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Development of Water Quality Index for Groundwater Sources in Kanduyi Sub County, Western, Kenya

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ABSTRACT

The increased demand for land to accommodate growing settlements, agricultural activities, coupled with the amplified utilization of chemicals to enhance crop yields, and the lack of adequate sanitation practices, have collectively contributed to the degradation of groundwater resources. The study analyzed the physio-chemical parameters of selected ground water sources (springs and wells) in Kanduyi, Bungoma County and developed the groundwater quality index (WQI) using Weighted Arithmetic Mean cocept. The study randomly sampled eighty-nine wells (89) and ten springs (10), gauging their susceptibility to contamination in connection with human activities and potential risk elements. From the study, it was found that 6% of the wells and 50% of the springs in the study area exhibited CWQI values falling between 38 and 50, categorizing them as 'good.' Conversely, a majority of the wells (58%) exhibited Water Quality Index values ranging from 103 to 458, rendering them unsuitable for consumption.

(Egbueri, 2020)

Keywords: human and sanitary risk Factors, Wells and springs, water quality

Introduction

Water, as the most indispensable natural resource, holds vital importance. Especially in developing nations, the access to clean and safe water is a pressing concern. The severe impact of polluted water on human health is evidenced by the staggering six million deaths attributed to waterborne illnesses like diarrhea (Ghebremichael, 2004). The quality of groundwater is heavily influenced by human activities altering the land use within watersheds, leading to potential degradation.(Ngoye & Machiwa, 2004) Land use encompasses diverse anthropogenic activities undertaken for economic, residential, recreational, conservation, and governmental purposes, closely intertwined with the evolution of human society. Historical land use patterns have shaped local and global environments, influencing present and future development trajectories (Craun, 2003; Elumalai, 2020). Furthermore, a study by Wright et al. (2013) in the peri-urban area of Kisumu, reported positive thermo-tolerant coliform counts and NO_3 values above the WHO limit of 10 Mg-N/l, in groundwater samples obtained near pit latrines. The construction of latrines near water sources increases the risk of water pollution.

Water Quality Index (WQI) constitutes a crucial tool for assessing water quality in urban, rural, and industrial settings. The WQI is defined as an index that captures the composite impact of various water quality parameters considered for its calculation (Janardhana Raju, 2009). These parameters encompass both bacteriological and physio-chemical aspects.

Originally devised by Horton in 1965, the tool measured water quality by utilizing the 10 most commonly employed water parameters. Over time, different experts have modified the method, resulting in indices that employ varying numbers and types of water quality parameters. The weight assigned to each parameter is based on its respective standards, signifying the parameter's significance and influence on the index. The typical WQI procedure follows three steps: parameter selection, establishment of a quality function for each parameter, and aggregation using a mathematical equation (Tyagi, 2013).

The index furnishes a single value that represents overall water quality at a specific location and time, drawing from multiple water parameters. This index allows for comparisons between different sampling sites, simplifying intricate data into easily comprehensible and applicable information. The water quality classification system within the WQI signifies the suitability of water for drinking. The single output value of this index, derived from several parameters, imparts crucial information about water quality, making it understandable even to non-experts (Chowdhury, 2012). Water quality index

In resource-constrained countries, achieving accessible and sustainable water resources poses significant challenges. The present study adopts the weighted arithmetic WQI method to communicate water quality information to Water and Sanitation Hygiene practitioners. An advantage of this approach is that it requires a smaller number of parameters to compare water quality for specific purposes (Tyagi, 2013).

Materials and Methods

2.1. Study Area

The study focused on Kanduyi Sub-County which is one of the seven sub-counties of larger Bungoma County. The area coverage is approximately 318.8 square kilometers and lies between latitude $0.566700^{00}$and longitude 34.566700^{00} (Figure 3.1). Bungoma town is the main urban Centre within the study area. Kanduyi sub-county has a population of about 341,605 people. Kanduyi sub-county is divided into seven wards (KNBS 2019). The study was conducted in seven selected administrative wards of which some are rural and others peri-urban. The Four wards that include: Bukembe West, Bukembe East, West Sang'alo and East Sang'alo are in rural set up, while the rest three wards that's Marakaru/Tuuti, Musikoma and Khalaba are within peri-urban areas of Bungoma town.

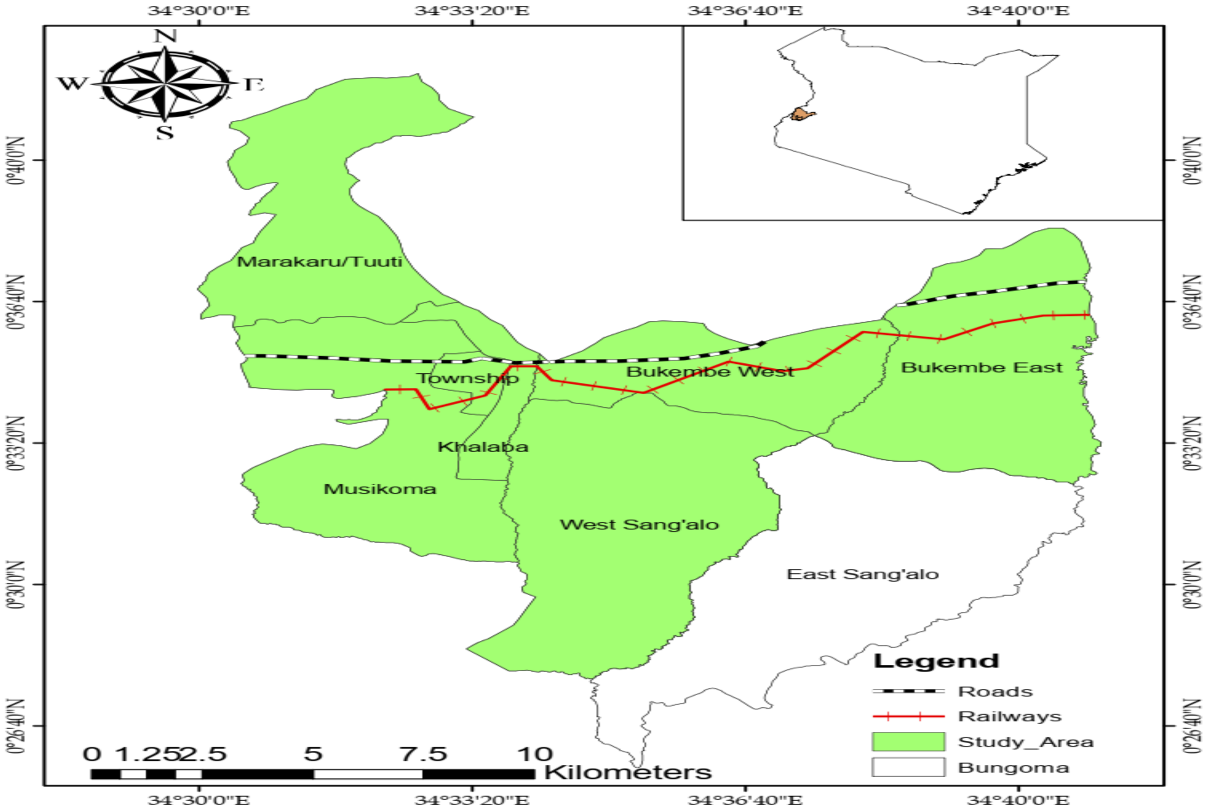

Figure 1.1 . Study area

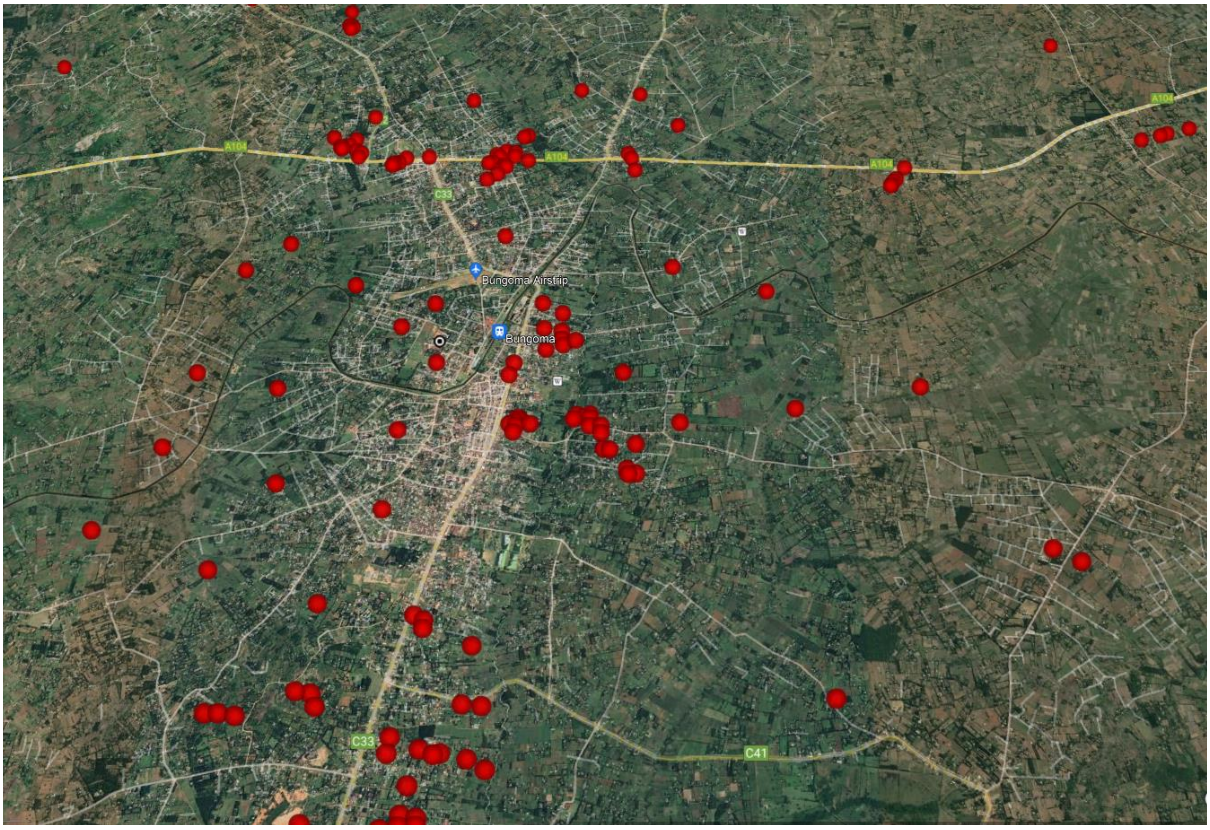

Figure 2.2: Showing sampling location of the study area.

2.3. Data Collection

2.3.1. Water Quality Sampling

Samples were picked in the month of July 2022, in all the selected wells and springs. The collection completely adhered to the sampling parameters outlined in ISO 5667-3. 1-liter capacity, clean glass bottles with caps were used. The sample bottles were cleaned with a nitric acid solution and rinsed completely with clean water to eliminate the acid. The bottles were then filled with sample water, carefully shaken, and emptied. Following multiple repetitions of the same technique, the final sample was taken. The sample bottle stoppers were carefully secured, and each bottle was appropriately labeled with the source name, sampling date, and time for identification purposes prior to transit. Each source yielded two samples; one for physical and chemical testing with measures against contamination.

2.4. Data Analysis

After each sample collection, the ALPHA, 1998 water analysis techniques for each parameter were applied (ALPHA, 1998). Water quality parameters were analyzed in-situ and in the laboratory where necessary. Total and Feacal coliforms (E-Coli) were analyzed using the plate count method in accordance with Egbueri (2019) protocols at a water laboratory (Egbueri, 2020). The physio-chemical parameters PH and Turbidity were measured on-site using a PH Meter (Merck KGa, Germany) and a Turbidimeter 2100Q (Hach, Switzerland) respectively. TDS, Nitrates, and Phosphates were also analyzed in a water laboratory using conventional equipment HACH Pocket pro TDS LR (Hack business, USA

2.4.1. **Calculation of the water quality Index**

Water Quality Index (WQI) values were computed using the measured physiochemical parameter results of PH, Turbidity, EC, TDS, Sulphates, Nitrates and phosphates in order to effectively evaluate pollution levels for each water source (wells and springs). The study employed the Weighted Arithmetic Mean concept created by Horton (1965), Brown et al. (1970), and Cude (2001) for ten measures of water quality(Katyal, 2011) as per the steps that follow;

$$\textbf{WQI} = \frac{\sum (WnXQn)}{\sum (Wn)}$$

Step 1: Assigning of weights to the parameters according to their importance in the overall water quality with maximum value of five and the minimum of one. A higher weight was assigned to the most significant parameters and letter weight attached to the lesser parameter

. Where the following steps were used to calculate the Index

Step 2: Calculation of the quality rating (**Qn** $= \frac{Vn-Vi}{Vs-Vi} x100$

Where: **Qn**- Is the sub-index of the nth parameter

Vn- Is the actual value or concentration of parameter in a water sample

Vi- The ideal value of the parameter (0) for all parameters except for PH which is 7

Vs- Is the standard value for the parameter

Step 3: Finding the Relative weight of the parameter (**Wn):** Wn-K/Vs where K is the proportionality constant such that

$$\textbf{K}= \frac{1}{\sum (1/Sn)}$$

Step 4: Calculation of the Water Quality Index,

$$\textbf{WQI}= \frac{\sum (WnXQn)}{\sum (Wn)}$$

The calculated values were compared with the rating scale of Weighted Arithmetic Mean indicated as indicated in table 2.1.

Table 2.1: WQI Levels

	WQI Levels	Rating Values	Description
1	0-25	Excellent	Water quality is protected with a virtual absence of threat, conditions very close to natural levels.
2	25-50	Good	Water quality is protected with only minor degree of threat, conditions rarely depart from natural or desirable levels.
3	51-75	Poor	Water quality is almost always threatened conditions usually depart from the desirable levels
4	76-100	Very Poor	Water quality is frequently threatened and thus often departs from natural levels.
5	>100	Unfit for consumption	Water quality is almost threatened with undesirable levels.

Results and Discussions

Water Quality Index (WQI) results for wells and springs was computed utilizing the measured physiochemical parameters in order to effectively assess the water pollution levels of each well and spring. Table 3.1 and Table 3.2 shows the results of WQI for wells and springs respectively.

3.1. Wells

Table 3. 1: Water quality index of sampled wells in Kanduyi Sub-county.

Name of Wards	Water Quality Index		Water Quality Class
Musikoma Ward (13)	Mean	118	Unsuitable
	Range	78-178	Very poor-Unsuitable
Khalaba Ward (14)	Mean	136	Unsuitable
	Range	64-176	Poor-Unsuitable
Bukembe East Ward (12)	Mean	152	Unsuitable
	Range	43-156	Good-Unsuitable
West Sang’alo Wards (12)	Mean	68	poor
	Range	38-190	Good-Unsuitable
Town ship Ward (14)	Mean	101	Unsuitable
	Range	56-177	Poor-Unsuitable
Bukembe West Ward (12)	Mean	81	Very poor
	Range	39-164	Good-Unsuitable
	Mean	125	Unsuitable

Name of Wards	Water Quality Index		Water Quality Class
Marakaru Tuuti Ward (12)	Range	56-204	Poor-Unsuitable

The study showed that the water quality Index (WQI) ranged from a minimum of 38 to a high of 204 throughout the seven wards. The average quality class fell between Excellent and Unfit for Usage. According to the Water Quality Indexing, the wells were classified with Excellent being the highest grade, followed by Poor and Very Poor. In West Sang'alo and Bukembe East wards, shallow wells with the lowest water quality grades of 38 and 43, respectively, were detected. From table 3.1, Bukembe west, Bukembe east, and West Sang'alo despite being located in rural areas, reported a significant frequency of water contamination leading to unfit water quality for human consumption.

The water quality index of the wells in the region under study suggests that most water sources are unfit for human consumption unless they are subjected to conventional treatment. The majority of wells (51.7%) were evaluated as having inadequate water quality while 22.5% and 20.2%, had poor and very poor water quality respectively. This suggests that only 5.6% of wells contain potable water. Khalaba, Musikoma, and Marakaru Tuuti wards had 33.7% of the wells improperly constructed.

3.2. Springs

Table 3.2: WQI from sampled springs

Name of the ward	Water Quality Index		Water Quality Classification
Musikoma Ward	Mean	52.63	Poor quality
	Range	52.63	Poor quality
Khalaba Ward	Mean	52.68	Poor quality
	Range	52.68	Poor quality
West Sang'alo Ward	Mean	55.73	Poor quality
	Range	34.26-77.2	Good-Poor quality
Bukembe East ward	Mean	41.84	Good quality
	Range	32.29-51.38	Good quality
Town ship Ward	Mean	18.54	Excellent quality
	Range	18.54	Excellent quality
Bukembe West Ward	Mean	32.89	Good quality
	Range	30.44-35.34	Good quality
Marakaru Tuuti Ward	Mean	27.78	Good quality
	Range	27.78	Good quality

From table 3.2 results, samples from springs were of higher quality than those from wells. 10% of the springs had a WQI score between 0 and 25, which indicates outstanding water quality. 50 percent of the springs had a score between 26 and 50, which indicates good water quality. The very poor category of this spring can be attributed to the contact of rainwater with the sedimentary rock in the area, resulting in the dissolution of ions into the aquifer, or to various anthropogenic activities, such as sewage disposal, waste disposal, agricultural activities, the presence of a dirty drainage behind the spring's water source, and anthropogenic pollution from the nearby dumpsite. The results indicate that there were no wells in the 0-25 category (excellent). Overally, 52% were unfit for human consumption (>100), 19% were extremely poor (76-100), 24% were poor (51-75), and 6% were excellent (26-50).

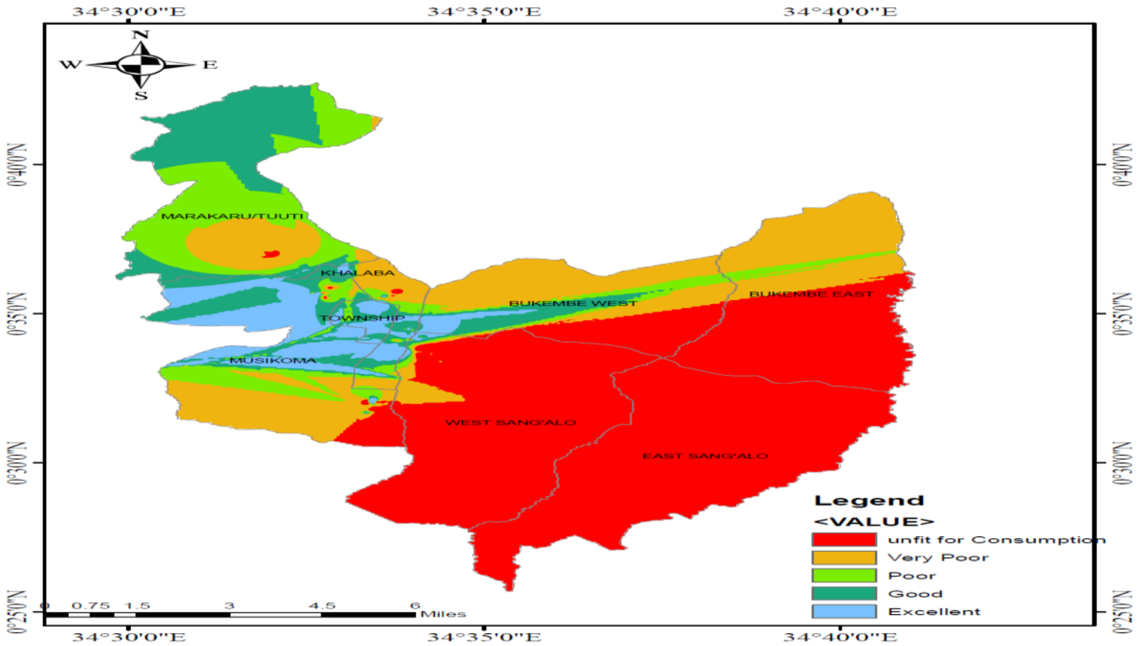

Figure 3.1.: Spatial distribution map of WQI wells and springs in the study area

From figure 3.1, wells and springs located in East Sang'alo and a section of West Sang'alo demonstrated the poorest Water Quality Index rendering the water unsuitable for human consumption. This deterioration was linked to a combination of various human-related factors and inadequate sanitary conditions, all contributing to the compromised water quality. Similarly, Bukembe West, along with a portion of Bukembe East, Musikoma, and Marakaru Tuuti, exhibited a poor Water Quality Index. This decline was attributed to various human activities that negatively influenced water quality.

Conversely, the study found that wells and springs situated in the Township area such as certain segments of Musikoma, as well as smaller portions of Khalaba, Marakaru, and West Sang'alo Wards, displayed good water quality. This positive result was attributed to effective sanitary practices and the protective measures in place to safeguard water sources from contamination. Furthermore, the investigation unveiled that a few number of wells and springs within the Township and Musikoma wards demonstrated an excellent

Water Quality Index. This outstanding performance was linked to the proper disposal of solid wastes through sound sanitary practices, combined with the effective protection of water sources to prevent pollution from contaminants.

Conclusion and Recommendations

4.1. Conclusion

The primary aim of this objective was to assess the Water Quality Index (WQI) of shallow wells within the confines area of study in Kanduyi. The findings revealed a spectrum of WQI values spanning from a minimum of 38 to a peak of 204 across the seven wards. This range of values illustrated that the average quality class straddled between "Excellent" and "Unfit for Use." Specifically, well water samples unveiled a distribution where 52% of them were deemed unsuitable for human consumption (WQI > 100), 19% were characterized as extremely poor (WQI 76-100), 24% were classified as poor (WQI 51-75), and 6% displayed excellent quality (WQI 26-50). Furthermore, the results established a notable difference between the quality of samples from springs and those from wells. Spring water samples exhibited a superior quality. Among the springs, 10% achieved WQI scores of 0 to 25, indicating excellent water quality. Additionally, 50% fell within the range of 26 to 50, 40% scored between 51 and 75, and only 1% landed within the range of 76 to 100, signaling very poor water quality.

Observations highlighted that merely two locations, West Sang'alo and Bukembe West, exhibited poor and very poor Comprehensive Water Quality Index (CWQI) values. Remarkably, except for the springs, none of the wells met the established standards for drinking water quality.

4.2. Recommendations of the Study

The leadership within the water sector should adopt a proactive approach to monitoring the Water Quality Index (WQI) of groundwater sources. This entails consistent and systematic assessment of water quality using WQI measurements, and utilizing the collected data that will guide management efforts and track the effectiveness of the existing interventions. By staying vigilant and responsive, water sector management can ensure safety and suitability of groundwater sources.

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