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Assessment of Groundwater Quality from Aquifers in Garissa County

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Authors' contributions

This work was carried out in collaboration between all authors. Author ESM designed the study, wrote the protocol and wrote the first draft of the manuscript. Authors P. K. Kairigo and EGM reviewed the experimental design and all drafts of the manuscript. Authors P. K. Kimani, JCO and DB managed the analyses of the study. Authors JGK and P. K. Kairigo performed the statistical analysis. All authors read and approved the final manuscript.

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ABSTRACT

Water currently consumed by rural residents in Kenya far exceeds drinking water guideline values proposed by the World Health Organization. The basement and alluvial formations are known to exhibit poor water quality, with predominantly slightly saline water at greater depths especially in areas where there is no groundwater movement. Wells are prone to pollution due to lack of well protection and that in effect compromises water quality. The main objective of this study was to assess the quality of water sampled from pans and wells in Garissa County. Representative samples were collected according to internationally approved methods of sample collection, transportation, and testing and data analysis. 40 boreholes, 45 water pans, various points of the river Tana, shallow wells and springs were sampled across the County and physicochemical and biological parameters ascertained. Results obtained identified high total water hardness, total alkalinity, fluoride, chloride and turbidity. Some water sources in sampled area had high fluoride,

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high arsenic levels (16 µg/l), pH (8.78) and conductivity (22000 µs/cm), exceeding WHO limits of 1.5 mg/l fluoride, 10 µg/l for arsenic, 6.0 - 8.0 for pH and 2,500 µs/cm for conductivity by WHO (2013). The study concluded that accessibility to good quality drinking water is hampered by the presence of pollutants in some areas.

Keywords: Surface water; water quality; total hardness; nutrient levels.

1. INTRODUCTION

Worldwide, 783 million people have no access to drinking water from improved sources. Sub-Saharan Africa accounts for more than a third of that number, with about 330 million people without access to safe drinking water. Africa's progress towards the MDG drinking water target is slow and uneven, and the continent as a whole will not reach the goal. Although the proportion of people in sub-Saharan Africa using improved sources of drinking water increased by 14 per cent from 1990 to 2008, only 60 per cent of its population had such access by the end of that period [1]. Based on current trends, sub-Saharan Africa will not reach the MDG water target until 2040. A recent survey revealed a bleak future in which only two countries (Kenya and South Africa) are estimated to have more than 75 per cent of what is needed to achieve the sanitation target, and five countries are estimated to have more than 75 per cent of what is needed to achieve the MDG target for drinking water [2].

Despite its location along the equator, Kenya faces extreme climate variations due to its various landforms, particularly the Rift Valley. The variable climate brings frequent droughts as well as floods. Rainfall is unevenly distributed throughout the country, with less than 200 mm/yr falling in northern Kenya [3]. Rainfall in the area is limited and is characterized by large temporal and spatial variability. The mountainous areas of Mt. Kenya and Mt. Marsabit have the highest rainfall (1100 mm and 600-700 mm per year respectively), while the lower lying areas receive only 150-350 mm a year [4]. Although perennial (permanent) surface water is important for the water supply in the study area, it is outweighed by ephemeral (seasonal) sources. There are two perennial water courses in the area underlain by the aquifer: the Rivers Tana and Ewaso Ng'iro (see Fig. 1). The Ewaso Ng'iro is relevant for the groundwater system underlying Habaswein and the surrounding areas. The Ewaso Ng'iro River drains the northern and western slopes of Mount Kenya and the NE slopes of the Aberdares. At Archer's Post (north of Isiolo), the mean annual flow was approximately 633 million cubic metres per year during the period 1949-1990 [4]. Surface water resources are also limited, covering only two per cent of Kenya's total surface area. Most of the Garissa County lies in arid and semi-arid lands where water resources are scarce. It is common to find the local communities using water whose physico-chemical parameters exceed the recommended WHO levels, mainly because there are no alternative water resources [3].

This study sought to determine the physico-chemical parameters of drinking water sampled from various locations in Garissa County, Kenya. Water sampled from different locations were analysed for physical parameters such as TDS, DO, pH, conductivity. The concentration of Nitrates, fluorides, Sodium, magnesium and selected heavy metals were also determined to ascertain the quality of drinking water from these sources. The concentration of major cation were analysed by the atomic absorption spectrometry method. Calibrations for cations analyses were carried out by appropriate standards. Both laboratory and international reference materials were used to check the accuracy of the chemical analyses.

2. MATERIALS AND METHODS

2.1 Sampling Area

All samples for the assessment were done in Garissa County. Garissa County is an administrative county in the North Eastern region of Kenya, covering an area of 45720.2 km^2. It has a population of 623,060 people with the population increase projected to reach 850,080 people in the year 2017 [5]. The region is low lying with altitudes, ranging from 70 to 140 M above the sea level. Fig. 1 shows an overview map of water sampling points in Garissa County. The sampled areas included Garissa Central, Dadaab and Lagdera sub counties. Groundwater samples were collected and kept in a polyethylene bottle at 10℃ for further laboratory analysis.

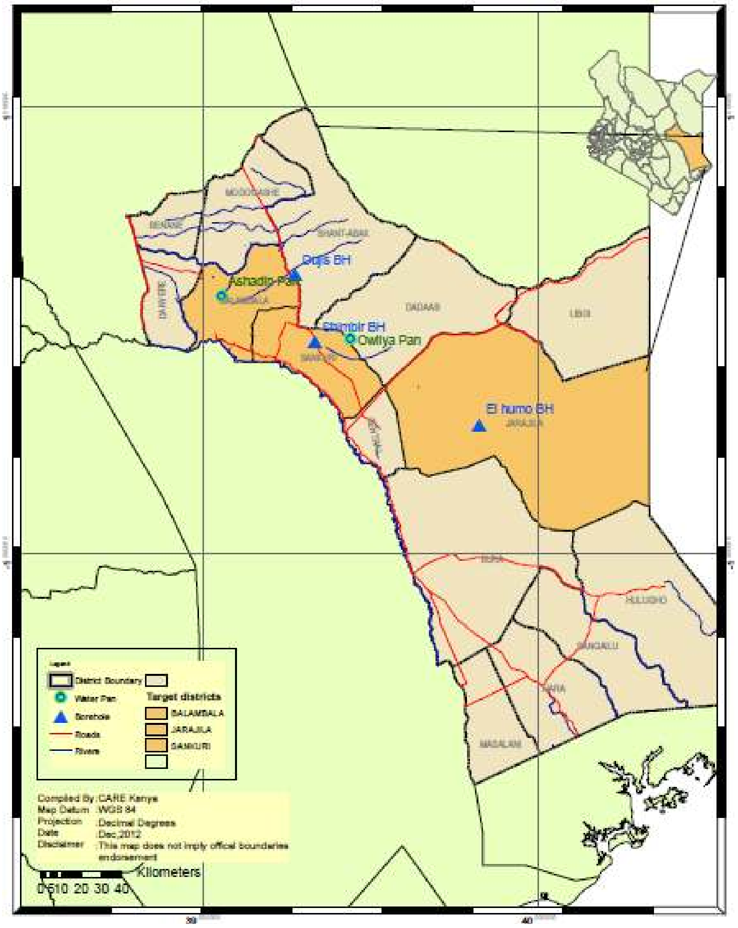

Fig. 1. Overview of surface water sampling points in Garissa County

2.2 Analytical Methods

Water samples were collected in accordance to guidelines proposed by the Environmental Protection Agency [6,7]. Maximum holding time and preservation methods were observed for each parameter. Physical and chemical water parameters were analyzed in accordance to the standard methods proposed by American water works association [8]. Physical parameters were determined on-site where applicable while chemical parameters were analyzed in the laboratory. Anions were analyzed using a Shimadzu 1800 UV/Visible spectrophotometer while a flame photometer FP-100 and a Shimadzu AA-6200 atomic absorption spectrophotometer were used for metal (cation) analysis.

2.3 Statistical Analysis

Statistical packages (SPSS v.18) were used for statistical analysis. Each parameter was determined in triplicate and the data represented as mean $\pm$ Standard deviation in order to show precision.

3. RESULTS AND DISCUSSION

3.1 Physical Parameters

Physical parameters define those characteristics of water that respond to the senses of sight, touch, taste or smell [8]. This parameters play an important role in classification and assessing water quality. Hence to evaluate water quality for different uses, water quality indices such as pH, TDS, conductivity, taste, and salinity are usually measured. The physical parameters monitored in this study included, temperature, turbidity, conductivity, pH and colour. The results obtained are depicted in Table 1, Table 2 and Table 3.

Table 1. Physical parameters of groundwater sampled from Dadaab Sub-county

Station name	Temp (0C)	pH (units)	DO (mg/l)	Turbidity (NTU)	Conductivity (µS/cm)	TDS (mg/l)	Salinity (ppm)
Welldon	30.7±1.1	7.14±0.8	0.15±0.05	0.38±0.02	937.50 ±3.4	648.9±3.4	930.3±0.1
Kokar	30.4±1.2	7.15±1.0	0.17±0.02	0.26±0.04	1,157.00 ±5.0	804.1±4.2	1,163.0±0.5
Liboi Market	30.7±1.1	7.64±0.5	0.17±0.02	0.15±0.04	1,113.00 ±4.5	775.9±4.2	1,118.0±0.5
Liboi Dobey BH 3	30.8±1.6	7.34±0.9	0.18±0.03	0.89±0.05	963.20±5.0	674.2±4.5	962.8.0±0.3
Kulan BH 1	29.7±1.5	7.15±1.0	0.21±0.5	0.77±0.03	1,510.00 ±5.5	1,037.0±5.0	1,531.0±0.5
Maley BH 2	29.2±1.3	7.56±0.4	0.21±0.01	1.48±0.01	1,452.00±5.01	1,001.0±0.05	1,471.0±5.0
Kumahumato	30.1±1.5	7.68±0.5	0.34±0.01	1.75±0.02	817.00 ±0.51	408.5±0.05	785.2±5.0
Libahlow	30±1.0	7.54±0.7	0.36±0.01	4.21±0.05	783.00 ±0.03	391.5±5.0	750.2±0.9
Alikune Market	30.2±0.9	7.88±0.2	0.37±0.01	11.63±0.02	701.50±0.05	479.5±0.1	680.2±1.5
Dertu BH 1	30.4±1.4	7.17±0.6	0.35±0.01	1.44±0.45	1,327.50 ±5.0	664.0±0.5	3,190±2.0
RC Dertu BH 1	30.3±1.2	7.17±0.2	0.30±0.05	0.84±0.21	3,102.00 ±5.0	1,546.5±5.0	1,553±1.0
Welhar	30.3±0.8	7.15±0.4	0.20±0.01	0.31±0.31	720.80 ±0.05	500.8±0.01	708±0.02
Labisigale CBH	30.5±0.9	7.15±0.7	0.20±0.25	0.39±0.21	751.50 ±0.02	520.1±0.05	737.9±0.5
Ifo 2 C1	30.4±1.3	7.15±0.5	0.25±0.01	0.25±0.43	740.10 ±0.01	512.7±0.01	727±0.02
Ifo 2 C2	30.5±1.2	7.18±0.6	0.29±0.01	0.27±0.24	734.00 ±0.03	367.0±0.05	699.8±0.05
Ifo 2 C3	30.2±1.1	7.15±0.4	0.20±0.05	0.39±0.12	871.60±0.04	602.2±0.1	860±0.05
Hgadera C2	30.5±1.0	7.15±0.8	0.67±0.01	0.67±0.05	1,224.00± 0.25	612.0±0.2	1,199.0±1.0
Hgadera C6	30.3±1.2	7.16±0.6	0.49±0.02	0.49±0.03	1,210.00 ±4.0	605.0±0.1	1,188.0±0.10
Hgadera C8	30.5±1.2	7.17±0.5	0.26±0.01	2.35±0.01	1,044.00 ±5.0	521.0±0.15	1,015.0±0.55
Dagahaley BH	30.5±1.0	7.16±0.4	0.21±0.02	0.87±0.02	1,102.00± 5.0	620.0±0.24	734.3±0.04
Dagahaley C3	30.3±1.3	7.15±0.7	0.40±0.01	0.40±0.01	778.00 ±3.45	389.0±0.65	742.0±0.55
Dagahaley C9	29.9±0.8	7.15±0.8	0.30±0.01	0.64±0.03	804.00 ±5.05	400.0±0.61	769.0±0.56
Seretho	30.4±1.2	7.16±0.6	0.32±0.02	0.90±0.05	4,110.00 ±5.0	2,044.0±0.55	4,249.0±0.70
Dadaab C2	30.1±1.1	7.16±0.5	0.16±0.03	0.66±0.04	1,120.50± 0.05	672.5±0.55	1201.0±0.65
Dadaab C3	30.9±1.3	7.16±0.05	0.17±0.01	0.96±0.01	850.60±0.56	639.5±0.57	899.0±0.55
Dadaab C4	30.4±0.7	7.16±0.05	0.15±0.01	1.17±0.15	1,861.00 ±5.0	1,399.0±0.56	1,118.0±0.55
Bogyar	31.5±1.0	7.16±0.50	0.12±0.02	16.45±0.55	2,197.00±5.0	1,646.0±0.65	2,435.0±5.0
Bulkhaheri BH	30.5±1.0	7.15±0.50	0.20±0.01	0.42±0.01	825.50 ±0.56	570.3±0.5	812.6±4.5

**BH = Borehole *C = Camp *CBH = Community Borehole*

Table 2. Physical parameters of groundwater sampled from Lagdera Sub-county

Station name	Temp (0C)	pH (units)	Turbidity (NTU)	Conductivity (µS/cm)	TDS (mg/l)	Salinity (ppm)
Shimbirey	30.3±0.01	9.13±0.01	1.07±0.1	6890.5±24.7	4,746±96	7,767±69
Gurufa Bore 7	30.9±0.01	8.9±0.01	1.4±0.7	2167±3.5	1,444±3.01	2,251.7±7.8
Kambi samaki	30.2±0.01	8.1±0.02	1576.7±51.3	225.5±0.7	2,050±1.12	3,281±3.0
Baraki BH	30.4±0.02	8.9±0.01	1.26±0.54	1436±1.0	152.6±0.3	211.4±0.1
Durwaya SW 1	30.6±0.02	8.1±0.02	690.3±12.4	688.3±7.5	457.1±3.2	671.6±5.9
Durwaya SW 2	30.6±0.01	8.1±0.1	152±15	423.6±0.2	287.9±0.7	402.5±0.5
Shantabak BH	30.7±0.02	8.7±0.01	4.1±1.3	1,732±1.4	1,163±3.0	1,783±3.0
Algaar BH	30.5±0.05	8.84±0.02	1.2±0.2	719.5±7.6	476.6±4.2	704.1±1.3
Durkiaya SW 2	29.9±0.05	9.5±0.01	1.6±0.3	4300±32	2,820±4.0	4,647±25
Dilmayale BH	30.2±0.5	8.7±0.01	0.45±0.01	4600 ± 14	3,109.01±5.0	4,402± 20
Togowien SW	31.2±0.1	8.13±0.01	532.5±0.05	419.7±3.5	330.25±5.0	421±5.0

**BH: Borehole *SW: Surface water*

According to WHO (2004) requirement for water quality, the pH for the most of the surface water sampled fell within the allowable limits [9]. However samples collected from Gonji Twin pan and Kambi Samaki spring had values exceeding the maximum permissible level with values of 8.98 and 8.56 respectively. This is attributed to the presence of algae in the two water resources [10]. The algae utilizes carbon dioxide gas which is responsible for water acidity thereby raising the pH [10,11].The slightly high pH however does not cause any significant alarm for the water users. On the other hand, temperature is an important parameter in natural surface water systems [12]. It is considered when assessing water quality. In addition to its own effects, temperature influences several other parameters and can alter the physical and chemical properties of water [7]. The temperature of surface waters governs to a large extent the biological species present and the rate of activity [13,14]. It has an effect on most chemical reactions that occur in natural water systems and also has a great effect on the solubility of gases in water [15]. Kora kora water supply and Egege water pans had the highest temperatures of 35.5 and 36.5℃ respectively whereas Kumhumato water pan and Kulan Mega water pan had the lowest temperatures of 26.1 and 29.7℃ respectively. The high temperatures could be explained by the high temperatures of the area during sampling. The conductivity which has a linear relationship with the Total dissolved solids in a sample of water, was within the allowable limits of below 2500 μS^{-1}. Groundwater samples classified as fresh (TDS < 500 mg/l) to brine (TDS > 30,000) waters, however most of the samples fall in the category of brackish water. The pH values groundwater samples ranges from 7.0 to 9.6 indicating neutral to slightly alkaline nature [16]. The colour for three sites exceeded the max value of 15 EBU. These sites include RGS401 Garissa, Korakora water supply and Eldere pan with values of 1750, 1500 and 350 EBU respectively. The high conductivity values are consistent with the high TDS values [17]. The high turbidity recorded in most of the areas was due to the rains experienced during the sampling period which is consistent with high sediments observed [16].

3.2 Metal Analysis

Trace quantities of many metals, such as manganese, chromium, copper, nickel, cadmium, zinc, and iron find their way into water system. Some of these metals are necessary for the growth of biological life when in very small concentrations, but harmful in higher concentrations. Calcium and magnesium cause hardness. Manganese > 0.05 mg and iron concentrations > 0.3 mg/ may cause colour problems [14,15]. The concentration of various ions in sampled water was compared with WHO standards and are given in Table 4. The minimum required amounts of calcium and magnesium in drinking water are 10 and 20 mg/l, respectively, and the desired amounts of magnesium and calcium in drinking water are 30–50 and 40–75 mg/l, respectively [9]. The calcium concentrations in water samples varied from 0 to 48.8 mg/l with minimum and maximum values, respectively while the concentration of magnesium in all water samples varied from 1.46 - 71.95 mg/L. The concentration of manganese was below 0.01 mg/l in all sampling points under study. Concentration of iron was less than 1 mg/l in all samples analyzed apart from Bogyar (1.3 mg/L). Iron concentrations greater than 0.3 mg/L may contribute to bad taste, pipe clogging,

Table 3. Physical parameters of groundwater sampled from water pans in Lagdera Sub-county

Station name	Temp °C (0C)	pH	DO (mg/l)	Turbidity (NTU)	Conductivity (µS/cm)	TDS (mg/l)	Salinity (ppm)
Weldon	30.6±0.1	7.69±0.1	0.15±0.01	938±5.5	100.8±0.5	71.3±0.5	97.8±0.56
War Deg Low	30.6±0.1	7.15±0.2	0.16±0.01	1158±5.0	383.3±0.05	269.8±0.5	372.8±0.78
Kulan Mega	29.7±0.2	7.45±0.01	0.19±0.05	16.7±0.01	339.7±0.02	234±5.0	323.5±0.56
Kumahumato	26.1±0.1	7.92±0.02	0.27±0.02	6950±10	1623±0.04	812±5.0	1494±5.0
Uthole	30.4±0.5	7.98±0.1	0.37±0.01	684.7±5.0	122.6±0.05	111.5±0.05	204.6±0.56
Orah	30.5±0.5	7.18±0.05	0.32±0.02	26.2±0.05	868±0.5	434.5±0.05	842.8±0.68
Eigege	32.8±0.1	7.16±0.05	0.15±0.05	253±5.0	294.1±0.05	219.7±0.02	307±3.0
Hagabul	32.1±0.1	7.16±0.01	0.09±0.05	12.9±0.56	398.5±0.05	301±1.5	310±2.15

Table 4. Concentration various metal ions in groundwater sampled from Dadaab Sub-county

Sampling Site	mgNa^+/l	mgK^+/l	mgCa^{2+}/l	mgMg^{2+}/l	µgAs^{2+}/l	mgFe^{2+}/l	mgMn^{2+}/l
Welldon	162.00 ±9.27	18±2.22	18.4±2.51	16.05±2.53	<LOD	<0.01	<0.01
Kokar	240.00 ±1.11	16±2.32	13.6±1.32	12.16±1.33	<LOD	0.5±0.02	<0.01
Liboi M BH 1	170.00 ±2.75	21±3.1	18.4±2.51	36.46±3.41	<LOD	0.07±0.01	<0.01
Liboi D BH 3	100.00 ±1.41	2.1±0.35	20±1.99	57.3±3.65	<LOD	<0.01	<0.01
Kulan BH 1	270.00 ±1.63	24±3.02	44.8±4.73	21.41±2.01	<LOD	<0.01	<0.01
Maley BH 2	140.00 ±0.92	26±4.12	58.4±4.99	71.95±2.09	<LOD	0.13±0.04	<0.01
Kumahumato	110.00 ±4.01	21±2.15	28±3.08	20.9±1.08	3.0±0.1	0.1±0.03	<0.01
Alikune	130.00±4.42	8.6±0.62	13.6±2.11	13.6±1.22	2.0 ±0.1	0.33±0.02	<0.01
Dertu BH 1	730.00 ±8.32	4.8±0.24	<LOD	4.86±0.66	2.0±0.05	0.17±0.01	<0.01
Dertu RC BH 2	335.00 ±1.99	7.4±0.54	8±1.12	9.24±1.03	3±0.1	<0.01	<0.01
Welhar	126.00±2.25	10±1.04	16.8±2.01	11.67±0.78	<LOD	0.3±0.02	<0.01
Labisigale BH	80.00 ±1.02	16±1.55	15.2±1.89	40.34±2.32	<LOD	0.07±0.06	<0.01
Ifo 2 C1	80.00 ±0.99	21±2..01	12.8±0.96	38.39±1.99	<LOD	0.07±0.004	<0.01
Ifo 2 C2	91.00 ±2.61	16±1.89	30.4±2.00	19.94±1.24	<LOD	<0.01	<0.01
Ifo 2 C3	95.00 ±3.24	24±1.98	10.4±0.56	46.65±3.47	<LOD	<0.01	<0.01
Hgadera C2	240.00 ±3.53	9±0.55	10.4±0.78	15.07±1.56	<LOD	0.3±0.07	<0.01

Sampling Site	$mgNa^{+}/l$	mgK^{+}/l	$mgCa^{2+}/l$	$mgMg^{2+}/l$	$\mu gAs^{2+}/l$	$mgFe^{2+}/l$	$mgMn^{2+}/l$
Hgadera C6	241.00 ±2.11	8.5±0.65	10.4±0.84	14.1±2.01	<LOD	0.1±0.02	<0.01
Hgadera C8	220.00 ±3.32	7.1±0.87	4.8±0.96	8.75±1.11	<LOD	0.23±0.04	<0.01
Dagahaley BH	61.00 ±2.14	19±3.04	30.4±2.08	38.41±2.04	<LOD	0.07±0.25	<0.01
Dagahaley C3	74.00±2.52	16±0.99	38.4±1.96	31.61±2.11	<LOD	0.13±0.005	<0.01
Dagahaley C9	90.00 ±3.01	2±0.11	43.2±2.03	26.27±1.99	<LOD	0.07±0.02	<0.01
Seretho	940.00 ±4.44	4±0.21	NIL	9.72±0.58	<LOD	0.07±0.031	<0.01
Dadaab C2	190.00 ±2.53	6.7±0.51	5.6±0.55	9.23±0.66	<LOD	0.07±0.027	<0.01
Dadaab C3	200.00 ±3.35	5.3±0.65	2.4±0.12	4.86±*0.45*	<LOD	<0.01	<0.01
Dadaab C4	205.00 ±2.91	22±1.54	18.4±0.88	15.46±*1.25*	<LOD	0.43±*0.12*	<0.01
Bogyar	532.00 ±6.22	3.4±*0.45*	NIL	4.86±*0.33*	1	1.63±0.11	<0.01
Bulkhaheri BH	100.00 ±2.37	19±1.11	10.4±*0.99*	40.34±*1.56*	<LOD	<0.01	<0.01

BH = Borehole *C =Camp * <LOD=below limit of detection

Table 5. Concentration of various metal ions in groundwater sampled from Lagdera Sub-county

Sampling Site	$mgNa^{+}/l$	mgK^{+}/l	$mgCa^{2+}/l$	$mgMg^{2+}/l$	$\mu gAs^{2+}/l$	mgFe/l	$mgMn^{2+}/l$
Shimbirey	1,670.00 ±30.15	4.2±0.23	<LOD	12.15±1.8	3±0.05	0.13±0.01	<0.01
Gurufa BH 7	493.00±8.63	9.6±1.02	<LOD	17±2.3	3±0.14	0.07±0.02	<0.01
Kambi samaki	643.00 ±9.34	101±6.5	<LOD	28.18±2.1	3±0.09	<0.01	<0.01
Baraki BH	320.00±3.87	6.4±0.54	9.6±0.57	6.32±1.2	2±0.14	0.13±0.04	<0.01
Durwaya SW 1	50.00 ±1.13	21±1.56	8.8±0.42	51.51±2.89	<LOD	1.96±0.032	1.2±0.014
Durwaya SW 2	19.00 ±0.25	8.3±0.96	10.4±0.85	36.45±1.63	<LOD	<0.01	<0.01
Shantabak CBH	372.00 ±4.51	13±1.01	11.2±0.78	11.67±2.01	2±0.12	0.7±0.042	<0.01
Algaar BH	160.00 ±1.67	5±0.12	7.2±0.69	2.43±0.23	<LOD	0.1±0.023	<0.01
Dilmayale BH	300.00 ±2.44	30±3.41	20.8±1.82	27.23±0.92	5±0.2	0.1±0.031	<0.01
Togowien SW	30.00 ±0.52	18±2.36	48.8±3.14	5.86±0.52	1±0.1	3.26±0.14	<0.01

BH = Borehole, *CBH = Community Borehole *SW = Surface water

and clothes, tub, sink, and teeth staining [9]. Arsenic concentration were found to be higher than 0.01 mg/L in most water pans (Table 5) as compared to ground water samples in which only Kumahumato (3 mg/L), Alikane Market (2 mg/L), Dertu (2 and 3 mg/L), Bogyar (1 mg/L) had concentrations higher than guideline value. Arsenic in concentration above 0.01 mg/l has been reported to be a carcinogen [18]. The U.S. Environmental Protection Agency (EPA) recommends a SMCL of 0.3 mg/L for iron and 0.05 mg/L for manganese based on staining and taste considerations.

3.3 Nutrient Analysis

These include all forms and occurrences of nitrogen, phosphorus and sulphur. Table 7 depicts the concentration of various nutrients in water sampled from Lagdera sub – County. From the results obtained, groundwater sampled from Shimbirey had the highest concentration of sulphates, chloride and fluoride ions. The concentration of nitrite ions was below 0.01 mg/L for all samples except Kambi samaki (0.4 mg/L) and Durwaya S/W (0.33 mg/L). The concentration of fluoride ion in all water samples were below guideline value of 1.5 mg/L set by WHO (2004) except in Shimbirey (2.15 mg/L) and Gurufa (2.82 mg/L).

Table 8 and Table 9 depicts the concentration of various nutrients in water sampled from Dadaab Sub-County. From the results obtained, groundwater sampled from Marley had the highest concentration of chloride (2,210 mg/L) while Seretho, Dagahaley camp 3 and Dertu had the highest concentration of sulphates (299.7 mg/L), nitrites (0.3 mg/L) and fluoride (4.1 mg/L) ions. Presence of high nitrite and nitrate concentrations in drinking water cause methemoglobinemia or the 'blue baby' syndrome. Sources of these nitrogen compounds often come from fertilizers, manure, refuse dumps and industrial wastes [14]. The concentration of nitrite ions was below 0.01 for all samples except Dagahaley (0.03 mgL$^-$) and Durwaya S/W (0.33 mg/L). The concentration of fluoride ion in all water samples were below guideline value of 1.5 mg/L set by WHO (2004) except in Dertu (4.1 mg/L), Seretho (2.04 mg/L), and Bogyar (2.91 mg/L) respectively. No health-based guideline value have been proposed for chloride in drinking-water. However, chloride concentrations above 250 mg/L give rise to detectable taste in water [17].

Table 6. Concentration of various metal ions in water sampled from water pans in Lagdera Sub-county

Sampling Point	mgNa^+/l	mgK^+/l	mgCa^{2+}/l	mgMg^{2+}/l	mgFe^{2+}/l	mgMn^{2+}/l
Weldon Bisiqle	15.35±0.5	43±0.46	2.4±0.55	1.46±0.86	6.03±0.32	0.2±0.01
War Deg Low	19±0.96	22±0.33	33.6±0.44	14.6±0.35	5.86±0.36	4±0.32
Kulan Mega	49±0.56	8.8±0.09	20.8±0.36	2.68±0.36	1.13±0.06	<0.01
Kumahumato	330±1.98	6±0.03	11.2±0.26	2.92±0.65	6.26±0.02	0.16±0.08
Uthole	10±0.05	29±1.23	22.4±0.35	20.91±0.56	3.53±0.06	0.1±0.05
Orah	15±0.85	110±1.95	37.6±0.65	44.24±0.98	0.5±0.01	1.6±0.65
Eigege	22±0.78	16±0.96	23.2±0.63	8.27±0.95	3.23±0.32	<0.01
Hagabul	30±0.65	4.8±0.53	44±0.85	6.98±0.56	0.43±0.06	<0.01

Table 7. Concentration of various nutrients in groundwater sampled from Lagdera Sub-county

Sampling point	mgSO_4^{2-}/l	mgNO_2^-/l	mgF-/l	mgCl-/l
Shimbirey	244±*2.33*	<0.01	2.15±0.03	1,315±5.23
Gurufa B/H 7	111.71±1.23	<0.01	2.82±0.02	235±2.35
Kambi samaki	8.83±0.78	0.4±*0.00*	ND	ND
Baraki B/H	56.43±0.95	<0.01	0.96±0.03	84±*1.03*
Durwaya S/W 1	<0.3	<0.01	0.59±0.02	10±0.05
Durwaya S/W 2	0.03±0.00	0.33±0.00	ND	<LOD
Shantabak CB/H	5.17±0.07	<0.01	0.71±0.02	277±1.06
Algaar B/H	24.9±0.96	<0.01	0.92±0.04	23±*0.33*
Dilmayale B/H	92.43±1.52	<0.01	1.49±0.02	183±1.66
Togowien S/W		<0.01	-	-

Table 8. Concentration of various nutrients in groundwater sampled from Dadaab Sub-county

Sampling Point	Sulphate (mg/l)	Nitrite (mg/l)	Fluoride (mg/l)	Chloride (mg/l)
Welldon	4.9±0.15	<0.01	1.31±0.23	51±0.56
Kokar	43.3±0.09	<0.01	1.28±0.15	113±1.06
Liboi B\H	43.43±0.12	<0.01	0.78±0.05	138±1.02
Liboi BH 3	68.43±0.93	<0.01	0.97±0.02	113±1.00
Kulan BH No 1	38.60±0.83	<0.01	0.59±0.04	261±1.23
Maley BH 2	36.3±1.23	<0.01	0.75±0.01	2,210±7.30
Kumahumato	12.2±0.15	<0.01	0.67±0.00	38±1.32
Alikune Market	16±0.23	<0.01	0.81±0.00	34±1.56
Dertu No1	65.71±1.12	<0.01	4.1±0.10	255±3.20
Dertu RC No 1	46.29±0.96	<0.01	1.41±0.02	133±2.45
Welhar	13.6±0.34	<0.01	0.73±0.03	15±0.63
Labisigale BH	15.9±0.32	<0.01	0.49±0.05	18±0.78
Ifo 2 C1	25.4±0.65	<0.01	0.6±0.03	18±0.98
Ifo 2 C2	25.2±0.74	<0.01	0.73±0.01	28±0.98
Ifo 2 C3	31.66±0.98	<0.01	0.66±0.06	49±0.89
Hagadera C2	46.43±0.74	<0.01	0.93±0.02	71±1.27
Hagadera C6	39.71±0.75	<0.01	1.14±0.09	92±1.98
Hagadera C8	4.3±0.09	<0.01	1.31±0.02	57±0.98
Dagahaley CB/H	15.57±0.87	<0.01	0.59±0.08	18±0.52
Dagahaley C3	25.5±0.35	0.03	0.57±0.04	26±0.32
Dagahaley C9	13.51±0.49	<0.01	0.5±0.06	23±0.99
Seretho	299.7±3.25	<0.01	2.04±0.02	660±3.22
Dadaab C2	28.71±0.99	<0.01	0.83±0.01	42±0.96
Dadaab C3	35±1.00	<0.01	2.29±0.03	30±0.32
Dadaab C4	39.3±1.12	<0.01	1.12±0.04	104±1.45
Bogyar	213.1±2.40	<0.01	2.91±0.12	205±2.33
Bulkhaheri BH	6.2±0.59	<0.01	0.83±0.11	34±1.22

**BH = Borehole *C = Camp*

Table 9. Concentration of nitrates and Nitrites in water sampled from water pans in Lagdera Sub-county

Sampling site	mgNO_3^-/l	mgNO_2^-/l
Weldon Bisiqle	1.9±0.01	0.44±0.00
War Deg Low	<0.01	<0.01
Kulan Mega	<0.01	<0.01
Kumahumato	0.64±0.01	0.1±0.00
Uthole	<0.01	0.12±0.00
Orah	0.13±0.00	<0.01
Eigege	0.07±0.00	0.41±0.00
Hagabul	0.44±0.01	<0.01

4. CONCLUSION

Chemical standards may not be applied too strictly in Garissa County. Most groundwater simply does not conform with quality norms accepted elsewhere and in the absence of other reliable sources of water, groundwater is the only option. Hence a detailed knowledge of the water quality and geochemical evolution of groundwater can assist in the understanding of the hydrochemical system, thereby promoting effective management and sustainable development of groundwater resources [19]. The results from this study suggested that the groundwater in specific sampling points did not meet accepted water quality standards for human consumption. The groundwater samples were dominated by high concentrations of K, Na, Cl, and HCO_3 ions. pH values revealed that the groundwater was slightly basic in nature. The excess amount of total dissolved solids in the groundwater was due to geological characteristics and anthropogenic factors of the aquifer. The changing chemical composition of groundwater was attributed to evaporation and rock–water interaction. The carbonate are mainly derived from carbonate mineral and silicate weathering while sulfate and chloride concentration in groundwater is attributed to weathering, dissolution of rock formations, and irrigation drainage return flow [20,21]. K, Na, Ca, Mg were derived from leaching and weathering of rock formations and anthropogenic activities. NO_3^- and NO_2^- are mainly derived from various agricultural and anthropogenic activities. The dramatic urbanization, weathering process of rock formations, and water dissolved natural organic and inorganic compounds are the main factors that contribute to groundwater quality degradation in Garissa County. Thus this water cannot be consumed directly from the source by the community but has to be treated first.

5. RECOMMENDATION

Groundwater remediation may be required whenever the concentration of certain pollutants is found to be higher than the guideline values. Before the feasibility of remedial or management strategies can be demonstrated and determined, the site hydrogeology and contaminant behaviour must be well understood. This will ensure that situations are improved and not worsened by remediation or management strategies.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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