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Quality Assessment of Surface Water for Domestic and Agricultural Purposes Using Hydro-chemical and Microbial Studies in Kilifi County, North Coast Region of Kenya

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Authors' contributions

This work was carried out in collaboration among all authors. Authors NAA, LMC and PSO conducted field collection of the water samples. Author BI conceptualized and designed the study, conducted the analysis of water quality parameters including laboratory analysis of metals, non-metals and microbial loads. Author MMC compiled the description and mapping of the study area. Author LMC conducted descriptive and inferential statistics of the data and drafted the manuscript. Authors SE and PSO revised and finalized the manuscript. Author PSO through funding from National Research Funds (NRF) contributed reagents and materials used in both field and laboratory work. All authors read and approved the final manuscript.

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ABSTRACT

Water has economic and ecological significance. However, quality deterioration due to salinity causes significant decrease in agricultural productivity and a public health problem. This study focuses on hydro-chemical and microbial quality of water sources in Kilifi County. Water samples were collected from 25 different locations within Kilifi County and indicators of salinity and microbial load analyzed. Temperature, pH, EC and TDS were determined using portable pH meter. Anions; F^-, Br^-, Cl^-, SO_4^{2-}, PO_4^{3-}, NO_2^-, NO_3^-, CO_3^{2-}, HCO_3- and NH_4^+ were determined using Ion Exchange Chromatography. Cations; Na^+, K^+, Ca^{2+}, Mg^{2+}, Zn^{2+}, Fe^{2+}, Cd^{2+}, Cr^{3+}, Al^{3+} and Ag^+ were determined using flame photometry. Standard methods were used to determine Microbial loads. Results were pH (7.42±0.52), Temperature (24.61±0.21°C), EC (3.44±0.75 $dscm^{-1}$), TDS (1672.53±122.87 mgL^{-1}) and Turbidity (152.29±41.20 NTU). Anions; F^- (2.90±0.24 mg/L), Cl^- (1756.68±900.50 mg/L), NO_2^- (4.47±0.49 mg/L), Br^- (11.72±1.20 mg/L), NO_3^- (4.67±0.38 mg/L), HCO_3^- (200.54±25.58 mg/L) PO_4^{3-} (0.94±0.10 mg/L), CO_3^{2-} (29.94±2.32 mg/L), and SO_4^{2-} (300.64±42.47 mg/L). Cations; K^+ (8751.80±214.04 mgL^{-1}), Na^+ (59.43±1.98 mgL^{-1}), Ca^{2+} (4.00±0.16 mgL^{-1}), Mg^{2+} (59.43±1.98 mgL^{-1}), Zn^{2+} (0.76±0.30 mgL^{-1}), Cu^{2+} (0.18±0.01 mgL^{-1}), Ag^+ (0.03±0.01 mg/L), Cd^{2+} (0.07±0.01 mg/L), $Cr3^+$ (0.35±0.01 mg/L), Al^{3+} (0.33±0.01 mg/L) and NH_4^+ (2.01±1.96 mg/L). Microbial load; MPN (20811.00±402.00), Total coliforms (2970.00±60.00 CFU 100 mL^{-1}), *E. coli* (26.00±3.00 CFU 100mL^{-1}), *S. aureus* (411.00±12.00 CFU 100mL^{-1}), *Shegela* (24.00±2.00 CFU 100mL^{-1}) and *S. typhi* (67.00±2.00 CFU 100mL^{-1}). Temperature, pH, EC, TDS, Turbidity, F^-, Cl^-, Br^-, PO_4^{3}-, Na^+, Zn^{2+}, Fe^{2+} and microbial load were above WHO limits whereas SO_4^{2-}, NO_2^-, NO_3^-, CO_3^{2-}, HCO_3-, NH_4^+, K^+, Ca^{2+}, Mg^{2+}, Cd^{2+}, Cr^{3+}, Al^{3+} and Ag^+ were below WHO limits. The study concludes that water sources in Kilifi County are unsuitable for domestic and agricultural uses. It's recommended that a continuous water quality monitoring program be put in place and development of effective management practices for utilization of the surface water resources be instituted.

Keywords: Quality assessment; surface water; salinity indicators; microbial load.

1. INTRODUCTION

One of the major environmental concerns throughout the Coastal regions of the world is salinity [1-4]. The economic viability brought about by growth and development of countries depends on Agricultural production system [5]. However, this depends on the quality of natural resources used for Agricultural productivity [6]. Salinized water resources constrain Agricultural and economic development by creating a hostile environment for normal crop production in Coastal belts of many countries [3-5]. The organic matter of Coastal soils is very low and highly salinized [3-5] resulting into deficiencies of Nitrogen (N), Sodium (Na) and Potassium (K) and a wide spread of micronutrients such as Copper (Cu), Zinc (Zn) among others [5]. This has negatively affected the economy of many countries in the Coastal regions of the world [3-5] due to reduction in Agricultural productivity. Furthermore, reduction in fresh water flow from the upstream tidal flow and ground water discharge exacerbate the problem [2, 4]. Although salinity challenges have been identified and management strategies put in place [7, 8], they still affect plant health and productivity [9-15] and human health [16-19].

The Coastal belt of Kenya consists of 6 Counties; among them is Kilifi County [20]. The Kilifi County lies between latitude 2°20° and 4°0° South, and between longitude 39° 05° and 40° 14° East. It borders Kwale County to the south west, Taita Taveta County to the west, Tana River County to the north, Mombasa County to the south and the Indian Ocean to the east. The County covers an area of 12,539.7 km^2 and has an estimated population of 1,453,787 composed of 704,089 males and 749,673 females [20]. The population was projected to rise to 1,841,958 (47.8% males and 52.2% females) by the year 2025 at a mean inter-censual annual growth rate of 3.05% [20]. The males represent 48.4% while the females represent 51.5% of the total population indicating a male: female ratio of 1:1.065 with the County's dependency ratio standing at 101.45% [20]. Kilifi County has a versatile child rich population, where 0-14 year olds constitute 47% of the total population. In Kilifi County, 16% of the population have no formal education, 23% have primary education and 39% have secondary level of education or above and are salaried employees [20]. The population of Kilifi County represents Kenya's fastest growing demographic population and thus requires corresponding food security and economic stability to be addressed.

Agriculture is one of the most important economic activities that support livelihoods of many communities within Kilifi County. However, the County experiences erratic rainfall patterns just like other Counties within the Coast region [4]. Consequently, the County depends on rain fed Agriculture practices, which give rise to insufficient Agricultural produce to sustain the ever growing population of the County. This pose a constant threat to food security in the County. The problem is further complicated by high microbial load and salinity levels of the water available [4, 21], that hinders Agricultural advancement within the County. In a bid to bridge food security issues, several non-governmental organizations (NGOs), including Japan International Corporation Agency (JICA), World Vision, DANIDA, United Nation's (UN) World Food Program (WFP) and Plan International partnered with the County Government of Kilifi to boost Agricultural activities. Some of the projects include Mudachi Irrigation Scheme (MIS) in Ganze sub-county establish by JICA, Galana Irrigation Scheme (GIS) in Malindi and Magarini sub-county by the central Government and Water Pan Project established by World vision in collaboration with WFP in Kaloleni sub-county, which aims at providing quality water for both domestic and Agricultural use.

Although the establishment of MIS and GIS were intended to improve the economy of the north Coast of Kenya [22], the success of these projects is tied to the availability and quality of the water [6, 23-26]. The MIS pays greater attention to production of horticultural crop leaving the burden of livestock production entirely to the farmers. River Nzovuni, the only source of water for MIS, also utilized for domestic purpose presents salinity and mineralization challenges necessitating scientific research and worthwhile interventions [22]. The crops grown in MIS have shown wilting suggesting the use of poor quality water [27], thus resulting in low productivity. The upstream of River Nzovuni including the source is fresh. The salinity level however, increases as the river flows through the Coastal lowlands and drains into the Indian Ocean via the Kilifi creek. Other rivers such as River Kombeni, River Mbogolo, River Rare, River Mukulu, River Galana (Sabaki) among others are suspected to follow the same trend just like River Nzovuni. The ocean water intrusion during high tides, dissolving bedrocks and industrial waste deposition are suspected cause for the salinity of the rivers and any other surface water source [3, 4]. The quality of water for both domestic and Agricultural use has been evaluated in several studies in several countries including Kenya [4, 28-42]. However, none was conducted in Kilifi County. Therefore, the quality of surface water within the county for its suitability for both domestic and Agricultural use need to be evaluated for the improvement of Agricultural productivity.

2. MATERIALS AND METHODS

2.1 Description of Study Area and Sampling

The study was carried out in Kilifi County situated in the northern part of the Coast province of Kenya (Fig. 1). It lies between latitude 2^o20^o and 4^o0^o South and between longitude 39^o05^o and 40^o 14^o East. The County borders Kwale County to the South West, Taita Taveta County to the West and Tana River County to the North, Mombasa County to the South and Indian Ocean to the East [20]. Administratively, it is divided into seven administrative sub-counties namely; Kilifi South, Kilifi North, Ganze, Malindi, Magarini, Kaloleni and Rabai and thirty-five (35) devolved political units (Wards) [20]. Water samples were collected from twenty-five (25) different sampling sites located in different administrative locations within Kilifi County (Table 1).

2.2 Collection of Water Samples

Water samples were collected randomly with different sites in Kilifi County for analysis of salinity indicators in 2018. Three collected water samples were mixed together for making a sample for each location. Samples were collected in 100 mL polyethylene plastic bottles. Each bottle was cleaned thoroughly by rinsing with diluted HCl followed by washing with distilled water. The water samples were filtered with Whatman 42 to remove suspended solids. Prepared sample solutions were sealed immediately to minimize exposure to air, and collected samples were transported within 48 hrs in a cooler box to the Environmental Science Laboratory of Jomo Kenyatta University of

Agriculture and Technology (JKUAT) and and Directorate of Research Grants and Endowments Laboratories Mount Kenya University (MKU). The samples were refrigerated at 4°C prior to analysis.

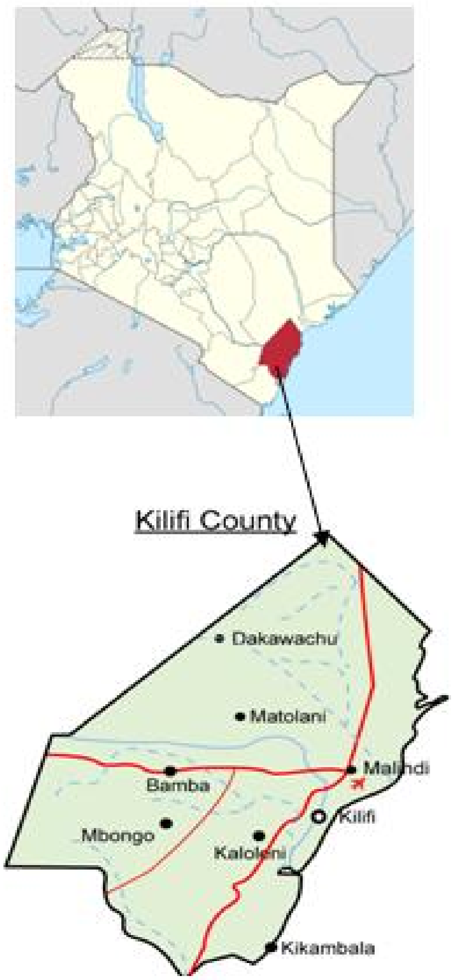

Fig. 1. Geographical map of Kenya showing the project area, Kilifi County
Source: Google Map

2.3 Analysis of Physico-chemical Properties of the Water Samples

The pH, electrical conductivity (EC), Salinity, Temperature, and Total Dissolved Solids (TDS) were determined in situ using a portable multi-parameter meter, Temp/pH/TDS/EC meter (Model MI 1399) as described by Jackson [43]. Anions; Fluoride (F^-), Chloride (Cl^-), Bromide (Br^-), Nitrite (NO_2^-), Nitrate (NO_3^-), Ammonium (NH_4^-), Hydrogen Carbonate (HCO_3^-), Carbonate (CO_3^{2-}) Phosphate (PO_4^{3-}) and Sulfate (SO_4^{2-}) were determined using Ion Exchange Chromatography (IEC) (Model: Dionex ICS-1600) as described by APHA 4110 method [44]. The samples and standard solutions were digested for 30 minutes on a hot plate in fume hood after which they were filtered and transferred to 100-mL volumetric flask. Prior to the analysis of Potassium, Sodium, Magnesium and Calcium in the water sample, 5 mL of 71% HNO_3 was used to digest 100 mL of the samples for 30 min on hot plate in a fume hood. Sodium (Na^+), Potassium (K^+), Calcium (Ca^{2+}) and Magnesium (Mg^{2+}) were determined by flame emission spectrophotometer (Model: Jenway, PFP7) at 589 nm and 769 nm wavelength, respectively as describe by Jackson, (1967). Cadmium (Cd^{2+}), Chromium (Cr^{3+}), Copper (Cu^{2+}), Iron (Fe^{2+}), Zinc (Zn^{2+}) Aluminium (Al^{3+}), and Silver (Ag^+) in water samples were determined with an Atomic Absorption Spectrophotometer (AAS) (Model: AA-7000, Shimadzu) followed by APHA 3111 method calibrated using certified reference materials (CRMs) [44].

2.4 Bacteriological Analysis of the Collected Water Samples

2.4.1 Isolation and enumeration

Ten (10) mL of the water samples were diluted with 90 mL sterile peptone water and thoroughly mixed. About 0.1 mL aliquot of each of the diluted samples were inoculated onto pre-sterilized Nutrient agar (NA) and solidified plate count agar (PCA) as basal medium. Presumptive isolation of coliform bacteria was made on MacConkey broth. Multiple tubes containing 1 mL, 0.1 mL and 0.01 mL samples were inoculated onto test tubes each containing 10 mL of single-strength MacConkey broth incubation at 37°C for 48 hours and the tubes with acid and gas were considered positive for coliforms. Fecal and total coliform counts were performed using the standard membrane filtration technique as described by APHA [44]. The distribution of positive tubes was used to determine the Most Probable Number (MPN) of total coliform count following standard probability table as described by APHA [44]. Further, the presence of *Escherichia coli* was confirmed by streaking loopful of broth culture onto Eosine Methylene Blue (EMB) agar and evaluating for the formation of metallic sheen color as described by APHA [44].

Table 1. Administrative location and use of sampled water sources of Kilifi County

Sampling site	Sample code	Location	Use
MIS inlet canal	MISIC	Ganze	Irrigation
MIS Quadrant 1	MISQ1	Ganze	Irrigation
MIS Quadrant 2	MISQ2	Ganze	Irrigation
MIS Quadrant 3	MISQ3	Ganze	Irrigation
MIS Quadrant 4	MISQ4	Ganze	Irrigation
MIS outlet canal	MISOC	Ganze	Irrigation
River Nzovuni (Upstream)	RNUS	Ganze	Multipurpose
River Nzovuni (Midstream)	RNMS	Ganze	Multipurpose
River Nzovuni (Downstream)	RNDS	Ganze	Multipurpose
River Kizurini (Upstream)	RKZUS	Kaloleni	Multipurpose
River Kizurini (Midstream)	RKZMS	Kaloleni	Multipurpose
River Kizurini (Downstream)	RKZDS	Kaloleni	Multipurpose
Chanagande Dam	CD	Kaloleni	Human consumption
Kolongoni Dam	KD	Kilifi South	Animal watering
Mwabaya Nyundo Dam	MND	Kaloleni	Human consumption
Water pan Project Dam (Right)	WPDR	Kaloleni	Multipurpose
Water pan Project Dam (Left)	WPDL	Kaloleni	Multipurpose
Kadzonzo Dam	KZD	Kaloleni	Multipurpose
River Kombeni (Upstream)	RKUS	Kaloleni	Multipurpose
River Kombeni (Midstream)	RKMS	Rabai	Multipurpose
River Kombeni (Downstream)	RKDS	Rabai	Multipurpose
Mariakani water Tank	MWT	Rabai	Human consumption
Mnagoni Dam	MD	Rabai	Animal watering
Mamburui Farm Dam	MFD	Magarini	Animal watering
Furunzi Dam	FD	Malindi	Animal watering

2.4.2 Characterization of bacterial isolates

About 10 - 15 colonies were randomly picked from countable plates of PCA and MacConkey agar and inoculated into 5 mL Nutrient broth tubes followed by incubation at 30 - 35°C for 24 hours. Cultures were purified by repeated plating on Nutrient agar and characterized to the genus level on the basis of their colonial, morphological and Biochemical reaction (Gram reaction, Catalase test, Cytochrome oxidase test) following standard microbiological methods by Bergey's Manual of Determinative Bacteriology [45].

2.4.3 Detection of salmonella

Pre-enrichment was performed by aseptically inoculating 1 mL of each sample into 10 mL of lactose broth (LB) and incubated at 37°C for 24 hours. Thereafter, 1 mL culture was transferred into 10 mL of Rappaport-Vassiliadis broth (selenite cystine broth) as secondary enrichment broth and incubated at 42°C for 48 hours. Loopful of cultures from Rappaport-Vassiliadis broth were separately streaked onto Salmonella–Shigella agar, Xylose Lysine Deoxycholate agar and modified Brilliant Green agar and incubation at 37°C for 18 hours. Characteristic colonies were picked, further purified and tested biochemically. Further, the proportion of *Salmonella* positive samples was determined based on biochemical test results after characterization of suspected non-lactose fermenting bacterial colonies inoculated into tubes containing Triple Sugar Iron (TSI) agar, Simmon's Citrate agar, Sulfur Indole motility (SIM) medium, Lysine Iron agar, Urea agar and fermentation tubes of glucose, sucrose and Mannitol [45].

2.4.4 Data Analysis

The data were analyzed using SPSS statistical software (version 20). Results of physico-chemical analysis and mean microbial counts of the investigated water samples were compared with the set standards [18] and interpreted as acceptable or unacceptable.

3. RESULTS

3.1 Hydro-chemical Properties of Water

The hydro-chemical properties of water samples collected from the twenty-five (25) sampling points within Kilifi County are given in Table 2. The pH values of the collected samples ranged from 6.89±0.06 (RNUS) and 9.65±0.30 (RNDS) with an average value of 7.42±0.52. The sample RNDS recorded pH value above the World Health Organization (WHO) recommendation for both drinking and irrigation water (6.5 - 8.5). The temperature readings of the collected water samples ranged from 23.47±0.19°C (MWT) to 26.27±0.34°C with an average of 24.61±0.21°C. The electrical conductivity (EC) values ranged from 0.96±0.10 dScm^{-1} (MWT) to 5.03±0.21 dScm^{-1} (MFD) with an average value of 3.44±0.75 dScm^{-1}. The TDS in the sampled water ranged from 124.00±5.51 mgL^{-1} (MWT) to 2063.00±41.36 mgL^{-1} (MFD) with an average value of 1672.53±122.87 mgL^{-1}. Further the turbidity of the collected water samples ranged from 60.40±5.16 (NTU) (MWT) to 215.17±4.40 (NTU) (MISIC) with an average value of 152.29±1.20 (NTU).Compared with the standard limit set by WHO values for Temperature (4°C to 18°C), pH (6.5 – 8.4), EC (3.0 dScm^{-1}), TDS (1000 mgL^{-1}), salinity and turbidity, the results from the study were above these set limits.

Fig. 2. Tomato grown in Mudachi irrigation Scheme (MIS) showing signs of wilting

Table 2. Hydro-chemical parameters of water samples collected from water sources in Kilifi County

CODE	pH	Temperature (°C)	EC (dscm^{-1})	TDS (mgL^{-1})	Turbidity (NTU)
MISIC	7.27±0.15	26.27±0.19	3.49±0.18	1776.67±9.80	215.17±4.40
MISQ1	7.43±0.04	24.20±0.10	3.46±0.04	1771.33±3.72	192.73±4.34
MISQ2	7.45±0.02	23.80±0.07	3.38±0.01	1696.33±3.15	143.72±3.81
MISQ3	7.44±0.00	24.50±0.29	3.40±0.00	1682.67±8.11	128.55±5.04
MISQ4	7.50±0.02	24.67±0.34	3.15±0.04	1575.67±23.84	146.85±6.52
MISQOC	7.92±0.15	25.61±0.39	3.80±0.26	1870.00±32.64	174.35±2.85
RNUS	6.89±0.06	24.30±0.20	3.13±0.13	1688.00±31.99	207.52±4.12
RNMS	7.23±0.11	24.59±0.35	3.25±0.12	1625.33±76.93	182.13±3.51
RNDS	9.65±0.30	25.80±0.32	4.65±0.17	1928.67±14.26	208.26±5.05
KD	7.75±0.10	26.25±0.17	3.97±0.12	1987.98±21.67	187.75±10.11
CD	7.51±0.10	24.92±0.11	4.80±0.06	2145.33±4.75	154.36±1.68
RKZUS	7.44±0.16	24.25±0.56	2.97±0.06	1414.00±56.46	83.62±2.30
RKZMS	7.12±0.07	24.44±0.30	3.28±0.06	1633.33±48.70	111.05±4.22
RKZDS	7.16±0.06	24.80±0.30	3.16±0.24	1742.00±4.58	126.37±4.71

CODE	pH	Temperature (°C)	EC (dscm^{-1})	TDS (mgL^{-1})	Turbidity (NTU)
MND	7.39±0.12	24.33±0.15	3.28±0.09	1553.00±28.11	154.32±18.71
WPDR	7.27±0.09	24.77±0.28	3.32±0.10	1769.33±24.35	142.33±13.49
WPDL	7.32±0.07	23.92±0.19	3.34±0.10	1763.67±32.03	121.96±3.39
KZD	7.24±0.11	24.51±0.17	3.37±0.12	1799.33±3.69	116.85±2.24
RKUS	7.27±0.05	24.41±0.22	3.50±0.15	1776.33±16.06	186.23±2.42
RKMS	7.19±0.14	24.17±0.22	3.37±0.09	1457.00±35.51	121.55±3.22
RKDS	7.58±0.05	25.16±0.15	3.77±0.08	1813.67±12.23	144.10±3.54
MWT	6.92±0.04	23.47±0.13	0.96±0.10	124.00±5.51	60.40±5.16
MD	7.36±0.01	24.26±0.15	3.56±0.08	1659.67±34.16	134.15±2.31
MFD	7.40±0.11	25.31±0.16	5.03±0.21	2063.00±41.36	215.41±6.26
FD	7.18±0.08	24.28±0.14	3.11±0.17	1812.33±13.06	182.95±6.90
Average	7.42±0.52	24.61±0.21	3.44±0.75	1672.53±122.87	152.29±41.20

Mean values of three replicate measurements (n=3) ± SEM

3.2 Concentration of Cations

The concentration of cations (Na^+, K^+, Mg^{2+}, Cu^{2+}, Ca^{2+}, Zn^{2+}, Cr^{3+}, Cd^{2+}, Fe^{2+}, Al^{3+}, Pb^{2+} and Ag^+) of water samples collected from the twenty-five (25) sampling points within Kilifi County are given in Table 3. The average concentration of K^+ in this study was 8751.80±214.04 mgL^{-1}. These were in the ranges of 3212.62±12.63 mgL^{-1} (RNMS), the lowest concentration to 21061±54.29 mgL^{-1} (MISQ3) the highest concentration with the values being beyond the WHO limit of of 200 mgL^{-1}. The levels of Na^+ in this study ranged from 61.99±1.21 mgL^{-1} (CD) to 79.90±0.48 mgL^{-1} (MFD). The average concentration of Na^+ in Kilifi County water sources was 59.43±1.98 mgL^{-1}. It was reported from this study that the level of Ca^{2+} ranged from 1.61±0.03 mgL^{-1} (MISQ1) to 7.66±0.31 mgL^{-1} and 7.66±0.41 mgL^{-1} in RKMS and RKZMS respectively. On average the Kilifi County water sources had a concentration of Ca^{2+} of 4.00±0.16 mgL^{-1}. The level of Mg^{2+} reported in this work ranged from 0.05±0.01 mgL^{-1} to 79.05±1.26 mgL^{-1} with an average value of 59.43±1.98 mgL^{-1}. Further, average Fe^{2+} (10.58±0.27 mgL^{-1}) was in the range between 1.18±0.30 mgL^{-1} (MISQ1) and 24.05±1.62 mgL^{-1} (MISQ3), Cr^{3+} (0.35±0.01 mgL^{-1}) ranging from 0.13±0.03 mgL^{-1} (RNUS) and 1.17±0.06 mgL^{-1} (FD), Zn^{2+} (0.76±0.30 mgL^{-1}) with ranges between 0.28±0.02 mgL^{-1} (MISIC) and 2.63±0.16 mgL^{-1} (KRDS), Cu^{2+} (0.18±0.01 mgL^{-1}) in the range between 0.02±0.00 mgL^{-1} (RNUS, KZD, RKZUS, RKZMS, RKUS, RKMS, RKDS and MND), Ag^+ (0.03±0.010 mgL^{-1}) within the range of 0.01±0.00 mgL^{-1} (MND) to 0.08±0.04 mgL^{-1} (MISQ4 and KZD) and Al^{3+} (0.33±0.01 mgL^{-1}) falling in the range of 0.13±0.00 mgL^{-1} (NRUS) and 0.43±0.02 (RKZDS and MISQ4). Comparison with standards values set for Na^+ (200 mgL^{-1}), Fe^{2+} and Cu^{2+} (0.02 mgL^{-1}) by WHO, the water samples had higher values above the standard limits. However, the samples had values below the standard limits for K^+, Mg^{2+} (100 mgL^{-1}), Ca^{2+} (20-30 mgL^{-1}), Zn^{2+} (2 mgL^{-1}), Ag^+, Cd^{2+}, Cr^{3+} and Al^{3+}.

3.3 Concentration of Anions

The concentration of anions (F^-, Cl^-, Br^-, HCO_3^-, CO_3^-, SO_4^{2-}, NO_2^- and PO_4^{3}) of water samples collected from the twenty-five (25) sampling points within Kilifi County are given in Table 4. The concentration of F^- in sample collected ranged between 0.42±0.04 mgL^{-1} (MWT) to 3.91±0.08 mgL^{-1} (CD). On average the F^- levels in the water sources from Kilifi County was 2.90±0.24 mgL^{-1}. The Cl^- anions were the most with an average value of 1756.900.50 mgL^{-1}. This was in the range between between 4.89±0.86 mgL^{-1} (MWT) and 5300.56±232.69 mgL^{-1} (MISQ2). In the present study, the levels of $SO4^{2-}$ ranged from 5.29±0.76 mgL^{-1} (MWT) to 505.93±24.35 mgL^{-1} (FD) with an average value of 300.64±42.47 mgL^{-1} in all the samples collected from Kilifi water sources. The levels of PO_4^{3-} in the present study ranged from 0.04±0.01 mgL^{-1} (MWT) to 1.40±0.17 mgL^{-1} (RNDS) with an average value of 0.94±0.10 mgL^{-1}. The average amount of NO_2^- and NO_3^- in the Kilifi County water sources was 4.47±0.49 mg^{L-1} and 4.67±0.38 mgL^{-1} respectively. However, NO_2^- were low ranging from 0.04±0.01 mgL^{-1} (MWT) to 6.73±0.41 mgL^{-1} (MISQOC) compared to NO_3^- which was in the range between 1.64±0.07 mgL^{-1} (MWT) and 6.81±0.37 mgL^{-1} (MISQ2). The average Br- were recorded in the water sources with concentrations ranging from 0.112±0.01

mgL^{-1} (MWT) to 16.79±195 mgL^{-1} (MISQ2), with an average value of 11.72±1.20 mgL^{-1}. The amount of CO_3^{2-} and HCO_3^- in the water samples ranged from 9.25±0.47 mgL^{-1} (MWT) to 35.87±0.34 mgL^{-1} (KRDS) and 12.52±0.63 mgL^{-1} to 385.56±10.05 mgL^{-1} (RKZDS). The average concentration of CO_3^{2-} and HCO_3^- was 29.94±2.32 mgL^{-1} and 200.53±25.58 mgL^{-1} respectively. The recommended levels for safe drinking water as described by Yilmaz & Koç [46] and WHO [18] are F^- (1.5 mgL^{-1}), Cl^- (250 mgL^{-1}), Br^- (2.0 mgL^{-1}) HCO_3^- , CO_3^-, SO_4^{2-} (400 mgL^{-1}), NO_2^- (45 mgL^{-1}), NO_3^- (45 mgL^{-1}) and PO_4^{3} (0.5 mgL^{-1}), therefore, F-, Cl-, Br-, PO_4^{3-} were above the permissible level whereas HCO_3^-, CO_3^-, NO_2^-, NO_3^- and SO_4^{2-} were below the permissible level for water used for both domestic and Agricultural purposes.

3.4 Microbial Load of Water Sources

The mean microbial counts for *E. coli,* total coliforms, *S. aureus*, *S. typhi* and *Shigella* in the water sources in Kilifi County are shown in Table 5. The positive samples after 24 hrs incubation in different medium are presented in Fig. 3.

Generally, the water sources from Kilifi County had high microbial load as depicted by the values, MPN, faecal coliforms and total coliforms. The MPN of water samples from Kilifi County ranged between 00.0±0.00 CFU 100 mL^{-1} (MWT) and 44351.00±890.00 CFU 100 mL^{-1} (KD) wit an average value of 20811.00±402.00 CFU 100 mL^{-1}. The *E. coli* was absent in MWT (00.0±0.00 CFU 100 mL^{-1}). The average value of *E. coli* of the water samples in Kilifi County was in the range between 0.00±0.00 CFU mL^{-1} (MWT) and 95.00±2.00 CFU mL^{-1} (WPDL) with an average of 26.00±3.00 CFU mL^{-1}. The WPDL water had the highest mean counts for *E. coli* contamination of 95.00±2.00 CFU mL^{-1}. The average Total coliform count for the water source from Kilifi County was 2970.00±60.00 CFU mL^{-1}. The MWT had no coliforms (00.0±0.00 CFU mL^{-1}) while MND had the highest mean coliform counts of 6950.00±33.00 CFU mL^{-1}. Mean total coliforms count across all the water sources differed significantly ($p \leq 0.05$). The MWT water had no *S. aureus* (00.0±0.00 CFU mL^{-1}) while MISQ1 water had the highest *S. aureus* count of 895.00±24.00 CFUmL^{-1}. The average *S. aureus* in the water sources from Kilifi County was 411.00±12.00 CFU mL^{-1}. The KD water sample had the highest *Shigella* count of 160.00±14.00 CFU mL^{-1} whereas MTW water had no *Shigella* (00.0±0.00 CFU mL^{-1}) with average *Shigella* count value of 24.00±2.00 CFU mL^{-1}. *S. typhi* was the abundant microorganism within the water source from Kilifi County with an average value of 67.00±2.00 CFU mL^{-1}. This was in the range between 0.00±0.00 CFU mL^{-1} (MWT) and 242.00±58.00 CFU mL^{-1} (FD). *The E. coli, S. aureus, Shigella* and *S. typhi* contamination in the water sources in Kilifi County significantly differed ($p > 0.05$) among all the the samples from different water sources. However, all the samples collected from different water sources within the county were significantly different ($p > 0.05$), compared with the standards. All the samples collected from Kilifi County water sources except MWT had a microbial load that was greater than the standard values for both domestic and agricultural use (WHO, 2011).

Fig. 3. Water samples from MIS after 24 hours of incubation in Nutrient Broth (a), Mac Conkey agar (b), Simmons Citrate agar (c) and Salmonella Shigella agar (d)

Table 3. Metal ion concentration (mgL^{-1}) of water samples collected from water sources in Kilifi County

Code	Na^+	K^+	Mg^{2+}	Cu^{2+}	Zn^{2+}	Ca^{2+}	Cr^{3+}	Cd^{2+}	Fe^{2+}	Ag^+	Al^{3+}
MISIC	66.96±1.81	4198.13±48.34	61.31±2.09	0.04±0.00	0.28±0.02	1.60±0.01	0.20±0.00	0.07±0.00	9.87±0.40	0.02±0.00	0.30±0.01
MISQ1	82.47±1.59	5141.90±68.49	54.50±1.46	0.05±0.00	0.31±0.00	1.63±0.01	0.30±0.00	0.08±0.00	1.18±0.30	0.08±0.04	0.32±0.01
MISQ2	91.58±0.77	5218.73±32.09	61.14±2.11	0.21±0.01	0.89±0.01	1.61±0.03	0.29±0.00	0.07±0.00	6.99±0.40	0.01±0.00	0.38±0.01
MISQ3	94.96±0.75	21061.56±54.29	57.77±0.10	0.85±0.02	1.40±0.02	1.96±0.02	0.32±0.00	0.08±0.00	24.05±1.62	0.02±0.00	0.41±0.01
MISQ4	97.30±0.51	5414.18±10.02	58.55±0.21	0.22±0.00	0.72±0.00	1.71±0.01	0.31±0.00	0.07±0.00	16.73±0.85	0.03±0.00	0.43±0.02
MISQOC	85.76±0.93	5109.26±38.33	58.07±0.04	0.31±0.02	0.61±0.01	1.86±0.02	0.29±0.02	0.06±0.00	3.79±0.14	0.03±0.00	0.32±0.00
RNUS	56.99±1.83	12008.85±17.88	59.26±0.23	0.02±0.00	0.24±0.01	1.96±0.04	0.13±0.03	0.05±0.01	16.73±0.85	0.02±0.00	0.13±0.00
RNMS	69.29±0.61	3212.63±12.63	55.17±0.08	0.38±0.00	0.56±0.00	2.07±0.01	0.27±0.01	0.07±0.00	7.78±0.28	0.02±0.00	0.30±0.00
RNDS	74.28±1.17	3371.20±18.04	58.50±0.45	1.02±0.00	1.66±0.07	2.37±0.12	0.32±0.01	0.10±0.00	3.73±1.71	0.02±0.00	0.41±0.00
KD	73.21±6.46	12776.11±44.60	61.91±0.73	0.02±0.00	0.42±0.01	1.67±0.03	0.26±0.01	0.06±0.00	5.36±1.06	0.02±0.00	0.30±0.01
CD	61.99±1.21	3858.78±392.42	61.57±1.63	0.04±0.00	0.82±0.02	2.86±0.22	0.42±0.01	0.05±0.01	19.68±3.86	0.03±0.00	0.32±0.01
RKZUS	70.99±0.34	12739.48±49.41	53.81±1.02	0.02±0.00	0.38±0.01	0.98±0.04	0.24±0.01	0.08±0.00	18.69±0.54	0.02±0.00	0.38±0.01
RKZMS	73.95±1.33	12078.85±17.88	62.85±0.81	0.02±0.00	0.54±0.01	7.66±0.41	0.36±0.01	0.08±0.00	7.12±2.02	0.02±0.00	0.41±0.01
RKZDS	72.29±0.49	12739.48±59.41	79.10±2.58	0.02±0.00	1.14±0.05	15.60±0.24	0.43±0.01	0.08±0.00	12.49±2.56	0.07±0.01	0.43±0.02
MND	88.16±2.95	5109.26±38.33	58.54±0.91	0.02±0.00	0.31±0.03	1.66±0.13	0.26±0.01	0.08±0.01	3.79±0.14	0.01±0.00	0.32±0.00
WPDR	96.80±0.32	12078.85±37.88	57.51±0.71	0.11±0.05	0.42±0.01	3.36±0.12	0.32±0.01	0.10±0.00	6.60±1.52	0.03±0.00	0.13±0.00
WPDL	94.19±1.70	12786.11±44.60	55.92±1.21	0.05±0.02	0.38±0.01	2.64±0.09	0.25±0.01	0.06±0.00	2.68±0.97	0.02±0.00	0.30±0.02
KZD	75.94±2.09	3868.78±82.42	55.88±2.39	0.02±0.00	0.34±0.01	1.76±0.04	0.32±0.01	0.05±0.01	14.84±4.21	0.08±0.04	0.41±0.00
KRUS	66.03±5.97	12774.29±50.64	59.94±0.81	0.02±0.00	0.42±0.01	2.85±0.22	0.33±0.01	0.07±0.01	19.87±0.98	0.02±0.00	0.30±0.01
KRMS	72.89±6.25	5218.73±32.09	54.21±1.25	0.02±0.00	0.44±0.01	7.66±0.31	0.43±0.01	0.09±0.01	12.22±2.70	0.02±0.00	0.32±0.01
KRDS	94.96±0.75	12776.11±27.60	88.67±1.53	0.04±0.00	2.42±0.08	14.89±0.85	0.60±0.02	0.08±0.01	6.41±1.38	0.07±0.01	0.38±0.01
MWT	97.30±0.51	3801.48±18.37	0.05±0.01	0.34±0.00	1.07±0.02	6.75±0.26	0.22±0.01	0.05±0.01	6.60±1.52	0.01±0.00	0.41±0.01
MD	76.10±3.65	4806.48±48.85	58.66±1.48	0.54±0.03	2.63±0.16	4.28±0.09	0.57±0.04	0.08±0.00	2.68±0.97	0.03±0.00	0.43±0.02
MFD	75.96±3.70	21001.56±92.79	79.05±1.26	0.07±0.00	0.30±0.02	5.16±0.09	0.19±0.01	0.07±0.00	14.84±3.44	0.05±0.00	0.32±0.00
FD	87.08±1.87	5474.18±20.02	73.87±1.88	0.06±0.02	0.30±0.01	3.44±0.11	1.17±0.06	0.08±0.00	19.87±0.03	0.06±0.98	0.13±0.00
Average	79.90±0.48	8751.80±214.04	59.43±1.98	0.18±0.01	0.76±0.03	4.00±0.16	0.35±0.01	0.07±0.01	10.58±0.27	0.03±0.01	0.33±0.01

Mean values of three replicate measurements (n=3) ± SEM

Table 4. Anion concentration (mgL^{-1}) of water samples collected from water sources in Kilifi County

Replicate	F^-	Cl^-	NO_2^-	Br^-	NO_3^-	HCO_3^-	PO_4^{3-}	CO_3^{2-}	SO_4^{2-}	NH_4^+
MISIC	3.46±0.14	1466.53±24.68	3.34±0.82	13.88±1.21	4.39±0.39	251.56±2.88	0.98±0.06	33.30±1.25	465.25±33.22	0.49±0.09
MISQ1	3.13±0.09	1751.27±83.83	4.29±0.11	13.87±0.69	4.40±0.19	249.29±2.74	0.86±0.09	29.75±0.57	354.40±10.40	0.45±0.04
MISQ2	3.33±0.11	5300.56±232.69	4.60±0.19	16.79±1.95	6.81±0.37	224.25±1.80	1.05±0.02	34.28±0.45	325.11±6.42	0.60±0.07
MISQ3	3.25±0.15	9240.40±102.59	6.01±0.53	15.73±2.39	4.74±0.61	212.96±4.35	1.02±0.02	33.17±1.35	302.75±2.23	0.92±0.04
MISQ4	3.34±0.06	7221.24±66.85	5.94±0.32	13.42±0.76	6.10±0.43	213.76±3.47	1.10±0.01	30.69±1.64	294.51±2.60	1.09±0.01
MISQOC	3.11±0.01	8391.25±159.38	6.73±0.41	12.97±0.56	4.55±0.28	186.99±3.67	1.05±0.04	35.27±1.02	290.45±2.09	0.98±0.04
RNUS	2.59±0.17	467.68±34.61	4.74±0.20	7.68±0.37	3.77±0.16	193.74±5.29	0.12±0.03	29.74±1.57	267.48±5.96	0.65±0.12
RNMS	3.27±0.08	728.49±69.12	3.22±0.45	9.10±0.20	5.14±0.19	245.54±10.47	0.66±0.04	27.86±1.04	280.323.56±	1.06±0.03
RNDS	3.78±0.04	2471.32±56.90	6.91±0.59	15.16±0.57	5.16±0.09	217.23±14.11	1.40±0.17	33.67±1.38	273.48±6.79	1.05±0.04
KD	2.73±0.02	632.51±18.98	3.77±0.22	8.73±0.40	3.75±0.12	162.17±14.16	1.05±0.01	26.85±0.60	233.91±7.17	0.70±0.08
CD	3.91±0.08	1076.92±45.45	6.62±0.42	11.78±0.88	6.56±0.36	255.43±16.91	1.09±0.02	40.72±2.14	350.99±20.61	0.70±0.29
RKZUS	2.67±0.10	516.73±11.29	3.75±0.14	9.18±0.49	3.93±0.06	314.30±10.21	0.96±0.02	26.39±0.76	327.06±5.15	0.68±0.10
RKZMS	3.09±0.02	547.92±51.59	3.16±0.21	12.30±0.63	4.36±0.14	345.79±9.55	1.03±0.01	31.80±0.91	334.67±4.30	0.97±0.04
RKZDS	3.21±0.07	675.52±11.61	4.83±0.06	12.34±0.40	5.24±0.26	385.56±10.05	1.12±0.01	33.76±0.36	360.91±2.16	1.08±0.02
MND	1.88±0.09	238.42±35.18	4.46±0.36	8.00±0.62	3.19±0.22	183.63±2.36	1.04±0.03	14.73±1.88	59.23±4.94	0.74±0.07
WPDR	2.43±0.11	426.59±12.22	4.16±0.09	10.67±0.21	4.23±0.12	167.14±5.25	1.12±0.02	22.88±1.54	74.33±5.15	0.89±0.06
WPDL	1.89±0.04	144.34±11.48	3.85±0.11	12.43±0.32	4.86±0.06	143.54±3.93	1.11±0.02	24.04±1.24	81.02±5.27	1.05±0.01
KZD	2.34±0.25	153.61±4.09	5.59±0.38	11.31±0.25	3.45±0.11	165.77±6.78	0.77±0.07	26.45±0.59	419.20±11.59	0.88±0.10
KRUS	2.85±0.08	357.43±13.94	3.41±0.13	12.91±1.19	4.69±0.17	145.56±3.57	0.83±0.05	31.50±1.62	345.25±3.57	0.75±0.96
KRMS	3.11±0.06	381.82±11.47	3.63±0.13	12.41±0.25	5.00±0.07	175.24±2.32	0.94±0.02	33.33±0.78	394.94±5.23	0.97±0.03
KRDS	3.35±0.06	607.22±76.04	4.47±0.14	17.43±0.67	6.64±0.36	157.82±13.90	1.09±0.02	35.87±0.34	415.27±8.29	0.76±0.19
MWT	0.42±0.04	4.89±0.86	0.04±0.01	0.12±0.01	1.64±0.07	12.52±0.63	0.04±0.01	9.25±0.47	5.29±0.76	0.26±0.07
MD	2.93±0.06	177.53±5.00	3.95±0.07	8.73±0.76	3.85±0.12	133.52±3.32	1.12±0.07	28.58±0.73	322.06±3.04	0.81±0.09
MFD	3.01±0.05	792.28±33.43	4.64±0.20	10.76±0.15	4.89±0.07	148.55±1.80	0.80±0.07	36.78±0.63	432.24±9.81	1.04±0.03
FD	3.36±0.09	144.48±3.53	5.69±0.20	15.21±1.75	5.48±0.15	121.61±3.17	1.10±0.03	37.96±0.85	505.93±24.35	1.12±0.02
Average	2.90±0.24	1756.68±900.50	4.47±0.49	11.72±1.20	4.67±0.38	200.54±25.58	0.94±0.10	29.94±2.32	300.64±42.47	2.01±1.96

Mean values of three replicate measurements (n=3) ± SEM

Table 5. Microbial Load of water samples collected from surface water sources in Kilifi County

Sample Code	MPN (100 mL^{-1})	Total coliforms (CFU mL^{-1})	*E. coli* (CFU mL^{-1})	*S. aureus* (CFU mL^{-1})	*Shigella* (CFU mL^{-1})	*S. typhi* (CFU mL^{-1})
MISIC1	17026.0±282.00	2166.00±95.00	5.00±4.00	674.00±18.00	2.00±1.00	31.00±4.00
MISQ1	14955.00±299.00	2723.00±56.00	4.00±2.00	895.00±24.00	3.00±0.00	22.00±7.00
MISQ2	27300.00±457.00	2450.00±12.00	15.00±5.00	308.00±8.00	6.00±1.00	60.00±13.00
MISQ3	26935.00±882.00	2183.00±25.00	12.00±3.00	448.00±45.00	3.00±1.00	45.00±6.00
MISQ4	21750.00±441.00	3177.00±29.00	3.00±1.00	125.00±3.00	6.00±2.00	24.00±3.00
MISQOC	15500.00±256.00	2079.00±49.00	2.00±1.00	138.00±13.00	7.00±3.00	18.00±2.00
RNUS	41500.00±483.00	5185.00±66.00	20.00±3.00	878.00±16.00	11.00±3.00	78.00±16.00
RNMS	22735.00±223.00	1850.00±28.00	13.00±2.00	131.00±13.00	8.00±2.00	38.00±10.00
RNDS	17510.00±265.00	1500.00±15.00	8.00±2.00	368.00±33.00	13.00±3.00	15.00±9.00
KD	44351.00±890.00	3513.00±15.00	18.00±11.00	400.00±14.00	160.00±14.00	125.00±15.00
CD	31525.00±168.00	2300.00±57.00	28.00±12.00	200.00±14.00	43.00±7.00	65.00±15.00
RKZUS	23131.00±392.00	1020.00±22.00	13.00±5.00	242.00±5.00	9.00±2.00	58.00±13.00
RKZMS	18978.00±168.00	4012.00±77.00	15.00±4.00	338.00±10.00	11.00±3.00	88.00±15.00
RKZDS	13107.00±139.00	1207.00±16.00	11.00±8.00	160.00±12.00	7.00±2.00	61.00±10.00
MND	12425.00±100.00	6950.00±33.00	38.00±11.00	242.00±5.00	15.00±3.00	33.00±12.00
WPDR	19175.00±135.00	2450.00±23.00	50.00±4.00	120.00±11.00	58.00±3.00	21.00±11.00
WPDL	21585.00±134.00	3150.00±17.00	95.00±2.00	110.00±22.00	25.00±10.00	17.00±16.00
KZD	17026.00±282.00	3750.00±70.0	40.00±3.00	725.00±13.00	75.00±17.00	58.00±18.00
KRUS	11864.00±137.00	2500.00±70.00	55.00±14.00	565.0±40.00	21.00±8.00	67.00±13.00
KRUS	16350.00±282.00	2800.00±22.00	35.00±34.00	450.00±10.00	38.00±16.00	87.00±16.00
KRDS	41500.00±483.00	4100.00±15.00	50.00±5.00	850.00±28.00	18.00±3.00	131.00±13.00
MWT	00.0±0.00	00.0±0.00	0.00±0.00	00.0±0.00	00.0±0.00	0.00±0.00
MD	15550.00±110.8c	4500.00±56.00	35.00±0.00	500±27.00	36.00±8.00	138.00±10.00
MFD	27500.00±837.00	3500.00±56.00	55.00±10.00	550.00±15.00	16.00±1.00	160.00±12.00
FD	21000.00±536.00	5185.00±66.00	38.00±10.00	878.00±16.00	15.00±5.00	242.00±58.00
Average	20811.00±402.00	2970.00±60.00	26.00±3.00	411.00±12.00	24.00±2.00	67.00±2.00

Mean values of three replicate measurements (n=3) ± SEM

4. DISCUSSION

Agricultural production in arid and semi-arid areas is entirely dependent on irrigation. Therefore, irrigation water should have little or no dissolved salts, which would harm the plant and/or alter soil properties, reducing the amount of agricultural produce. Such quality water is often not available in arid and semi-arid forcing farmers to go for saline water for irrigating their plants. Different cations and anions are inconsistent in saline water. The degree of salinity effects on crops, livestock and aquatic life may not be the same [47]. Water of such substandard quality usually lacks some aspects of plant nutrient requirements. The plants grown using saline water are not optimally productive and the soil requires intensive treatment to recover its usefulness. The pH values of the water samples analyzed are within the permissible levels of pH from FAO, which range from 6.50 to 8.40 [18]. The high pH levels can be attributed to high calcium concentration (4.00 ± 0.16 mgL^{-1}) obtained from the study. Drinking water should have a temperature which is equal to or less than 15°C. Temperature above 15°C enhances the growth of nuisance organisms leading to increase in problems related to odor, taste, color and corrosion. In livestock production, cattle prefer drinking water at temperatures between 4.4°C and 18.3°C. Temperature more than 27°C decrease water and feed intake rates affecting animal productivity [48].

The EC depends on concentration, mobility, valence, type of ions present and temperature [42, 49]. As a parameter used to assess water purity, it indicates the amount of total dissolved ions [46]. The average value EC of water sources from Kilifi County (3.44 ± 0.75 $dScm^{-1}$) were above the WHO guidelines value (3.00 $dScm^{-1}$) for domestic water [18]. Only two samples MWT and RKZUS had EC value of 0.96 ± 0.10 $dScm^{-1}$ and 2.97 ± 0.06 $dScm^{-1}$ respectively that is below the WHO guideline value for domestic water. The high EC values obtained from this study might be attributed to F^-, Cl^-, HCO_3^-, SO_4^{2-}, Na^+, Mg^{2+} and Ca^{2+} among other dissolved ions. The levels of dissolved ions in the surface water sources from Kilifi County were significantly high (Table 3 and Table 4) which may have resulted from runoffs from agricultural farms. Safe drinking water sources had EC values of less than 3.00 $dScm^{-1}$. High EC values of between 1.00 $dScm^{-1}$ and 2.9 $dScm^{-1}$ in drinking water may cause mild diarrhea, whereas above 3.00 $dScm^{-1}$, domestic animals may detest water drinking, considered a precursor for acute diarrhea [18]. Excessive concentrations of boron, Cl^-, HCO_3^-, Na^+ among other ions have been implicated in specific ion toxicity [50, 51]. Similarly, cations, anions and EC in Kilifi County water sources were recorded at an extremely toxic levels. For instance, the water EC in this study was found to be 3.44 ± 0.75 $dScm^{-1}$, while recommended values are 0.75 - 4 $dScm^{-1}$ and 3.00 $dScm^{-1}$ for domestic and agricultural use respectively [18].

Studies conducted elsewhere have suggested an increase in salinity across Coastal belts at a rate of 39% by 2050 [2]. The intensity and spread of salinity across the Coastal belts are due to changes of sea level rise, temperature, acidic rainfall, altered riverine flow and sea water intrusion [2-5]. Extreme levels of soil and water salinity trends across Coastal belts in many countries of the world negatively affect crops, fish, and livestock production [5, 47]. Coastal Agriculture provides livelihood support for its community with several groups of people often suffering a shortage of freshwater in different areas of these Coastal belts [52, 53]. Many regions in the world along the Coastal belt use saline water for food crop cultivation, fodder crop production, drinking, and bathing [1, 3, 4]. This increased usages of saline water have contributed to enormous negative effects on Agricultural production systems and products as well as human health [19, 54, 55]. This lack of quality drinking water can result into overconsumption of saline water leading to malnutrition, under nutrition, water and food borne diseases and even starvation among Coastal people [5, 19, 56-58]. Crops, livestock and fish production have been negatively affected due to the high salt in the Coastal belt [59-61]. The TDS is the sum of all components dissolved in water including K^+, Na^+, Ca^{2+}, Mg^{2+}, SO_4^{2-}, Cl^-, PO_4^{3-} and H4SiO42$^-$ among others [18]. The TDS value ≥ 1000 mgL^{-1} significantly affects drinking water [18]. In Kenya there is no health-based guideline for TDS. However, 1000 mgL^{-1} is recommended for human use [18]. High TDS in water may impair physiological processes leading to gastrointestinal irritation in individuals with kidney problems [62]. Further, high TDS renders the water unfit for industrial use due to scales formation, accelerated corrosion and precipitate foaming in boilers besides interfering with the taste and color of final industrial products [63].

The toxicity of various metals is also a point of concern. In this study, the average concentration of Na^+ was 8751.80±214.04 mgL^{-1} which is approximately 44 times above the permissible limit of 200 mgL^{-1} [18]. The high Na^+ levels may result from sewage discharge, domestic effluents, leachates of Na^+ containing rocks and recharge water from underground systems which are rich in brine [42]. With absence of desalination plants to extract the brine in the water, these regions experiences low Agricultural productivity. Moreover, fractures within water sources such as rivers may lead to mineralized regimes producing mineral veins and saline intrusion which in turn result in the elevation major ions [42]. Kilifi County being adjacent to the Indian Ocean suffers from the effect of seawater intrusion [3, 4] contributing further to the concentration of major ions in water sources. High levels of Na^+ in drinking water has been associated with hypertension in pregnant women [64] and children [65], fluid loss (dehydration), hypernatraemia and neurological damage [65, 66]. There is no recommended limit of K^+ in water. However, increased exposure may lead to significant health effects in individuals with kidney disease, heart disease, coronary artery disease, hypertension, diabetes, adrenal insufficiency, aging and specific medications [67, 68].

Presence of heavy metals such as Cd^{2+}, Hg^{2+}, Pb^{2+}, Ag^+ Zn^{2+}, Cu^{2+}, Fe^{2+}, and Cr^{3+} in water sources indicate pollution and make the water harmful if they are in excessive concentrations [35]. They poison aquatic ecosystems destroying life while poisoning the water resources besides being a threat to crop production [11, 33]. Accumulation of metals in the plants and soil occur due to continued use of metal loaded water for agricultural purposes [68]. Bioaccumulation or biomagnification of these metals via plants lead to their entry into human bodies as they consume these plants produce posing risks to human health [15, 16, 18]. The average level of Ca^{2+} and Mg^{2+} of 59.43±1.98 mg^{L-1} and 4.00±0.16 mgL^{-1} were reported in this study respectively. All the samples collected and analyzed had Mg^{2+} levels below the permissible limit of 100 mgL^{-1} [18, 67]. Calcium is important for good health, and levels between 20 mgL^{-1} and 30 mgL^{-1} are desirable in drinking water [67]. The Zn^{2+} values in most of the water samples were below 2.0 mgL^{-1} thus the lying in the permissible levels. The FAO acceptable limit for Cu^{2+} concentration is 0.20 mgL^{-1}. Some water sources were within the limit while others had Cu^{2+} concentrations higher than the permissible levels. The average levels of Cr^{3+} and Cd^{2+} in the water sources were found to 0.35±0.01 mgL^{-1} and 0.07±0.01 mgL^{-1} respectively and such high levels are toxic for continued irrigation use.

On average, the F^- in the study was found to be 2.90±0.24 mgL^{-1}. These values were considerably above the recommended guideline for drinking water set at 1.5 mgL^{-1} [18]. High F^- in drinking water may lead to dental and skeletal fluorosis [69] as evident in Nakuru County around Salgaa and Molo in Kenya [42]. Skeletal fluorosis may be manifested upon drinking water containing 3 to 6 mgL^{-1} of F^- [69, 70]. Although moderately high values of F^- were obtained in this study, signs of dental and skeletal fluorosis are not common in Kilifi County. This may be attributed by the fact that many parts of Kilifi County have a good and well maintained piped (tap) water system provided by Malindi Water and Sewerage Company (MAWASCO) and Kilifi Mariakani Water and Sewerage Company (KIMAWASCO).

The study established that the average value of SO_4^{2-} was 300.64±42.47 mgL^{-1} which is below the permissible limits of 400 mgL^{-1} [18, 69]. However, sources MISIC (465.25±33.22 mgL^{-1}), KD (419.20±11.59 mgL^{-1}), KRDS (415.27±8.29 mgL^{-1}), MFD (432.24±9.81 mgL^{-1}) and FD (505.93±24.35 mgL^{-1}) recorded SO_4^{2-} values beyond the recommended levels of 400 mgL^{-1}as indicated (Table 4). Concentrations of SO_4^{2-} above 200 mgL^{-1} in drinking water can lead to gastrointestinal irritation and bowel discomfort [18, 71]. The average PO_4^{3-} levels for the samples was 0.94±0.10 mgL^{-1} which was above permissible limit of 0.5 mgL^{-1} [18, 72]. This may be attributed to use of fertilizers and weathering of rocks (gypsum) [42]. Although PO_4^{3-} is not very mobile in soils and only moderately soluble, transportation through surface runoff and soil erosion significantly increase its solubility in surface waters [73]. Further, PO_4^{3-} is not harmful to humans but has a significant impact on natural ecosystems as a result of eutrophication. It damages the health of water sources due to massive growth of algae (algal bloom) clouding water and reduce sunlight available to other plants [73] The death of algae as a result of consumption in the water by algae biodegradable bacteria deprive aquatic systems of oxygen leading to suffocation of aquatic life [63].

The average amount of NO_2^- and NO_3^- in Kilifi County water sources ranged from 4.47±0.49

mgL^{-1} and 4.67±0.38 mgL^{-1} respectively which are below the 45 mgL^{-1} limits for safe drinking water (18, 48]. The sources of nitrates include animal and human waste, industrial effluent, use of chemicals, fertilizers and silage through drainage systems [69]. High NO_3^- levels above 40 mgL^{-1} in water has been associated with "blue baby syndrome" or "methemoglobinemia" in children as experienced in some of the Coastal regions of the world such as the Gaza Strip of Palestine [65, 70]. The average value of Cl^- (1756.68±900.60 mgL^{-1}) in the collected water samples was significantly high above the permissible limit of 250 mgL^{-1} and thus pose health risk to consumers. The Cl^- above 100 mgL^{-1} in water leads to salty taste and may have laxative effect for individuals not accustomed to such waters [18]. This problem is rampant in Coastal region of Gaza Strip of Palestine [18]. The high chloride concentration in Kilifi County water sources is an indicator of pollution by sewage or irrigation leachates as suggested by Sarda & Sadgir [62]. The average CO_3^{2-} and HCO_3^- in this study were 200.54±25.58 mgL^{-1} and 29.94±2.32 mgL^{-1} respectively. The content of HCO_3^- has no known adverse health effect and all the collected samples from the surface water of Kilifi County fall within the desirable limit of 300 mgL^{-1} [18, 72].

In the present study on the bacteriological analysis of the water samples, it was observed that 24 out of 25 samples (96%) did not reach the standard of 0.00±00 MPN 100 mL^{-1} recommended WHO guidelines for drinking water. The transformation of nutrient broth from clear to cloudy is a clear indication of microbes in the water. From the observed levels of microbiological organisms, it can be safely concluded that the microbiological quality of the water sources in Kilifi County present a challenge to the utilization of the various water sources both for domestic (drinking) and agricultural (irrigation) purposes. Microbial hazards in irrigation water have been on the rise owing to contamination of surface water. Increased levels of microbial load have been directly linked to the increase in food-borne diseases in the developing world [19]. Horticultural production is perhaps the most relevant since the produce is consumed raw. Farmers are required to use microbe-free water for irrigation. This will allow the production of potentially germ-free food [27]. Microbes such as *E. coli* and *Salmonella* draw particular concerns for their effects on human enteric health [19]. Farmers are required to assess the water before using it on farm. Risk assessment enables these farmers to pre-determine the potential risk of illness posed by the water in question prior to using it. The production of Leafy and low growing crops, for instance, vegetables calls for the use of highly sterile water to avoid spreading contamination to the population and other parts of the farm. The drinking of such water also poses a health risk to the consumers including poor enteric health, diarrhea and stomach upsets [74].

5. CONCLUSION

This Coastal area in Kenya constitutes 20% of the country of which about 53% is affected by different degrees of water salinity [4]. In fact, declining land, fish, and livestock productivity with a shift toward negative nutrient balance is among the main concerns for food security problems in the country. High pH values as demonstrated in this study indicates alkalinity of Kilifi County water sources possibly due to fertilizers application in nearby farms around the sampling area in addition to other anthropogenic sources. The temperature, TDS, EC, F-, Br^-, PO_4^{3-}, Na^+, K^+ and Cu^{2+}, were above the WHO permissible limit while Mg^{2+}, Ca^{2+}, Zn^{2+}, Fe^{2+}, Ag^+, Cd^{2+}, Cr^{3+}, Al^{3+}, NH_4^+, HCO_3^-. CO_3-, SO_4^{2-}, NO_2^- and NO_3^- were below the WHO permissible limits. Further, the microbial load of the water source in Kilifi County was above the required limit of < 2 CFU 100 mL^{-1}. Most of the water sources from Kilifi County are highly saline containing significant levels of copper, calcium, zinc, cadmium, and chromium. The copper, zinc, and cadmium pose potential risks following long-term irrigation within the county's farmlands. The reduced crop yields in the scheme can be attributed to the quality of the water and poor Agricultural practices such as the use of gross Agricultural chemicals and fertilizers. In turn, this may lead to soil infertility and possible desertification. The high values of these parameters makes the Kilifi County water sources unsuitable for irrigation as well as domestic use. Further, these high concentrations may serve as precursors for water and food borne diseases among other diseases including fluorosis and hypertension. The significant high *Samonella, Shigella,* and *E. coli* of < 2 CFU 100 mL^{-1} exposes the local population around these farms to a risk of enteric infections. Due to weak policy implementation on monitoring of agricultural and domestic water quality, the salinity problem in the county continues to impact negatively on food quality and food security.

6. RECOMMENDATIONS

For domestic and agricultural irrigation purposes, farmers in Kilifi County may be advised to continuously monitor the sampled water sources due to high salinity. Desalination of the water may not be an option since the process is capital intensive. Rather, they ought to find alternatives for metal based fertilizers and herbicides on their farms in order to lower salinity levels in the water. Industries and homes in the vicinity of the sampled water sources should design befitting waste disposal schemes. Better disposal of wastes would save the farmers and the locals from the salinity hazards in their face. The government may consider harvesting the water from the sampled water source and putt up water treatment plant (s) to supplement the already existing Baricho water treatment plant that is being used by MAWASCO and KIMAWASCO since some parts of the Kilifi County are not supplied with the piped (tap) water system. Treating the water before use would go a long way in saving farmers from microbial hazards. Maintaining proper hygiene alongside the use of latrines is also crucial in reducing the microbial load of the water sources. It is significantly important to explore the possibilities for increasing agricultural production for the growing population in Kilifi County. Thus, combating this land salinization problem is a vital issue for food security in the country through adoption of long-term land management strategies. Further studies should be conducted especially in the piped (tap) water system to establish its suitability for domestic purposes.

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DISCLAIMER

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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