoir site). A total of 30 samples were collected from five sites, with three replicates at two seasons (dry and wet seasons) (5 sites $*$ 3 replicate $*$ 2 seasons). The water samples from the five sites were collected using the composite sampling technique of APHA [34] by manually inserting a plastic jar at different depths of the river [35], and the grabbed water samples were collected into 10 L plastic bucket, from where the one composite sample was taken using 1000 ml plastic bottles for quality analysis in the laboratory (Supplementary file 1).

Sample bottles were carefully washed with distilled water before taking the samples to prevent any cross contamination from the previous samples. All bottled composite water samples were capped immediately, stored in an icebox (below 4°C), and transported immediately to the Jimma University Environmental and Technology Water Quality Laboratory. To avoid decomposition, water samples were immediately filtered in the laboratory using a water jet vacuum pump at low pressure before nutrient analysis [36].

2.3. Physico-chemical and Bacteriological Analysis

2.3.1. Physico-chemical Analysis. All physico-chemical characteristics of the water were analyzed following the

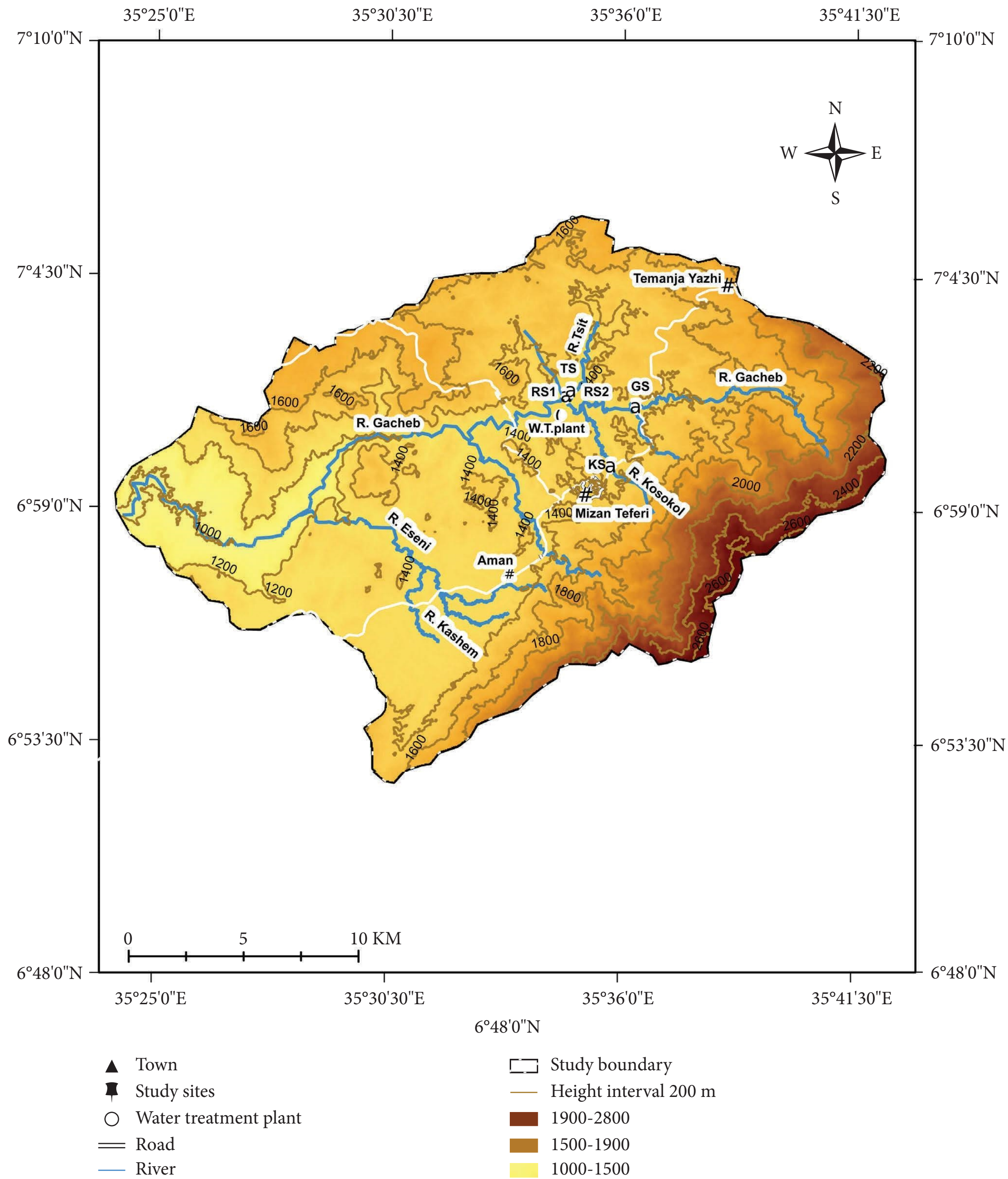

Figure 1: Location of the sampling sites at the Kosokol, Tsite, and Gacheb rivers in the Gacheb catchment.

standard methods for the examination of water and waste water [34]. The analysis of the physico-chemical parameters was carried out within 48 hours of the sampling time. The water samples were carried through icebox and kept in the refrigerator until the analyses were performed. All the reagents were of high purity along with ultrapure water which was used for reagent preparation and analysis for the present study.

(1) In Situ Analysis. The five sites' wet and dry season water physico-chemical characteristics such as pH, temperature, electrical conductivity (EC), and total dissolved solid (TDS) were tested onsite by using a portable multimeter (model HQ40d multi Hach Lange).

(2) Ex Situ (Laboratory) Analysis. The wet and dry season water samples' physico-chemical characteristics such as turbidity, total suspended solids (TSS), total hardness (TH), biological oxygen demand (BOD), phosphate (PO_4-3), nitrate (NO_3-N), and ammonia (NH_3-N) were analyzed at the Jimma University Environmental and Technology Water Quality Laboratory. The wet and dry season water samples' physico-chemical analysis was conducted by following the standard methods for the examination of water and waste water [34].

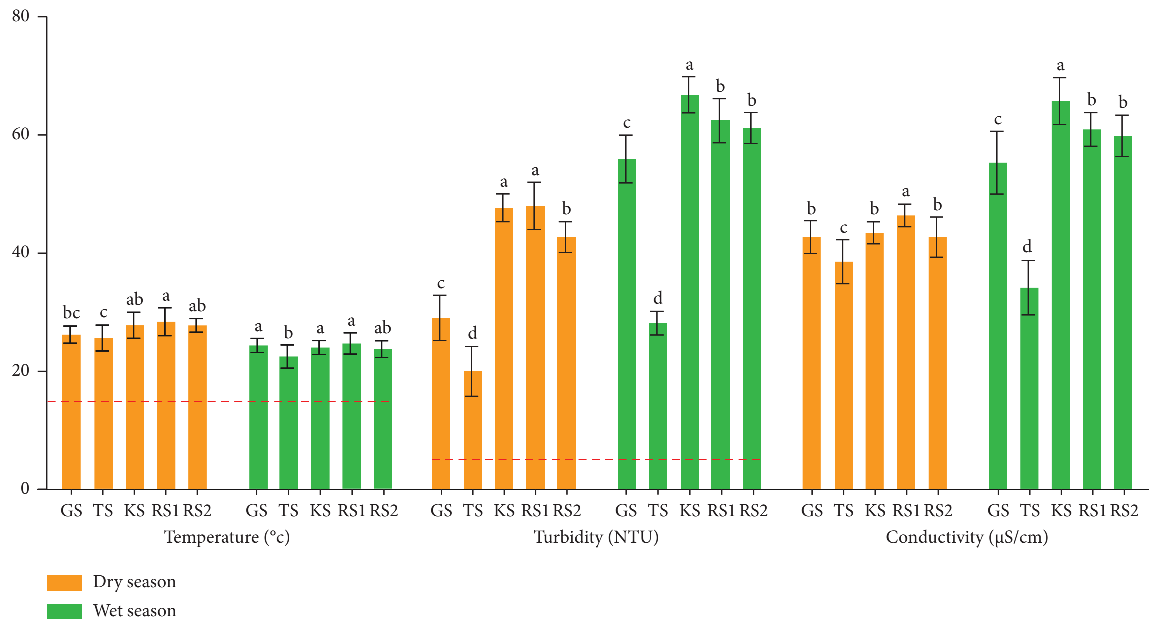

Figure 2: Water temperature, turbidity, and conductivity of the different river sites at wet and dry seasons of the year. Study sites: GS = Gacheb site, TS = Tsit site, KS: Kosokol site, RS1 = Reservoir site 1, and RS2 = Reservoir site 2. Number of replicates ($n = 3$). Mean values of the different sites' water temperature, turbidity, and conductivity with similar letter within the same season (wet or dry season) are not significantly different to each other at $p < 0.05$. The red dotted line is the WHO limits for drinking water quality.

The water turbidity of the samples was determined by using a digital turbidity meter (model Oakton: T-100), electrical conductivity by digital conductivity meter, total suspended solid (TSS) by using Whatman paper filtration techniques, total hardness by the titration method, PO_4-3-P by the ammonium molybdate method, NO_3-N by the sodium salicylate method, and NH_3-N by the indophenols blue method. The biological oxygen demand (BOD) was determined by azide modification of Winkler's titrimetric method by determining the dissolved oxygen contents of the samples before (D1) and after five days (D2) of incubation at 20°C.

2.3.2. Bacteriological Analysis. Wet and dry season bacteriological characteristics of total coliform (TC) and fecal coliform (FC) were analyzed using the standard method specified by Clesceri et al. [37]. Wet and dry season water samples' bacteriological indicators such as total coliform (TC) and fecal coliform (FC) were analyzed by the 100 ml membrane filtration technique using 0.47 mm diameter and 0.47 μm size filters as specified in the standard methods [37]. For TC and FC membranes, lauryl sulphate (MLS) media were used, samples were incubated at 35°C and 44.5°C for 24 hr, respectively, and yellow colonies were counted as TC and FC.

2.3.3. Data Analysis. The five sites' wet and dry season water physico-chemical and bacteriological characteristics were tested by one-way ANOVA using SPSS (version 20). The mean differences in physico-chemical and bacteriological characteristics of the five sites were compared by the least significant difference (LSD) at a 5% level of significance.

3. Results and Discussion

3.1. Physico-chemical and Bacteriological Characteristics of Drinking Water Source River Sites

3.1.1. Physical Characteristics of Drinking Water Source River sites

(1) Temperature. There was a significant difference ($p < 0.05$) in the wet and dry season water temperatures among river sites. The highest dry and wet season water temperature was recorded in KS (27.7 ± 1.1°C), RS1 (28.4 ± 1.2°C), and RS2 (27.6 ± 0.6°C) sites (Figure 2). The presence of high temperature on those sites may be related to the increase in light absorption associated with the presence of high total suspended sediment (TSS) on those sites. This is inconsistent with the results of Nyanti et al. [38]. The wet season water temperatures in GS, KS, RS1, and RS2 sites were significantly different ($p < 0.05$) from TS (Figure 2). The highest water temperature was recorded in GS, KS, RS1, and RS2 sites. The wet and dry season temperatures of the water in all sites were found above the permissible limit of the WHO (<15°C) [39].

(2) Turbidity. The dry and wet season water turbidity was significantly different ($p < 0.05$) between the sites (Figure 2). The high-water turbidity was recorded in the KS site (66.7 ± 1.5 NTU), and the presence of high turbidity is related to high suspended sediment and nutrients in the river because of soil erosion from the new road construction site and farming land on the upper catchment of the Kosokol river site (KS). Furthermore, since the KS site is the river

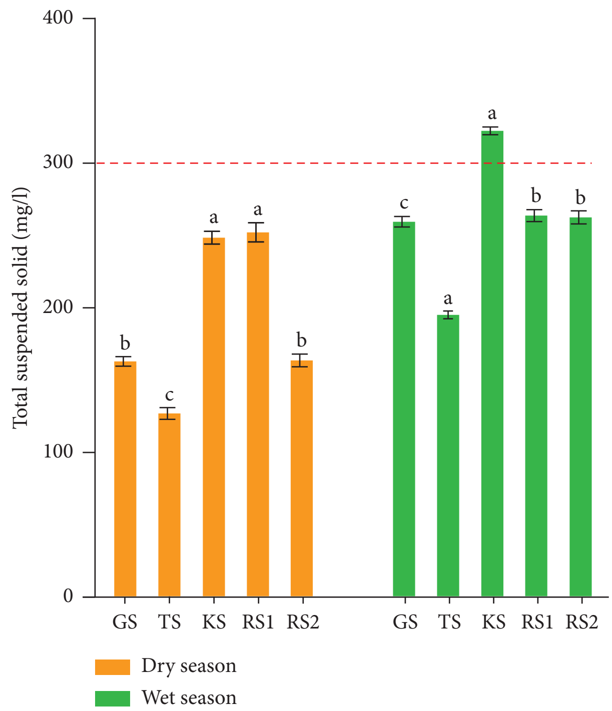

Figure 3: Water total suspended solid of the different river sites at wet and dry seasons of the year. Study sites: GS = Gacheb site, TS = Tsit site, KS: Kosokol site, RS1 = Reservoir site 1, and RS2 = Reservoir site 2. Number of replicates ($n = 3$). Mean values of the different sites water total suspended solid with similar letter within the same season (wet or dry season) are not significantly different to each other at $p < 0.05$. The red dotted line is the WHO limits for drinking water quality.

crossing the main town, there is discharge of organic effluents from urban households. This is in agreement with the statement of Göransson et al. [40] and Adeola Fashae et al. [41] that the presence of high sediment and discharge of sewage organic effluents increase river turbidity. The wet and dry season water turbidity of the river water in all the sites exceeds the limit set by ES (7 NTU) and the WHO (5 NTU).

(3) Electrical Conductivity (EC). The dry and wet season water EC content was significantly different ($p < 0.05$) between the river sites (Figure 2). The highest dry season EC content was recorded in the RS1 site due to the presence of the high sediment load from upper urban and agricultural land uses. The presence of high EC during the wet season in the KS site ($65.6 \pm 2.0\,\mu$S/cm) is associated with high sediment transport from the urban road and agricultural land during high rainfall events and the availability of chloride, phosphate, and nitrate ions from the urban sewage system. The wet and dry season water EC of all the sites is below the limit set by ES (1500 μS/cm) and the WHO (1000 μS/cm). The finding is in line with the results of Bhateria and Jain [42] who reported an increase in EC with an increase in the clay soil load and ions in the lake water. The increases in water's electrical conductivity during dry periods are related to evaporation and low precipitation and discharge of ion containing effluents from cities [6].

(4) Total Suspended Solids (TSSs). The dry and wet season water TSS content was significantly different ($p < 0.05$) between the sites (Figure 3). The presence of dry and wet season high TSS in the KS site (dry: 248.4 ± 2.2 mg/L and wet: 322.6 ± 1.3 mg/L) is attributed to the soil loss from agricultural land, new road sites, and urban sites into waterways. This finding is in line with Hart's [43], who reported a high TSS content of water after road construction, urbanization, and agricultural land expansion. Except for the KS site, the dry and wet season TSSs of water in all sites are within the limit set by the WHO (<300 mg/l).

3.2. Chemical Characteristics of Drinking Water Source River Sites

3.2.1. pH Value. The dry and wet season pH of the water in the KS site was significantly different ($p < 0.05$) from the other sites (Figure 4). The presence of high pH on the KS site (dry: 8.7 ± 0.3 and wet: 8.3 ± 0.3) is related to the use of soap and other detergents for washing of clothes and body on the upper sites of the KS river. The finding is consistent with Goel and Kaur's [44], who reported increases of water pH due to soap and detergents' presence in the water. Except for the wet season pH at the KS site, the dry and wet season pH of the water in all sites is within the permissible limit of ES (6.5–8.5) and the WHO (6.5–8.5). Similarly, a study conducted in Malaysia by Sulaiman and Mohd Kasim [45] reported that the pH values of the samples were within the recommended WHO range.

3.2.2. Total Hardness (TH). The wet and dry season TH content of the water at the KS site was significantly different ($p < 0.05$) from the other sites (Figure 5). The highest TH

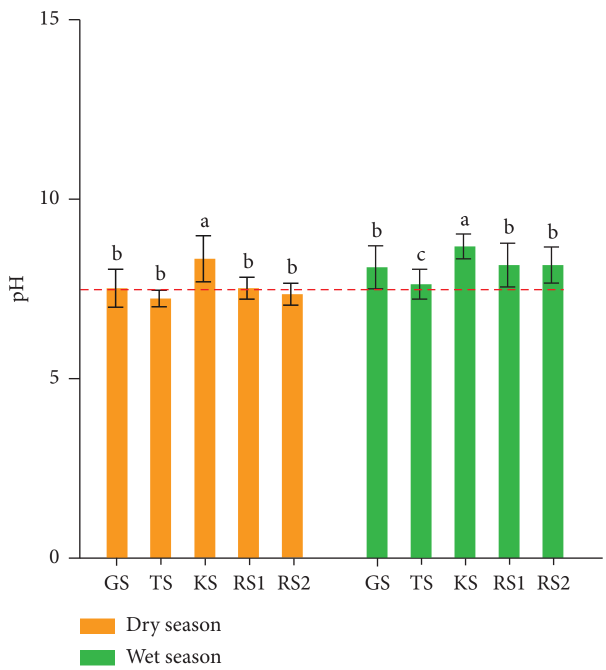

FIGURE 4: Water total suspended solid of the different river sites at wet and dry seasons of the year. Study sites: GS = Gacheb site, TS = Tsit site, KS: Kosokol site, RS1 = Reservoir site 1, and RS2 = Reservoir site 2. Number of replicates ($n = 3$). Mean values of the different sites water temperature, turbidity, and conductivity with similar letter within the same season (wet or dry season) are not significantly different to each other at $p < 0.05$. The red dotted line is the WHO limits for drinking water quality.

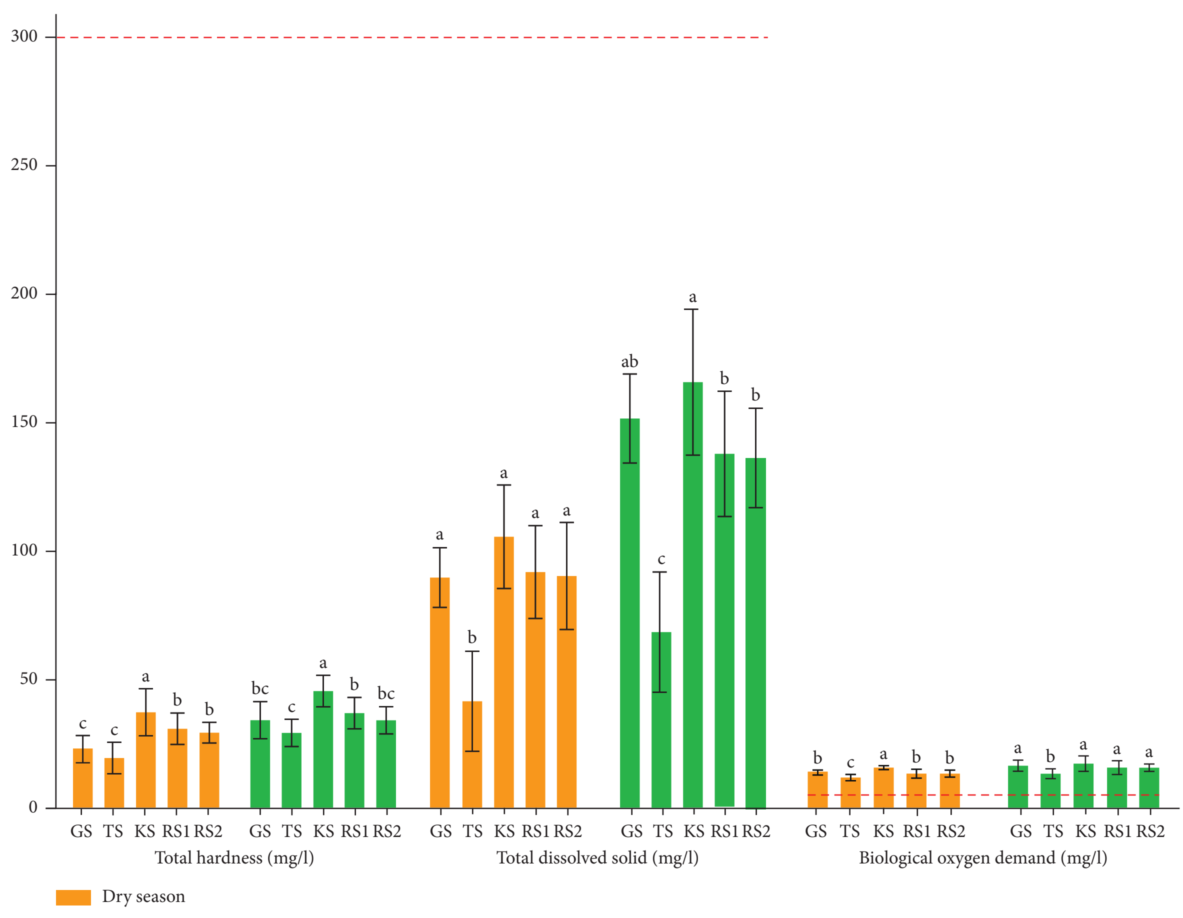

FIGURE 5: Water total hardness, total dissolved solid, and biological oxygen demand (BOD) of the different river sites at wet and dry seasons of the year. Study sites: GS = Gacheb site, TS = Tsit site, KS: Kosokol site, RS1 = Reservoir site 1, and RS2 = Reservoir site 2. Number of replicates ($n = 3$). Mean values of the different sites water total hardness, total dissolved solid, and BOD with similar letter within the same season (wet or dry season) are not significantly different to each other at $p < 0.05$. The red dotted line is the WHO limits for drinking water quality.

was recorded in the KS site (dry: 37.0 ± 4.6 mg/L and wet: 45.3 ± 3.1 mg/L). The presence of high TH in the KS site is attributed to the presence of dissolved minerals such as calcium and magnesium from urban effluent discharge into the waterways. The finding is similar to the results reported by Dudziak and Kudlek [46], who reported the high Ca and Mg content and water hardness due to discharge of wastewater effluent from the urban area. Both wet and dry season water hardness of all the sites was below the permissible limit of ES (300 mg/l) and the WHO (300 mg/l).

3.2.3. Total Dissolved Solids (TDSs). The dry and wet season TDS content was significantly different ($p < 0.05$) between the sites (Figure 5). The presence of high-water TDS on the KS site (dry: 105.1 ± 10.1 and wet; 165.2 ± 14.2) is associated with the discharge of urban household effluents into the waterways and urban and agriculture runoff. This result is matched with Rusydi [47] who reported an increase in water TDS with an increase in domestic waste effluent discharge and agriculture runoff. The TDS content of water in all sites are below the permissible limit set by ES (1000 mg/l) and the WHO (300 mg/l).

3.2.4. Biological Oxygen Demand (BOD). The wet and dry season BOD content of water was significantly different ($p < 0.05$) between the sites (Figure 5). The presence of a high BOD content in the KS site (20.6 ± 0.5 mg/l) during the dry season is attributed to the discharge of organic waste effluents from the urban households into the waterways, as evidenced by the high ammonium concentrations on the site. This result is in agreement with Edokpayi et al. [48]. The presence of high BOD in the KS (22.9 ± 2.0 mg/l), GS (21.9 ± 1.5 mg/l), RS2 (20.8 ± 1.8 mg/l), and RS1 (20.5 ± 1.0 mg/l) sites in the wet season is associated with the increase in the organic material load from agriculture and urban land use. Both the wet and dry season BOD contents of water is above the permissible limit set by ES (10 mg/l) and the WHO (5 mg/l). This finding is in line with the report of Patil et al. [15] and Susilowati et al. [49]. At the surface of the water, anionic surfactants produce foam, limiting the gas exchange between water and the atmosphere, destroying aerobic bacteria responsible for decomposing organic matters [50, 51].

3.2.5. Phosphate. The wet and dry season phosphate content of the water was significantly different ($p < 0.05$) between the sites (Figure 6). The highest dry and wet season phosphate content of water was recorded in the KS site (dry: 4.2 ± 0.1 mg/l and wet: 5.7 ± 0.1 mg/l). The higher phosphate content of water in the KS site is attributed to the discharge of organic effluents from urban areas, the use of soap for washing clothes and bodies, and sediment transport and phosphorous fertilizer from the agricultural land. A similar result was reported by Wu et al. [52] who reported increases in the phosphate level in water due to human interventions such as municipal waste water and agriculture runoff. Both wet and dry season phosphorous contents of the sites were above the permissible limit set by ES (0.02 mg/l) and the WHO (0.01 mg/l).

3.2.6. Nitrate and Ammonia. The dry and wet season nitrate and ammonia content of the water was significantly different ($p < 0.05$) between the sites (Figure 6). The highest dry and wet season nitrate (dry: 13.9 ± 0.1 mg/l and wet: 8.6 ± 0.7 mg/l) and ammonia content (dry: 2.8 ± 0.1 mg/l and wet: 6.5 ± 0.2 mg/l) was recorded in the KS and GS sites. The high nitrate and ammonia content on those sites is associated with organic effluent discharge from municipal and soil organic and inorganic nitrogen source loss from the agricultural lands. The results of both nitrate and ammonia contents are in agreement with the findings of Yeo et al. [53], Patil et al. [15], Causse et al. [54], and Górski et al. [55] who reported that the discharges from municipal waste effluent and agricultural runoff have led to an increase in the concentration of ammonia and nitrate in river water. The wet and dry season nitrate content of the water on all sites was below the permissible limit set by ES (50 mg/l) and the WHO (11.3 mg/l) [10]. However, the odor and test threshold of ammonia at alkaline pH were approximately 1.5 mg/L and 35 mg/L, respectively [8]. Thus, the ammonia content of the water at the KS and GS sites is above the odor threshold level for ammonia.

3.3. Bacteriological Characteristics of Drinking Water Source River Sites

3.3.1. Total Coliform and Fecal Coliform (TC and FC). The dry and wet season TC content of water was significantly different ($p < 0.05$) between the sites (Figure 7). The presence of high TC content in the GS (428.0 ± 28.0 CFU/100 ml) and KS (427.0 ± 37.8 CFU/100 ml) sites was attributed to the discharge of sanitary wastes and effluents from the urban households and leaching of animal manure into the river passing the upper catchment. Furthermore, the lack of hygiene facilities in most rural setups of the upper catchment of the two sites promotes open human waste disposal, thus increasing the TC content. The report is inconsistent with the findings of Onyango et al. [56], who reported a high concentration of TC in river water due to defecated materials and municipal wastes from urban and rural settlements. The highest wet season TC content of water was recorded in RS1 (591.0 ± 51.7), RS2 (566.7 ± 65.6), and KS (530.7 ± 61.8) sites. The wet and dry season TC of the water is above the permissible limit set by ES (0 CFU/100 ml) and the WHO (0 CFU/100 ml).

The dry and wet season FC content of water was significantly different ($p < 0.05$) between the sites (Figure 7). The highest FC content of the water was recorded in the RS1 (dry: 233.3 ± 5.5 CFU/100 ml and wet: 349.3 ± 15.6 CFU/100 ml) and RS2 (dry: 232.3 ± 3.5 and wet: 347.7 ± 13.1 CFU/100 ml) sites. The dry and wet season FC is beyond the acceptable limit set by both ES and the WHO (Table 1). The finding is consistent with Alemu et al. [19] and Haydar et al. [57] who reported high dry and wet season water FC content, which is unacceptable and unfit for human consumption. Similarly, the findings of Rosca et al. [51] who observed the high content of fecal coliforms (181.46 bacteria/ml) in several lakes in Romania. The study indicates that the inhabitants are under

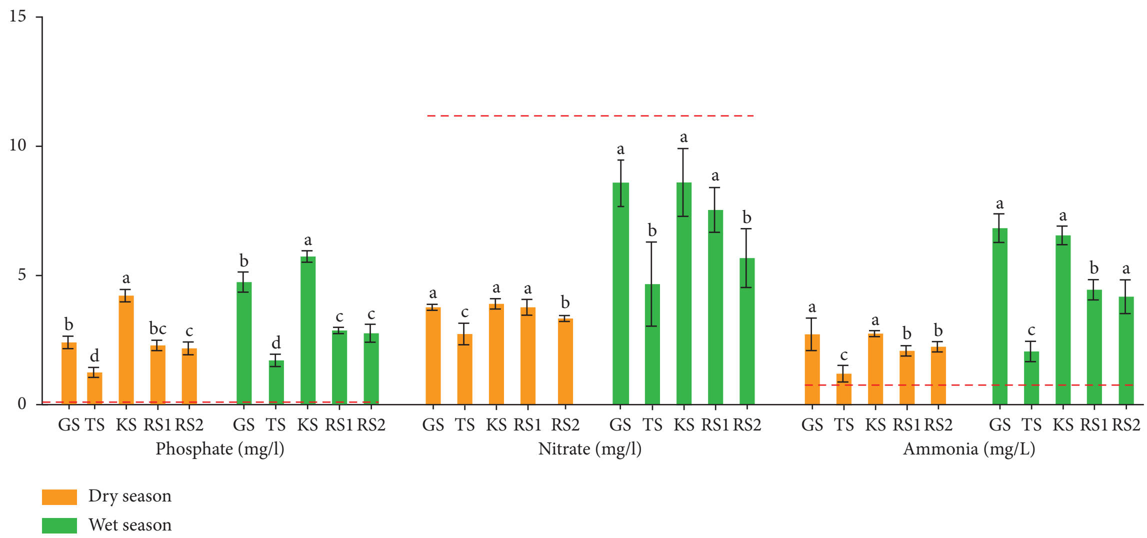

FIGURE 6: Water phosphate, nitrate, and ammonia of the different river sites at wet and dry seasons of the year. Study sites: GS = Gacheb site, TS = Tsit site, KS: Kosokol site, RS1 = Reservoir site 1, and RS2 = Reservoir site 2. Number of replicates ($n = 3$). Mean values of the different sites water phosphate, nitrate, and ammonia content with similar letter within the same season (wet or dry season) are not significantly different to each other at $p < 0.05$. The red dotted line is the WHO limits for drinking water quality.

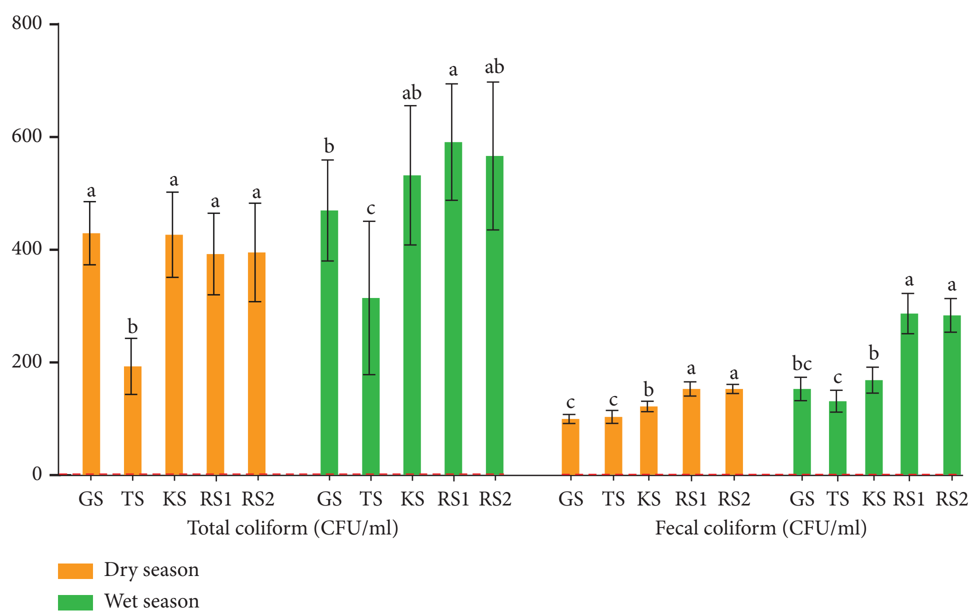

FIGURE 7: Water total coliform and fecal coliform of the different river sites at wet and dry seasons of the year. Study sites: GS = Gacheb site, TS = Tsit site, KS: Kosokol site, RS1 = Reservoir site 1, and RS2 = Reservoir site 2. Number of replicates ($n = 3$). Mean values of the different sites water total coliform and fecal coliform with similar letter within the same season (wet or dry season) are not significantly different to each other at $p < 0.05$. The red dotted line is the WHO limits for drinking water quality.

the severe threat of water-related diseases and health risks. The continuous consumption of such contaminated water could pose severe health risks, especially in children, the elderly, and immune-compromised individuals.

3.4. Seasonal Physico-chemical and Bacteriological Characteristics of Water. The physico-chemical and bacteriological characteristics of the river water during the wet season were found to be significantly different ($p < 0.05$) from the dry season (Table 1). The wet season turbidity, conductivity, TSS, pH, TH, TDS, BOD, phosphate, nitrate, ammonia, TC, and FC content were significantly higher than that of the dry season. This is due to the transport of nutrients, soil, and wastes into the waterways by the runoff during the high rainfall events during the wet season. This study finding is consistent with the findings of Ioryue et al. [58] and Mohd Shafiq et al. [59], who reported higher physicochemical characteristics of water in the wet season than in the dry season in Nigeria. However, the water temperature in the dry

Table 1: Seasonal variation in water physicochemical and bacteriological characteristics.

Seasons	T (°C)	TU (NTU)	EC (μS/cm)	TSS (mg/l)	pH	TH (mg/l)	TDS (mg/l)	BOD (mg/l)	PO_4 (mg/l)	NO_3 (mg/l)	NH_4 (mg/l)	TC (cfu/100 ml)	FC (cfu/100 ml)
Dry	27.1 ± 1.4a	37.4 ± 12b	42.6±3b	190.8 ± 52b	7.6 ± 0.4b	27.8±7b	83.5 ± 24b	18.1 ± 1.8b	2.4 ± 1.0b	3.5 ± 0.5b	2.2 ± 0.6b	366.5 ± 97b	209.5 ± 21b
Wet	23.8 ± 1.0b	54.8 ± 14a	55.0 ± 12a	260.5 ± 42a	8.1 ± 0.4a	35.8±6a	131.4 ± 36a	20.7 ± 2.2a	3.5 ± 1.5a	7.0 ± 1.7a	4.8 ± 1.8a	494.3 ± 114a	278.3 ± 61a
Overall mean ± SD	25.4 ± 2.0	46.1 ± 16	48.8 ± 10	225 ± 59	7.9 ± 0.5	31.8 ± 8	107.4 ± 39	19.4 ± 2.3	2.9 ± 1.4	5.2 ± 2.1	3.5 ± 1.9	430.4 ± 123	243.9 ± 62
ES	—	7	1500	—	6.5–8.5	300	1000	10	0.02	50	1.5	0	0
The WHO	<15	5	1500	<300	6.5–8.5	300	1000	5	0.01	50	1.5	0	0

TU: turbidity unit, NTU: nephelometric turbidity unit, TSS: total suspended solid, EC: electrical conductivity, TH $CaCO_3$: total hardness, T°: temperature, TDSs: total dissolved solids, RC: residual chlorine, ND: not detected, BOD: biological oxygen demand, TC: total coliform, and FC: fecal coliform. The analytical results were statistically significant at $p < 0.05$. Means in columns followed by the same letter(s) are not significantly different at 5% level of significance. Water standard: ES: Ethiopian standard for drinking water quality and the WHO: the World Health Organization.

season was found to be higher than in the wet season. The findings are in line with Ngabirano et al. [60], who also reported a higher temperature in the dry season than in the wet season.

4. Conclusions

Water physico-chemical and bacteriological characteristics are important indicators of potable water quality. The Kosokol site (KS) is one the majorly polluted sites compared to others study sites, and the water quality at the site falls below the standard limits set for drinking water by Ethiopia and the WHO standards. The water quality during the wet season showed a significant deterioration compared to the dry season. In general, the study reveals that the physico-chemical and bacteriological characteristics vary with change in space and time. Moreover, the water quality deteriorates further during the wet season. Therefore, it is crucial to urgently focus on strengthening sustainable management practice in the catchment area to improve drinking water quality, reduce water treatment costs, and ensure human health security by mitigating waterborne disease. Furthermore, it is essential to enhance watershed management practices in the upper reach of the Gacheb catchment and conduct long-term studies at multilocations within the study area.

Abbreviations

BOD: Biological oxygen demand
EC: Electrical conductivity
ES: Ethiopian standard
FC: Fecal coliform
GS: Gacheb site
KS: Kosokol site
RS1: Reservoir 1
RS2: Reservoir 2
TC: Total coliform
TDS: Total dissolved solids
TH: Total hardness
TS: Tsit site
TSS: Total suspended solids.

Data Availability

All data generated or analyzed during this study are included within the article.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

Authors' Contributions

Zelalem Tadesse conceptualized the study and conducted experimental methodology investigation, data creation, validation, and original draft preparation. Mihret Dananto conducted methodology, data creation, investigation, validation, supervision, reviewing, and editing. Henok Kassa conducted experimental methodology, investigation, data creation, visualization, supervision, reviewing, and editing. Lalit Ingale conducted drafting of the manuscript, reviewing, and editing and is the corresponding author of the manuscript. All authors have read and approved the final manuscript.

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Supplementary Materials

Supplementary file 1: Figure 1: the three major rivers of the Mizan water treatment plant. Figure 2: onsite water quality measurement at different locations. Figure 3: different parts of the Mizan water treatment plant. (*Supplementary Materials*)

References

[1] M. Z. Hossain, "Water: the most precious resource of our life," *Glob. J. Adv. Res.*,vol. 2, pp. 1436–1445, 2001.
[2] L. Fewtrell and J. Bartram, *Water Quality: Guidelines, Standards and Health*, IWA publishing, London, UK, 2001.
[3] K. Katsanou and H. K. Karapanagioti, "Surface water and groundwater sources for drinking water," *Applications of Advanced Oxidation Processes (AOPs) in Drinking Water Treatment*, Springer, Cham, Switzerland, 2019.
[4] M. Chen, X. Qin, G. Zeng, and J. Li, "Impacts of human activity modes and climate on heavy metal spread in groundwater are biased," *Chemosphere*, vol. 152, pp. 439–445, 2016.
[5] J. A. Duran-Encalada, A. Paucar-Caceres, E. R. Bandala, and G. Wright, "The impact of global climate change on water quantity and quality: a system dynamics approach to the U.S.–Mexican trans border region," *European Journal of Operational Research*, vol. 256, no. 2, pp. 567–581, 2017.
[6] T. Dippong, C. Mihali, D. Năsui, Z. Berinde, and C. Butean, "Assessment of water physicochemical parameters in the strîmtori-firiza reservoir in northwest Romania," *Water Environment Research*, vol. 90, no. 3, pp. 220–233, 2018.
[7] World Health Organization, *UNFPA, World Bank: Trends in Maternal Mortality: 1990 to 2008". Estimates Developed by WHO, UNICEF*, World Health Organization, Geneva, Switzerland, 2010.
[8] World Health Organization, *Guidelines for Drinking-Water Quality [electronic Resource]": Incorporating First Addendum*, World Health Organization, Geneva, Switzerland, 2006.
[9] N. R. J. N. Tufenkji and M. Elimelech, "Bank filtration, a simple technology may inexpensively clean up poor-quality raw surface water," *Environmental Science and Technology*, vol. 36, p. 21, 2002.

[10] World Health Organization, *Water, Sanitation and hygiene Links to Health Facts and Figures*, World Health Organization, Geneva, Switzerland, 2004.

[11] World Health Organization, *Progress on Sanitation and Drinking Water: 2015 Update and MDG Assessment*, world health organization, Geneva, Switzerland, 2015.

[12] World Health Organization, *A Global Overview of National Regulations and Standards for Drinking-Water Quality*, World Health Organization, Geneva, Switzerland, 2018.

[13] R. Lenton, K. Lewis, and A. Wright, "Water, sanitation and the millennium development goal," *Journal of International Affairs*, vol. 61, no. 2, pp. 247–258, 2008.

[14] World Bank, "Ethiopia one wash—consolidated water supply, sanitation, and hygiene account project (One wash—CWA)," *International Development Association Project Appraisal Document Report Pad 3016*, World Bank, Washington, DC, USA, 2019.

[15] B. Patil, L. Ingale, and S. T. Ingle, "Evaluation of tropic status of certain lakes in Nagpur city"," *Environmental Sciences an Indian Journal*, vol. 5, no. 1, pp. 31–37, 2010.

[16] A. Woldesenbet, *Physicochemical and biological water quality assessment of Lake Hawassa for multiple designated water uses" Journal of Urban and Environmental Engineering*, vol. 9, pp. 146–157, 2015.

[17] Undp, *Statistical Update Development Annual Report of 2008*, Ministry of finance and economic development, New Delhi, India, 2008.

[18] G. Andualem and M. Yonas, "Prediction of sediment inflow to Legedadi reservoir using swat watershed and CCHE1D sediment transport models," *Nile basin Water Engineering Scientific Magazine*, Waterethiopia, Addis Ababa, Ethiopia, 2008.

[19] Z. A. Alemu, K. T. Teklu, T. A. Alemayehu, K. H. Balcha, and S. D. Mengesha, "Physicochemical quality of drinking water sources in Ethiopia and its health impact: a retrospective study," *Environmental Systems Research*, vol. 4, no. 1, p. 22, 2015.

[20] H. Negash, *Assessment of Physicochemical and Bacteriological Quality of Drinking Water Supply from Different Boreholes of Addis Ababa*, Addis Ababa University, Addis Ababa, Ethiopia, 2018.

[21] E. Bernard and N. Ayeni, "Physicochemical analysis of groundwater samples of Bichi local government area of Kano state of Nigeria," *World Environment*, vol. 2, no. 6, pp. 116–119, 2012.

[22] H. Yohannes and E. Elias, "Contamination of rivers and water reservoirs in and around Addis Ababa city and actions to combat it"," *Environ Pollut Climate Change*, vol. 01, no. 02, pp. 1–12, 2017.

[23] A. Ayaliew Werkneh, B. Zimbelachew, and A. Kelemwork, "Physico-chemical analysis of drinking water quality at Jigjiga city, Ethiopia," *American Journal of Environmental Protection*, vol. 4, no. 1, pp. 29–32, 2015.

[24] E. Chekole, H. Kassa, A. Aschalew, and L. Ingale, "Physicochemical characterization of dembi reservoir water for suitability of fish production, southwest Ethiopia," *Biochemistry Research International*, vol. 2022, Article ID 1343044, 9 pages, 2022.

[25] H. Kassa, A. Frankl, S. Dondeyne, J. Poesen, and J. Nyssen, "Sediment yield at southwest Ethiopia's forest Frontier," *Land Degradation and Development*, vol. 30, no. 6, pp. 695–705, 2019.

[26] K. W. Wolancho, "Watershed management: an option to sustain dam and reservoir function in Ethiopia"," *Journal of environmental science and technology*, vol. 5, no. 5, pp. 262–273, 2012.

[27] E. Assegide, T. Alamirew, Y. T. Dile, H. Bayabil, B. Tessema, and G. Zeleke, "A synthesis of surface water quality in awash basin, Ethiopia," *Front. Water*, vol. 4, Article ID 782124, 2022.

[28] Macwe-Rws-Spc, *Mizan-Aman City Administration Water Supply Raw Water Supply Sediment Prevention and Controlling Project*, Macwe-Rws-Spc, Bangalore, India, 2014.

[29] S. K. Sundaray, U. C. Panda, B. B. Nayak, and D. Bhatta, "Multivariate statistical techniques for the evaluation of spatial and temporal variations in water quality of the Mahanadi River–estuarine system (India)"—a case study"," *Environmental Geochemistry and Health*, vol. 28, no. 4, pp. 317–330, 2006.

[30] H. Bu, X. Tan, S. Li, and Q. Zhang, "Temporal and spatial variations of water quality in the jinshui river of the south qinling mts., China"," *Ecotoxicology and Environmental Safety*, vol. 73, no. 5, pp. 907–913, 2010.

[31] L. C. Jeznach, C. Jones, T. Matthews, J. E. Tobiason, and D. P. Ahlfeld, "A framework for modeling contaminant impacts on reservoir water quality," *Journal of Hydrology*, vol. 537, pp. 322–333, 2016.

[32] National meteorology agency, "Ethiopia meteorology station 30-year rainfall data," *New Merged 30-year Climate Time Series*, National meteorology agency, Addis Ababa, Ethiopia, 2013.

[33] Central Statistical Agency, "Ethiopia population projection based on 2007 census," *Regional, Zonal, District and Town Level Population Data*, Central Statistical Agency, Addis Ababa, Ethiopia, 2019.

[34] American Public Health Association, *Standard Methods for the Examination of Water and Wastewater*, American Public Health Association, Washington, DC, USA, 1998.

[35] W. Kebede, M. Tefera, T. Habitamu, and T. Alemayehu, "Impact of land cover change on water quality and stream flow in lake Hawassa watershed of Ethiopia"," *Agricultural Sciences*, vol. 05, no. 08, pp. 647–659, 2014.

[36] C. Monica, *Microbiology Tests Part 2". District Laboratory Practice Tropical Countries*, Cambridge, Cambridge, United Kingdom, 2002.

[37] L. Clesceri, A. Greenberg, and A. Eaton, *Standard Methods for the Examination of Water and Wastewater"*, American public health association, Washington, DC, USA, 1998.

[38] L. Nyanti, C. L. Soo, and M. S. Danial-Nakhaie, "Effects of water temperature and pH on total suspended solids tolerance of Malaysian native and exotic fish species" Aquaculture, aquarium," *Conservation and Legislation*, vol. 11, no. 3, pp. 565–575, 2018.

[39] Who, "Guidelines for drinking-water quality," *Health Criteria and Other Supporting Information*, WHO, Geneva, Switzerland, 2nd edition, 1996.

[40] G. Göransson, M. Larson, and D. Bendz, "Variation in turbidity with precipitation and flow in a regulated river system – river Göta Älv, SW Sweden," *Hydrology and Earth System Sciences*, vol. 17, no. 7, pp. 2529–2542, 2013.

[41] O. Adeola Fashae, H. Abiola Ayorinde, A. Oludapo Olusola, and R. Oluseyi Obateru, "Landuse and surface water quality in an emerging urban city," *Applied Water Science*, vol. 9, no. 2, p. 25, 2019.

[42] R. Bhateria and D. Jain, "Water quality assessment of lake water: a review," *Sustainable Water Resources Management*, vol. 2, no. 2, pp. 161–173, 201.

[43] H. M. Hart, "Effect of land use on total suspended solids and turbidity in the little river watershed, Blount county," 2006, https://trace.tennessee.edu/utk_gradthes/1569.

[44] G. Goel and S. Kaur, "A study on chemical contamination of water due to household laundry detergents," *Journal of Human Ecology*, vol. 38, no. 1, pp. 65–69, 2012.

[45] N. Sulaiman and Z. Mohd Kasim, "The efficacy of treated water from water filtration machines for safe drinking water supply in bandar baru bangi and kajang, selangor," *Journal of Food Quality*, vol. 2020, p. 9, 2020.

[46] M. Dudziak and E. Kudlek, "Removal of hardness in wastewater effluent using membrane filtration"," *Architecture Civil Engineering Environment*, vol. 12, no. 2, pp. 141–147, 2019.

[47] A. F. Rusydi, "Correlation between conductivity and total dissolved solid in various type of water: a review," in *IOP Conference Series Earth and Environmental Science*, IOP publishing, Bristol, UK, 2018.

[48] J. N. Edokpayi, J. O. Odiyo, and O. S. Durowoju, "Impact of wastewater on surface water quality in developing countries: a case study of South Africa," *Water Quality*, vol. 20, pp. 401–416, 2017.

[49] S. Susilowati, J. Sutrisno, M. Masykuri, and M. Maridi, "Dynamics and factors that affects DO-BOD concentrations of Madiun river," *AIP Conference Proceedings*, vol. 2049, no. 1, pp. 020–052, 2018.

[50] D. Dunea, P. Bretcan, D. Tanislav et al., "Evaluation of water quality in ialomita river basin in relationship with land cover patterns," *Water*, vol. 12, no. 3, p. 735, 2020.

[51] O. M. Roşca, T. Dippong, and M. Marian, "Impact of anthropogenic activities on water quality parameters of glacial lakes from Rodnei Mountains, Romania," *Environmental Research*, vol. 182, pp. 109–136, 2020.

[52] B. Wu, W. Zeng, H. Chen, and Y. Zhao, "Grey water footprint combined with ecological network analysis for assessing regional water quality metabolism," *Journal of Cleaner Production*, vol. 112, no. 4, pp. 3138–3151, 2016.

[53] S. E. Yeo, F. P. Binkowski, and J. E. Morris, "Aquaculture effluents and waste by-products characteristics, potential recovery, and beneficial reuse," 2004, https://dr.lib.iastate.edu/handle/20.500.12876/55943.

[54] J. Causse, E. Baurès, and Y. Méry, "Variability of N Export in water: a review," *Critical Reviews in Environmental Science and Technology*, vol. 45, no. 20, pp. 2245–2281, 2015.

[55] J. Górski, K. Dragon, and P. M. J. Kaczmarek, "Nitrate pollution in the warta river (Poland) between 1958 and 2016: trends and causes," *Environmental Science and Pollution Research*, vol. 26, no. 3, pp. 2038–2046, 2019.

[56] A. Onyango, M. Okoth, C. Kunyanga, and B. O. Aliwa, "Microbiological quality and contamination level of water sources in Isiolo County in Kenya," *Journal of Environmental and Public Health*, vol. 2018, Article ID 2139867, 10 pages, 2018.

[57] S. Haydar, M. Arshad, and J. A. Aziz, "Evaluation of drinking water quality in urban areas of Pakistan: a case study of southern Lahore," *Pakistan Journal of Engineering Applied Sciences*, vol. 5, pp. 16–23, 2009.

[58] I. S. Ioryue, R. Wuana, and A. Augustine, *Seasonal Variation in Water Quality Parameters of River Mkomon Kwande Local Government Area*, Federal University of Lafia, Lafia, Nigeria, 2018.

[59] Z. Mohd Shafiq, M. S. Amir Shah Ruddin, H. H. Zarul, P. Khaled, M. Syaiful, and W. O. Wan Maznah, "The effect of seasonal changes on freshwater fish assemblages and environmental factors in bukit merah reservoir (Malaysia)," *Transylvanian Review of Systematical and Ecological Research*, vol. 16, no. 1, pp. 97–108, 2015.

[60] H. Ngabirano, D. Byamugisha, and E. Ntambi, "Effects of seasonal variations in physical parameters on quality of gravity flow water in Kyanamira sub-county, Kabale district, Uganda," *Journal of Water Resource and Protection*, vol. 08, no. 13, pp. 1297–1309, 2016.