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Vulnerability of Rural Communities to Contaminated Water and Its Implications: A Case Study from KSD Local Municipality

Tokozani Mangesi, Asabonga Mngeni*

Department of Biological and Environmental Sciences, Walter Sisulu University, Mthatha Private Bag X1 UNITRA 5117, South Africa

Corresponding Author Email: amngeni@wsu.ac.za

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ABSTRACT

Supplying adequate water and sanitation facilities to small, scattered rural communities and/or large, fast growing settlements in remote areas is a challenge not easily met anywhere in the world. The aim of this study was to identify and evaluate the alternative water sources used in the Xwili administration area in King Sabata Dalindyebo local municipality. To determining the water quality parameters in all the identified springs (Escherichia coli, turbidity, pH, temperature, electrical conductivity, nitrite, nitrate, ammonia, phosphate, sulphate, magnesium, and calcium), Membrane filtration technique, Hanna multiprobe parameter, Hanna turbidity meter, and HACH DR 900 were employed. Analysis of Variance (one-way ANOVA) utilizing the Statistical Package for Social Sciences (SPSS) was used to analyse the data. The study's findings showed that the guidelines for domestic water use and the data on water quality matched. The study's conclusions, including those regarding pH, nitrite, nitrate, ammonia, sulphate, phosphate, magnesium, and calcium, are in accordance with domestic water use guidelines. On the other hand, turbidity levels exceeded the domestic water use guidelines.

1. INTRODUCTION

Apart from being a human right, water is a basic nutrient of the human body and is critical to human development, however, water service delivery continues to be a challenge in most developing countries including South Africa [1]. According to United Nations (UN) [2], access to safe drinking water is crucial for poverty reduction, sustainable development and for achieving any and every one of the Millennium Development Goals. Although that is the case, about 1.2 billion people, constituting about one-fifth of the world's population, live in areas of physical water scarcity, and 500 million people are approaching this situation [3]. Domestic water demand has been growing at more than twice the rate of population increase, and there is an increasing number of developing cities in the world that are chronically experiencing water service backlogs [4].

The problems of water service delivery in rural communities are a continuous concern which has, in many instances, left communities with no choice but to rely on unprotected water sources such as rivers, streams, springs and hand dug wells [5]. According to Damba-Hendrik [6] this water is used for all domestic purposes including cooking and drinking, and it is consumed without any prior treatment. Meride and Ayenew [7] assert that since these sources are not protected, they are vulnerable to animal and human contamination, making the water dangerous to drink, but they are the sole supply that is available virtually all year.

Springs have traditionally served as a source of water for humans, particularly in arid locations with little annual rainfall [8]. According to Annalakshmi and Amsath [9], springs contain less than 1% of the world's fresh water and have greater ecological and social significance. They are being polluted by indiscriminate disposal of sewerage, industrial waste, and excess human activity, which affects their physicochemical characteristics and has a variety of negative effects on aquatic organisms and human beings [8].

Water quality gives up-to-date information on the concentrations of different solutes at a specific location and time. Its quality defines its utility for any purpose [10]. Depending on the requirements, water may be tested for certain characteristics and its contamination is defined by numerous physical, chemical, and biological factors. Increased anthropogenic activities because of urbanization, industrialization and unregulated mining amongst others have contributed to a reduction in water quality. Even when no pollution is present, the water quality of rivers and lakes varies with the seasons and geographical [8]. Water quality may be thought of as a network of parameters such as electric conductivity, pH, dissolved oxygen, temperature, and so on, and any changes in these physical and chemical variables can have a wide range of effects on biota [11]. According to Singh et al. [12], since water quality is directly tied to health and is crucial for determining water utility, it is critical to assess the quality of water before it is utilized for drinking and domestic reasons. Water's utility for diverse purposes is determined by its physicochemical and biological qualities.

The lack of capacity within municipalities has a way of impacting negatively on issues of operation and maintenance and other issues required in facilitating service provision, leaving municipalities unable to attend to these challenges as they would like to [13]. Rural municipalities including King Sabatha Dalindyebo Local Municipality (KSDLM) are struggling to provide services to communities such as water, as per constitutional mandate. KSDLM is largely rural in character, and some of its areas were provided with communal standpipes. Yet communities still experience the problem of water service delivery which has in many instances forced residents to consider unprotected springs that are prone to pollution as alternate sources of water for domestic use. Therefore, the present paper focuses on the physicochemical quality of the selected springs water and effect of pollutants. In order to ascertain whether spring water is safe for human consumption, the study aims to assess the degrees of physical, chemical, and microbiological pollution. The study's second objective is to examine possible pollution sources and how they affect the quality of spring water. Lastly, the study aims to supply information to guide management strategies for water quality, assisting in the enhancement of water quality through focused initiatives like pollution prevention or habitat restoration near spring sources. The study's hypothesis is that Xwili's alternative water sources do not adhere to South African household water use regulations.

2. MATERIALS AND METHODS

2.1 Study area

The study was carried out in Xhwili administration area Ward 32 of King Sabata Dalindyebo local municipality, Eastern Cape Province, South Africa. The municipality is generally hot and humid, and it receives much of its rainfall during summer season. The study area includes three sampling points (springs) that were randomly selected as natural sources of water that serves the area (Mkhanzini 31°44'08,09"S; 28°36'11,11"E, one in Matyenengqina, 31°44'15,45"S; 28°37'13,85"E, and Konqeni, 31°45'31,41"S; 28°37'14,23"E), refer to Figure 1 below.

2.2 Sampling design

The study had three sampling sites: Matyenengqina, Mkhanzini and Konqeni, which were purposefully selected to incorporate sites that exhibit characteristics or conditions pertinent to the research subject, which is springs that are currently used as alternate water sources and that leads to better understanding of the investigation in question.

A total of 324 water samples were collected 9 times once a week between July and October 2023. Twelve water parameters were tested, including physical parameters (temperature and pH) and chemical parameters (electrical conductivity, nitrite, nitrate, phosphate, and sulphate) tested onsite. Hardness (calcium and magnesium) was measured using the HACH DR 900 onsite. For microbial activities (E. coli and total coliforms) sterile bottles were used to collect water samples, and the containers were labelled with the location, date, and time of the sampling. The samples were delivered to the national pollution laboratory in two hours after being promptly stored in a cooler with ice packs. The membrane filtration method was used, where a 100 mL water sample was filtered through a membrane with a pore size of 0.45 mm. After filtration, the bacteria remained on the filter paper was placed in a petri dish with a nutrient solution. The Petri dishes were placed in an incubator at 35°C. After incubation, the bacteria colonies were seen using a magnifying glass. A colony counter was used to count the colonies in each square of the membrane filter. The CFU/mL sample (100) was determined for the colony count by dividing the total number of colonies by the sample volume multiply by 100 (×100).

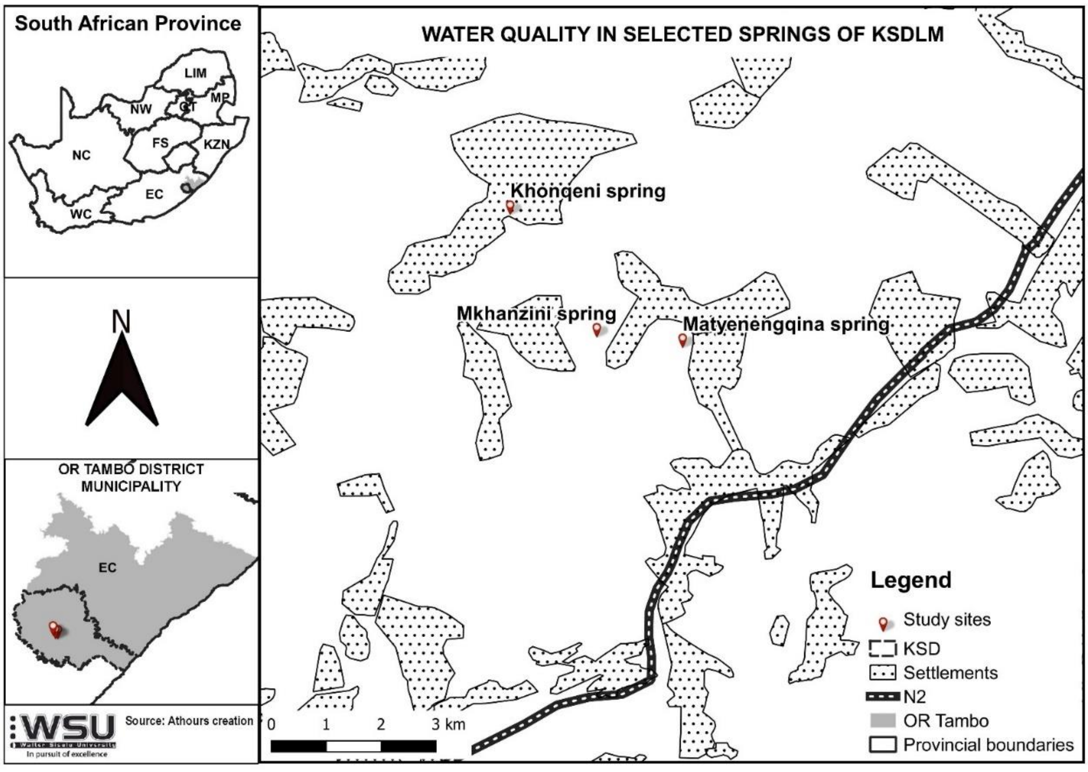

Figure 1. Map of KSDLM showing the three selected springs

2.3 Data analyses

Data collected was examined and entered to the Statistical Package for Social Sciences (SPSS) software. Subsequently, Shapiro wilk test was used to test for data normality for each water parameter. Temperature and calcium data was found to be normally distributed, whereas all other parameters (electrical conductivity, turbidity, pH, ammonia, nitrite, nitrate, phosphate, sulfate, magnesium, E. coli, and total coliform) were not normally distributed. To determine whether the normal distributed water parameters were the same across the different sampling stations, one way analysis of variance (ANOVA) was utilized. One-way ANOVA contrasts the means of more than two normally distributed samples/observations [14-16]. When one-way ANOVA showed significant differences, the Tukey HSD test was used for pair-wise comparisons between the site categories. In order to ascertain whether the water parameters from the three sampling sites were identical, a non-parametric test known as the Kruskal-Wallis test was used to compare the water parameters that were discovered to be non-normally distributed, including electrical conductivity, pH, ammonia, nitrite, nitrate, phosphate, sulfate, magnesium, E. coli, and total coliform.

The South African National Standards (SANS) for domestic water use were used to determine whether the water from the three sampling stations is fit for human consumption. To further assess whether the water quality of each of the three springs is in good or poor state, the weighted Water Quality Index (WQI) was utilized. Lastly, permutational ANOVA in PRIMER 7 was used to check for water quality parameters composition across the three sites. Significant differences in the composition of water parameters across the three sampling stations were visualised using canonical analysis of principal coordinates [17].

Water quality index: The WQI has been determined using the drinking water quality recommended by South African Bureau Standards (SABS), and has been calculated using the weighted arithmetic method, which was originally proposed by Horton [18] and developed by Brown et al. [19]. Water parameters, both biological and physicochemical, were examined to determine whether they were suitable for human consumption. The weighted arithmetic WQI is represented in the following way [20]:

$$\text{WQI} = \sum_{i=1}^{n} W_i\, Q_i / \sum_{i=1}^{n} W_i \quad (1)$$

where, n = number of variables or parameters, W_i = unit weight for parameter, Q_i = quality rating (sub-index) of the i_{th} water quality parameter. The unit weight (W_i) of the various water quality parameters is inversely proportional to the recommended standards for the corresponding parameters.

$$W_i = K / S_n \quad (2)$$

"K" was calculated using the following equation [21]:

$$K = 1 / \sum\left(\frac{1}{S_n}\right) \quad (3)$$

where, W_i = unit weight factor, K is the proportional constant and S_i is the standard permissible value of i_{th} parameter. The quality rating scale (Q_i) of i_{th} parameter of contaminated water was calculated using the following equation:

$$Q_i = \frac{V_i}{S_i} \times 100\% \quad (4)$$

where, Q_i is the quality rating scale of i_{th} parameter, V_i is the mean concentration of i_{th} parameter and S_i the standard permissible value of i_{th} parameter. After finding W_i and Q_i both values were multiplied by each other by having $W_i\,Q_i$.

$$W_iQ_i = W_i \times Q_i \quad (5)$$

The overall WQI was calculated using the following equation:

$$\text{WQI} = \sum_{i=1}^{n} \text{W}_\text{i} \times \text{Q}_\text{i} \quad (6)$$

3. RESULTS

The Konqeni spring had the highest mean temperature concentration (M = 16.35, SD = 2.53), followed by Matyenengqina (M = 15.30, SD = 2.12), and Mkhanzini spring (M = 15.02, SD = 1.56). Additionally, Khonqeni spring had highest mean calcium concentration (M = 2.70, SD = 1.004), followed by Matyenengqina spring (M = 1.90, SD = 1.08), and Mkhanzini (M = 1.74, SD = 1.34). Using a statistically significance level of p = 0.05 for the test of homogeneity of variance, the p-value is 0.07, which is greater than 0.05, therefore we failed to reject the null hypothesis which states that there is no difference in concentration of water parameters across the sampling sites, thus, necessitating interpretation of ANOVA table.

The distribution of physical water parameters (turbidity and electrical conductivity) (Figure 2), secondly, pH, ammonia, nitrate and sulphate (Figure 3), varied between sampling points. Moreover, microbial water parameters (E. coli and total coliforms) (Figure 4) varied between the sampling points ($p < 0.001$) refer to Table 1. The results show that Matyenengqina's turbidity was much lower than Konqeni's ($p < 0.001$) (Figure 2a). In the same way, Matyenengqina's turbidity level was higher than Mkhanzini's ($p = 0.001$) (Figure 2a). The sampling site at Mkhanzini and Konqeni did not significantly differ (p = 0.46, Figure 2a). The electrical conductivity of the Mkhanzini sampling site was found to be significantly greater than that of the Konqeni ($p < 0.001$) and Matyenengqina ($p = 0.003$) sampling sites (Figure 2b). But there was no difference between the Konqeni sampling site and the Matyenengqina sampling sites ($p = 0.223$) (Figure 2b). As shown in Figure 3a, the pH of the Mkhanzini sampling site was significantly higher than that of the Matyenengqina site ($p = 0.029$) and the Konqeni sample site ($p < 0.001$). However, there was no difference between the Konqeni and Matyenengqina sampling sites ($p = 0.06$) (Figure 3a). Figure 3b shows that the ammonia level at Konqeni sampling site was substantially greater than that at Mkhanzini ($p= 0.008$). Both the Matyenengqina and Mkhanzini sample sites ($p = 0.41$) and the Matyenengqina and Konqeni sampling sites ($p = 0.07$) did not significantly differ from one another (Figure 3b). Nitrate levels at the Konqeni site ($p = 0.003$) and Mkhanzini sampling site ($p = 0.001$) are much lower than those at the Matyenengqina sampling site, as Figure 3c illustrates. There was no discernible difference between the Konqeni and Mkhanzini sampling sites ($p = 0.17$) (Figure 3c). As shown in Figure 3d, the sulphate level at Konqeni sample site was substantially greater than that at Mkhanzini sampling site ($p = 0.006$) and Matyenengqina ($p < 0.001$). But there was no discernible difference between the Matyenengqina and Mkhanzini sampling sites ($p = 0.07$) (Figure 3d). In comparison to Mkhanzini ($p < 0.001$) and Konqeni ($p = 0.015$), the Matyenengqina sampling site showed significantly higher E. coli levels (Figure 4a). Similarly, Figure 4a shows that the E. coli levels at Mkhanzini sampling site were considerably lower than those at Konqeni sample site ($p = 0.015$). The total coliform count at the Matyenengqina sampling site was found to be considerably higher than that of the Mkhanzini ($p = 0.015$) and Konqeni ($p = 0.015$) sampling sites (Figure 4b). Furthermore, Figure 4b shows that the total coliforms from Konqeni sampling site were substantially lower ($p = 0.015$) than those from Mkhanzini sampling site. Lastly, other water parameters (nitrite, phosphate, magnesium, calcium, and temperature) did not differ significantly.

The sampling sites significantly impacted (Pseudo-F = 9.81, $P = 0.0001$) the composition of water quality parameters. The composition of water quality parameters at Konqeni spring differed from that at Matyenengqina spring ($t = 2.32$, $p = 0.0001$) and Mkhanzini ($t = 3.94$, $p = 0.0002$) (Figure 5). Lastly, the composition of water quality parameters at Matyenengqina spring differed from that at Mkhanzini spring ($t = 3.24$, $p = 0.0001$) (Figure 5).

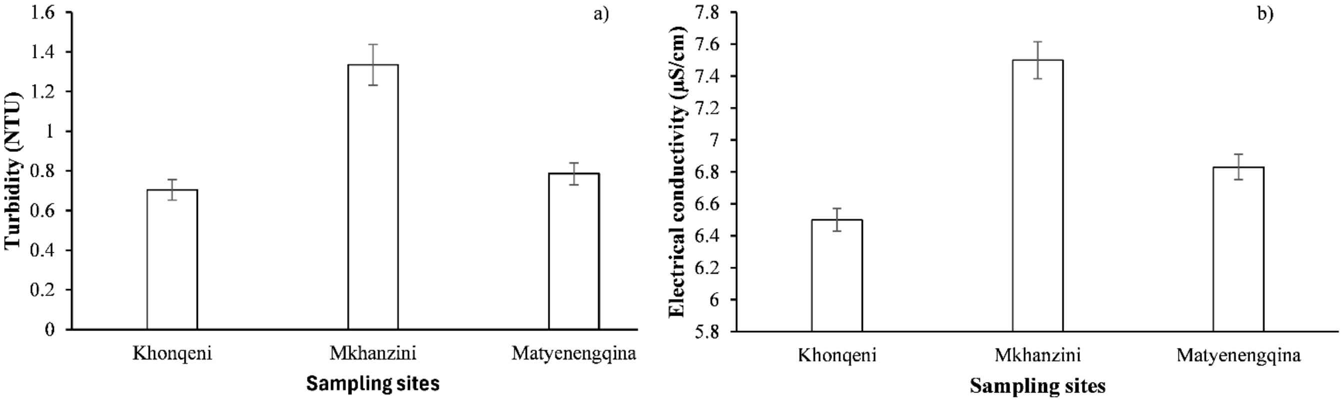

Figure 2. Bar graph showing phyical water concentartions across the 3 sampling sites

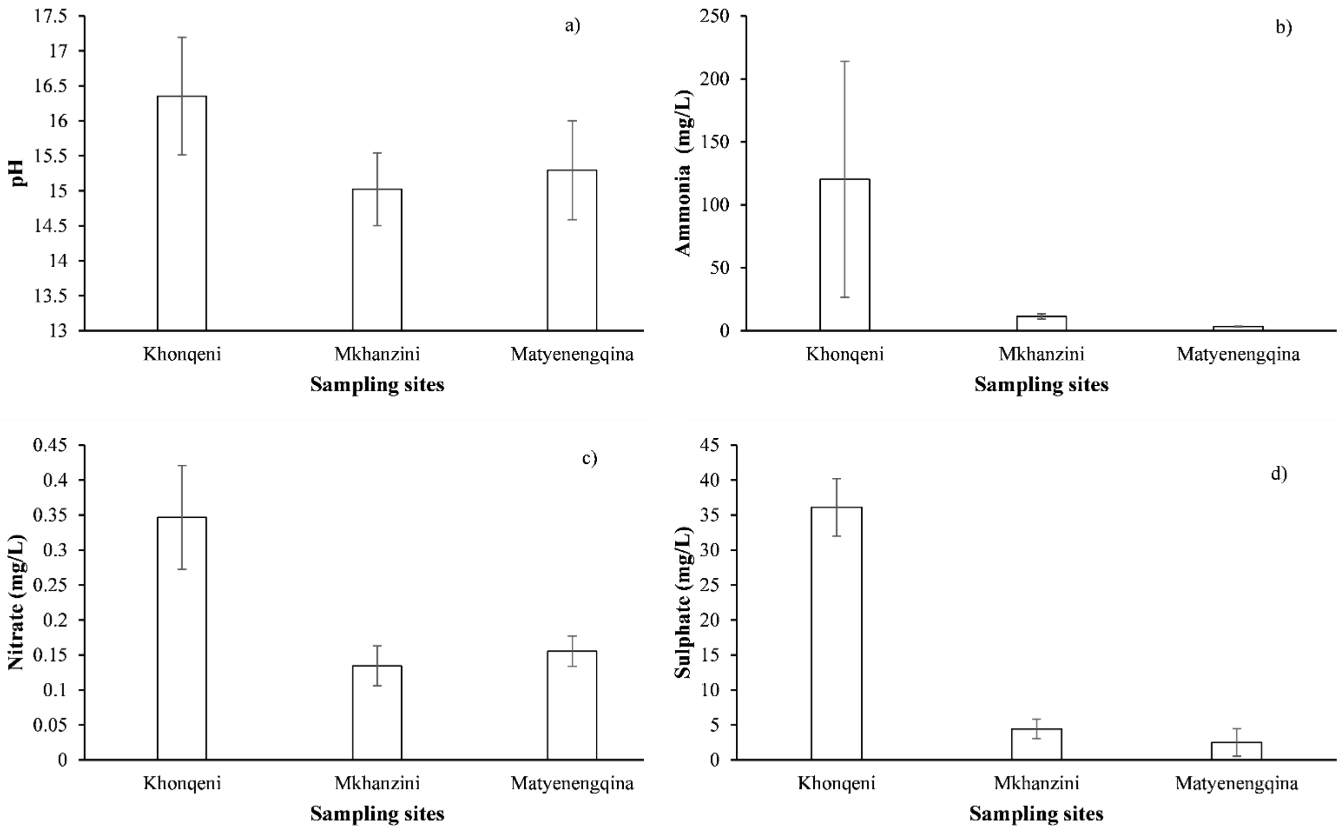

Figure 3. Bar graphs showing the concentration of chemical water properties

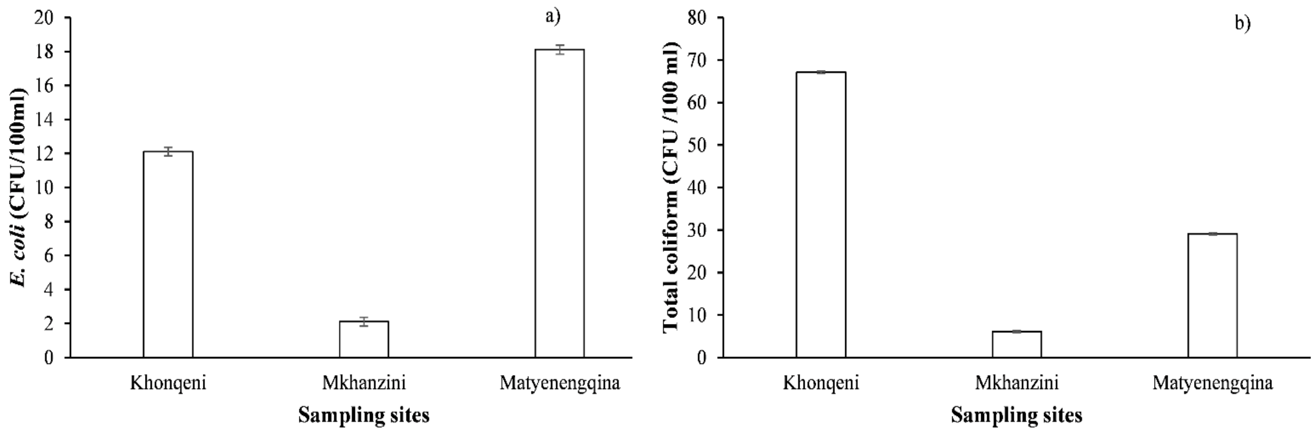

Figure 4. Bar graph showing the concentration of biological water properties

Table 1. Kruskal-Wallis and ANOVA statistical test results

Kruskal-Wallis			**ANOVA**				
	X^2	p		SS	MS	F-value	p
pH	16.84	**0.001**	Temperature	8.89	4.44	1.00	0.38
Electrical conductivity	18.84	**0.001**	Calcium	4.65	2.33	1.76	0.19
Turbidity	17.91	**0.001**					
Ammonia	7.46	**0.022**					
Nitrate	19.24	**0.001**					
Nitrite	1.53	0.47					
Phosphate	1.60	0.35					
Sulphate	20.75	0.001					
Magnesium	1.12	0.57					
E. coli	23.47	**0.001**					
Total coliform	23.47	**0.001**					

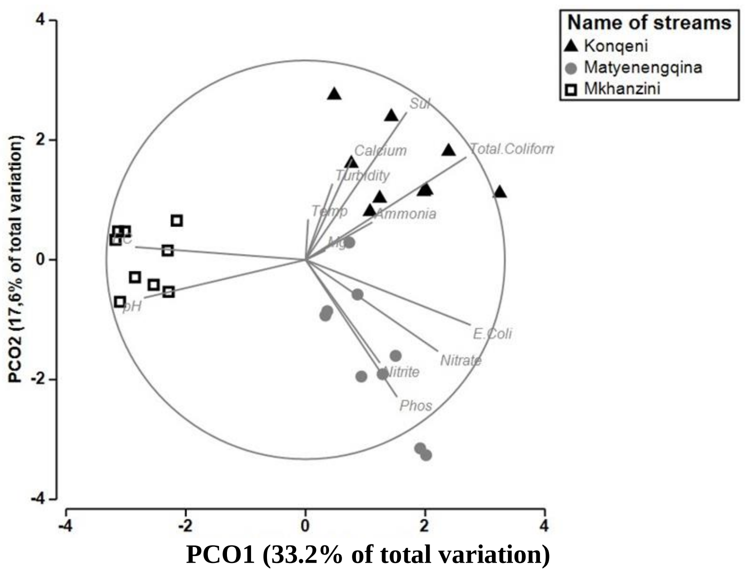

Figure 5. Canonical analysis of principal coordinates (CAP) of the physico-chemical and biological water quality parameters

3.1 Water quality index

According to the weighted arithmetic WQI values, the three springs of Xwili location that were selected for testing have water quality and status that is unfit for human consumption (>100). According to the water WQI data, Matyenengqina spring has the lowest WQI value (170,962), Konqeni spring has the greatest WQI value (3,850.759), and Mkhanzini spring comes in second with a WQI value (362,759) (see Table 2).

Table 2. Water quality index and its quality class for the three selected springs

Spring Name	Source	WQI Value	Class
Matyenengqina	Spring	1,709,623.685	Unfit for consumption
Mkhanzini	Spring	3,627,587.737	Unfit for consumption
Konqeni	Spring	3,850,083.527	Unfit for consumption

3.2 Correlation

The correlation results for the three selected spring of Xwili are shown in Table 3. The correlation indicates water quality indicator relationship or common pollution sources as well as mutual dependents or similar activities in an area [22-24]. The study found a statistically significant association (*r* = 0.385, p = 0.047) between pH and sulphate at the 0.05 significant level. Ammonia further demonstrated a significant association with total coliforms (*r* = 0.418, p = 0.030) and sulphate (*r* = 0.473, p = 0.013). Furthermore, in relation to Ca (*r* = 0.424, p = 0.028), Mg (*r* = 0.401, p = 0.038), E. coli (*r* = -0.404, p = 0.037), and total coliforms (*r* = 0.438, p = 0.022), sulphate demonstrated a statistically significant association.

Table 3. Correlation between microbiological and physico-chemical indicators revealed the Mthatha River's water quality

		pH	**EC (μs/cm)**	**Turbidity (NTU)**	**Ammonia (mg/L)**	**Nitrate (mg/L)**	**Nitrite (mg/L)**	**P (mg/L)**	**Sulphate (mg/L)**	**Ca (mg/L)**	**Mg (mg/L)**	**E. Coli (CFU/100mL)**	**Total Coliforms (CFU/100mL)**
Spearman's Rho	Temperature	-0.15 (0.45)	0.20 (0.31)	0.09 (0.67)	0.12 (0.56)	0.09 (0.68)	0.02 (0.92)	-0.14 (0.48)	0.12 (0.55)	0.06 (0.77)	0.002 (0.99)	0.14 (0.47)	0.25 (0.21)
	pH		0.71** (**0.000**)	-0.01 (0.98)	-0.49** (**0.01**)	-0.33 (0.096)	-0.24 (0.24)	-0.199 (0.32)	-0.385* (**0.047**)	-0.21 (0.29)	-0.25 (0.21)	-0.35 (0.08)	-0.705** (**0.000**)
	EC			0.11 (0.59)	-0.27 (0.17)	-0.33 (0.097)	-0.17 (0.40)	-0.43 (0.23)	-0.33 (0.98)	-0.20 (0.31)	-0.12 (0.57)	-0.51 (0.01)	-0.74 (0.000)
	Turbidity				0.17 (0.39)	-0.74** (**0.000**)	0.084 (0.68)	-0.05 (0.80)	0.68** (**0.000**)	0.03 (0.89)	0.03 (0.89)	-0.59** (**0.001**)	0.15 (0.45)
	Ammonia					0.15 (0.44)	0.30 (0.13)	-0.19 (0.34)	0.473* (**0.013**)	0.37 (0.06)	0.21 (0.29)	0.07 (0.72)	0.418* (**0.030**)
	Nitrate						-0.05 (0.81)	0.10 (0.62)	-0.456* (**0.017**)	-0.05 (0.82)	-0.08 (0.69)	0.797** (**0.000**)	0.25 (0.21)
	Nitrite							0.09 (0.65)	0.30 (0.13)	0.01 (0.98)	0.10 (0.62)	-0.09 (0.67)	0.12 (0.57)
	P								0.05 (0.82)	-0.16 (0.43)	-0.03 (0.90)	0.22 (0.26)	0.24 (0.23)
	Sulphate									0.424* (**0.028**)	0.401* (**0.038**)	-0.404* (**0.037**)	0.438* (**0.022**)
	Ca										0.24 (0.23)	0.01 (0.95)	0.26 (0.19)
	Mg											-0.26 (0.18)	-0.08 (0.71)
	E. coli												0.549** (**0.003**)

Note: **. Correlation is significant at the 0.01 level (2-tailed); *. Correlation is significant at the 0.05 level (2-tailed).

4. DISCUSSION

4.1 Biological parameters

Studying Escherichia coli and total coliform in drinking water is crucial for safeguarding public health, as these microorganisms serve as indicators of fecal contamination and potential pathogens. Keeping an eye on them makes it easier to spot problems with the water quality and put the right solutions in place to guarantee safe drinking water. When evaluating the safety of water, E. coli is crucial since it is a specific indicator of fecal pollution [25]. Compared to other fecal coliforms, its detection is more accurate and economical, improving the monitoring of drinking water quality [25]. Localized water quality assessments are necessary because studies have revealed that E. coli levels vary by region [26]. There are serious health problems associated with the possible emergence of antibiotic resistance when E. coli is present in drinking water [27]. Waterborne disease epidemics can result from contaminated water sources, which highlights the necessity of routine testing [28].

4.1.1 Escherichia coli

The results of this study indicate that the springs water quality is impaired. While nitrite, phosphate, magnesium, calcium, and temperature are unaffected, land-use activities such as livestock farming, crop farming, and others alter water quality parameters such as ammonia, pH, electrical conductivity, turbidity, sulphate, E. coli, total coliforms, and nitrate. It appears that these water parameters have a common source due to the significant positive correlation that exists between them [29]. Similarly, Vika et al. [30] also discovered a significant positive correlation between total coliform and E. coli in Mthatha river catchment.

Humans and domestic animals such as grazing cattle, sheep's, goats, pigs, dogs, donkeys, share water from the selected springs. Therefore, the prevalence of E. coli and total coliforms in the springs may have resulted from people and animals sharing water. For example, in the study area, animals use water from the spring while tissue paper with human faeces was found in one of the streams. A study conducted by Al-Hamaiedeh et al. [31] in South Jordan also found that spring water had higher E. coli levels. These findings are in line with those of Sara et al. [32], who discovered that domestic animals contribute to faecal contamination of water. Conversely, the results of this investigation contradict those of Tchoumou et al. [33], who reported good microbiological quality because no microorganisms were found in their study.

Vomiting, cramping in the abdomen, bloody diarrhoea, and other health issues can result from drinking water tainted with Escherichia coli. These symptoms can range widely in intensity and provide serious health hazards, especially for young children (less than five years old) [34]. The UN Sustainable Development Goal 6 promote access to safe and affordable drinking water. This is violated when E. coli is found in drinking water. Given that residents of the study area are thereafter compelled to buy water from water tanker vendors, particularly those who can afford it. Since some individuals would have access to pathogen-free water while others will be drinking water tainted with germs, this scenario further exacerbates inequality as per sustainable development goal 10.

4.1.2 Total coliform

The total coliform found in the study is higher than the 10 CFU/mL WHO [35] and 0-5 CFU/mL DWAF [36] recommended limits. Al-Hamaiedeh et al. [31] also found that spring water had higher total coliform levels. According to Divya and Solomon [37], human and animal waste is typically the source of total coliform. When they drink water from the springs, animals relieve themselves. The investigation's total coliform source could be the animal faeces dumped into the water and the runoff that carried the waste into the springs. Furthermore, the existence of total coliform in water can be explained by the unsanitary conditions in the study location. In a similar vein, Vika et al. [30] linked inadequate sanitation to the occurrence of total coliforms in water. Therefore, the water from the springs needs to be disinfected before it can be used for domestic purposes. Headaches, cramps, nausea, and diarrhea are among the gastrointestinal problems that can result from drinking water tainted with total coliform. Additionally, it might signal the presence of dangerous fecal infections, raising the possibility of developing severe illnesses such hemolytic uremic syndrome [38].

4.2 Physical parameters

The health concerns connected to waterborne infections can be greatly impacted by physical factors such as temperature, pH, turbidity, and total dissolved solids (TDS). Frequent evaluation of these attributes aids in the detection of contamination and guarantees adherence to health regulations. Monitoring physical properties helps to detect contaminants that can lead to diseases like cholera and typhoid [39].

4.2.1 Turbidity

The study's findings indicated that the turbidity levels were higher than what is considered safe for drinking water. For example, study area turbidity levels are above the recommended limit of <5 NTU for drinking purposes by WHO [35] and 0-1 NTU [36]. The elevated turbidity levels may have been caused by domestic animals sharing the same spring with people. For example, the author once discovered a pig swimming in one of the springs, which caused the water to become rather murky. Additionally, the fact that the study was carried out during the dry season and that the sampling locations are close to a gravel road and a place where there is farming, which causes dust particles to become suspended. Similar findings were made by Bwire et al. [40], who also found higher turbidity levels that were above WHO recommendations [35]. Contrarily studies conducted elsewhere discovered turbidity levels which were within the acceptable levels of WHO standards [31, 35, 40]. Turbidity levels which are within acceptable standards were attributed to low precipitation during the sampling season. Precipitation has a direct impact on the number of suspended solids that are normally carried to the springs by runoff [41, 42]. According to Kowalczyk et al. [43-45], there may be a correlation between elevated drinking water turbidity and a higher incidence of gastrointestinal sickness in specific contexts or levels. Public health standards may also be impacted by inadequate UV of E. coli caused by high turbidity in drinking water.

4.2.2 Electrical conductivity

While the electrical conductivity of the other two springs is within permissible limits, the Mkhanzini spring's levels exceed the permitted standards of 0-700 µs/cm recommended by DWAF for domestic use [32]. The access road located 50 meters from Mkhanzini Spring provides an explanation for its elevated electrical conductivity levels. Pollutants from this spring are probably coming from the access road, which makes the spring more electrically conductive.

4.2.3 Hydrogen ion concentration (pH)

The study's pH results fall between the permissible ranges of 6 and 9, per DWAF recommendations [36]. However, while Matyenengqina and Mkhanzini springs meet WHO standards [46], Konqeni spring's pH levels are outside of those range. The presence of granite rocks in the vicinity of Konqeni spring is thought to be the cause of its decreased pH level. Konqeni is situated in a mountainous region. These findings are similar to those of Umuhorakeye and Mupenzi [46], who linked the presence of igneous rocks to lower pH values. A pH of spring water that is lower than the WHO [35] suggested level was also found by previous studies such as those [31, 39, 41, 47].

4.3 Chemical properties

Chemical pollutants pose serious health risks, especially to populations that are already at risk. Frequent evaluation and monitoring of these attributes aids in spotting possible risks and guiding required actions. Contaminated drinking water is connected to waterborne illnesses like cholera and typhoid, which highlights the importance of routine quality checks [48, 49]. Thus, monitoring aids in locating these sources, enabling focused remedial actions to enhance the quality of the water [50].

Nitrate: The concentration of nitrate in water is raised by surface runoff [30]. For example, surface runoff from fertilized agricultural area washes the soil into water bodies, raising the nitrate levels. The results of this study indicate that, while the nitrate concentrations of the other two springs are within the required level, those of Matyenengqina spring were above the acceptable limit of 0-6 mg/L as indicated by DWAF [36] and within the 50 mg/L recommended by WHO [35]. The planting of vegetables, which occurs approximately 100 meters from the spring, is the cause of Matyenengqina Spring's exceeding the advised level. The results of this investigation are similar to those of Ram et al. [48], who found nitrate levels beyond the recommended safe limits [35]. Based on the physicochemical tests, it can be determined that all these springs contain low-quality water, increasing the danger of waterborne infections for those who drink them without first getting treated.

4.4 Water quality index

The water quality index values obtained in this study shows poor water quality index with Matyenengqina sitting at 1709624, Mkhanzini 3627588 and Konqeni 385084, which may be caused by several issues including anthropogenic activities that take place within and proximity of the springs. These results make the water unfit and unsuitable for drinking purposes.

Similarly, a study conducted by Priyanshi et al. [49], which used WQI to test water quality reflected showed that anthropogenic activities alter water quality. The study results are comparable to those of Kaynar et al. [50].

4.5 Water properties composition

The composition of water quality metrics is altered by various land use activities. As a result, the various land use activities that may be found in the immediate vicinity of the three springs, Matyenengqina, Mkhanzini, and Konqeni could be the cause of the difference in the water parameters composition of total coliforms, E. coli, pH, and nitrates. For instance, the farmed area near the Matyenengqina Spring is probably the primary source of nitrates, but the underlying igneous rock at the Konqeni site is probably the primary source of pH. Additionally, disruptions like animals using human-shared springs and animal grazing raise the concentration of water turbidity and raise levels of coliform and E. coli. This can be explained by turbidity and E. coli having a positive association [30].

The findings of this study indicate that crop farming causes phosphates and nitrates to be washed into springs, whereas domestic animals are responsible for the presence of E. coli and total coliform in water. The springs' water quality is significantly impacted by this circumstance, making the water unfit for human consumption. Therefore, to redirect run-off water away from the spring, it is advised that canals be built above them. Additionally, if possible, the springs should be fenced to keep domestic animals from using them.

5. RECOMMENDATIONS

To prevent livestock or wildlife from accessing and contaminating the spring water with excrement or pathogens, the study suggests appropriately fencing the springs to prevent pollution and ensure that the water is safe for drinking and other household uses. second, in order to minimize surface runoff and absorb possible pollutants from adjacent land, the study suggests planting grass and shrubs surrounding the spring. Lastly, we would like to suggest using concrete to direct water flow and seal the spring area, keeping pollutants out of the spring.

6. LIMITATIONS OF THE STUDY

To provide a more comprehensive and accurate picture of the health, safety, and variability of the spring, a well-rounded research of spring water quality should preferably cover both the dry and rainy seasons. Nevertheless, this study was restricted to the dry season, when locals depend more on springs for household needs and do not have access to water. Given that less rainfall can result in less fecal contamination from runoff and less microbial migration into the spring water concentrating on the dry season may have lowered the detection of microbial contamination. This could lead to an underestimating of the presence of pathogens and an incomplete evaluation of microbial hazards.

7. CONCLUSION

Water quality index results from the study revealed poor water quality that is not fit for human consumption which is induced by anthropogenic activities. For example, the findings of this study indicate that domestic animals and cultivation have a role in lowering the quality of water. Fencing the springs and building canals, which will help to divert runoff, will lessen the contamination, nevertheless. Future research should focus on sources whose water parameters fall outside of WHO drinking standards in order to guarantee access to clean drinking water. To ascertain whether seasonal fluctuations exist in spring water quality concerning anthropogenic activities, more research is required.

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