Archives of Current Research International
6(4): 1-13, 2016; Article no.ACRI.31995
ISSN: 2454-7077

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Suitability of Athi River Water for Irrigation within Athi River Town and Its Environs

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Authors' contributions

This work was carried out in collaboration between all authors. Author JOA designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors PGN and PM managed the analyses of the study and the literature searches. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/ACRI/2016/31995
Editor(s):
(1) Wang Mingyu, School of Metallurgy and Environment, Central South University, China.
Reviewers:
(1) Malgorzata Gniewosz, Warsaw University of Life Science, Poland.
(2) Rajaram Pandurang Dhok, Savitribai Phule Pune University, India.
Complete Peer review History: http://www.sciencedomain.org/review-history/17995

Original Research Article

Received 2nd February 2017
Accepted 20th February 2017
Published 28th February 2017

ABSTRACT

Aims: To assess the suitability of the Athi River water for irrigation in Athi River area and its environs.

Study Design: The study design was purposive with sampling points deliberately chosen to assess the water quality of the Athi River within the study area.

Place and Duration of Study: The study was carried out in Athi River town and its environs in Kenya from January 2015 to March 2015.

Methodology: Seven sampling points were selected along the study transect and sampling was done once every week from 21st January to 6th March 2015. The water samples collected were analyzed for sodium (Na^+), Magnesium (Mg^{2+}), Calcium (Ca^{2+}), Electrical Conductivity (EC), alkalinity, acidity (pH), *E. coli*, Total Dissolved Solids (TDS) and heavy metals (lead and Chromium). Field observations and administration of questionnaires were used to identify major sources of pollution into the river. The data so collated and collected was analyzed using SPSS and Microsoft Office Excel.

Results: The level of *E. coli* was above the Food and Agricultural Organization (FAO) standards at

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all sampling points (M=1,073-2,202 MPN). The levels of all physico-chemical parameters measured were within the recommended limits. However there was an increasing trend in the concentration of most of the parameters along the study transect, an indication the impact of pollution input from the Athi River area on the river water quality. 42.9% of the sites sampled had a moderate sodicity hazard while 100% of the sites sampled had a moderate alkalinity hazard.
Conclusion: The Athi river water within Athi River is polluted with *E. coli* and it is recommended that the public is sensitized on the health risks paused by the high concentration of *E. coli* in irrigation water and encouraged to adopt risk minimization strategies. It is also recommended that periodic monitoring of river water quality be done and pollution control measures should be put in place.

Keywords: E. coli; magnesium hazard; salinity; sodicity; water pollution.

1. INTRODUCTION

There are a variety of uses applied to water. Whereas the quantity of water on earth remains constant, its quality changes both temporally and spatially and is highly influenced by human activities. As such, a negative impact that may arise from the consumption of water may cause great strain on the supply systems [1]. The strain caused may be quantitative or qualitative or both. Water pollution has been identified as one of the major problems facing many countries of the world [2] which may be either anthropogenic, natural or both [3].

Water pollution has been a perpetual problem in the world since the onset of civilization. It has been reported that some 60% of coastal rivers and bays in the U.S. have been moderately to severely degraded by nutrient pollution and this has been attributed to increased human activity. The contribution and impact of human activities to the pollution of the Ganga River basin in India has also been reported [4,5].

Kenya has had water pollution cases. Studies done in 1976 by the Ministry of Water and Development found out that the Nzoia, Nyando and Kerio rivers were polluted by industrial effluent. There is an increasing trend in water pollution in Kenya from both point and nonpoint sources due to agriculture, urbanization, and industry which contribute to organic, inorganic and aesthetic pollution of water. Water pollution in the developing countries is increasingly becoming a threat to the natural water resources and that this phenomenon is attributed to the increasing quest of these countries to attain industrialization status and diversification of the national development goals. Pollution of several rivers in Kenya has been documented by various studies. An assessment of the quality of Nairobi River and Athi River waters found out that the waters were highly contaminated with pathogenic bacteria [6] and it was also reported that Nairobi River and Athi River were polluted by effluents from the Dandora Sewage Treatment Plant (DSTP) [1,7].

Mavoko area, popularly known as Athi River, is a growing industrial town and has over the last sixty years experienced an exponential industrial growth (see Fig. 1). However, this industrial growth has not been matched with the development or expansion of infrastructure to deal with the increased industrial waste, a situation that has resulted in poor waste management and associated environmental degradation [8,9]. Several studies have highlighted the impact of human activities on the water quality of Athi River. In a water quality survey of Athi River and its upstream distributaries, it was established that both microbial and chemical pollution particularly lead, arsenic and chromium pose a pollution risk to Athi River thus endangering the health status of the people downstream [10]. The presence of heavy metals in the water and fish tissues from the Athi-Galana-Sabaki tributaries and that level of heavy metals such as lead (Pb), nickel (Ni), manganese (Mn) and cadmium (Cd) were higher than the World Health Organization's (WHO's) limits has also been reported [3]. The upper Athi River mainly receives domestic and industrial pollution from Mavoko town-Athi River town and its environs [8] before confluence with Nairobi River, a heavily polluted tributary to the east side of the Nairobi city. As such Athi River is not free from pollution conditions that characterize other rivers in the world and in Kenya. It is therefore imperative that the quality of the water in Athi River be ascertained to verify if it meets the recommended standards for various uses under which the water is subjected to.

Water pollution is one of the main environmental concerns especially in developing countries [1]. The Athi River town and its environs are characterized by poorly maintained sewage systems leading to the pollution of Athi River (WRMA, 2015). The waters of Athi River are used for irrigation, drinking, and fisheries. The Athi River waters are also used for domestic and agricultural farming by both upstream and downstream communities [3,6]. Though the government of Kenya came up with Water Quality Regulations to curb pollution of water bodies, there have been reports of non-compliance by effluent discharging bodies [11]. In a survey of seventeen Sewerage plants by the Water Resources and Management Authority three plants were commended, two were shut down while the remaining including Mavoko Water and Sewerage Company were served with warning letters. The domestic/agricultural use of Athi River water may therefore put at risk the health of the locals and impact negatively on the economy [12]. The purpose of this study was to determine the suitability of the Athi River waters for irrigation use in Athi River town.

The main sources of water pollution are industrial discharge, sewage, agricultural waste, fertilizers, and seepage from waste sites, decaying plant life, road, railway and sea accidents involving large oil carriers. River water is also open to many polluting agents especially those which gain direct entry of discharges from urban centers and that both microbial and chemical pollution poses a pollution risk to Athi River [10,13]. However, it has been observed that the main cause of water pollution in Mavoko (Athi River) is industrial pollution, poor waste management and municipal waste water [8].

The characteristics of water for irrigation which are essential in determining its quality are; Salinity hazard, Sodium hazard (sodicity), Soluble Sodium percentage, Acidity and Alkalinity, Residual sodium carbonate, specific ions like chloride, magnesium, sulfate and nitrate [14]. It is worth noting that microbial pathogens are one of the potential irrigation water quality parameters but it is often neglected and e-coli is the most preferred indicator of microbial contamination [15].

Various parameters/ qualities of irrigation water have an impact on the yield and health of crops and soil fertility. Salinity (the amount of salt dissolved in water) directly affects plant growth and generally has an adverse effect on agricultural crop performance and can adversely affect soil properties thus leading to a long term decrease in irrigated crop productivity [16].

The study transect is within Athi River town and its environs which is within the jurisdiction of Mavoko constituency and in Machakos County, Kenya (See Fig. 2 and 3).

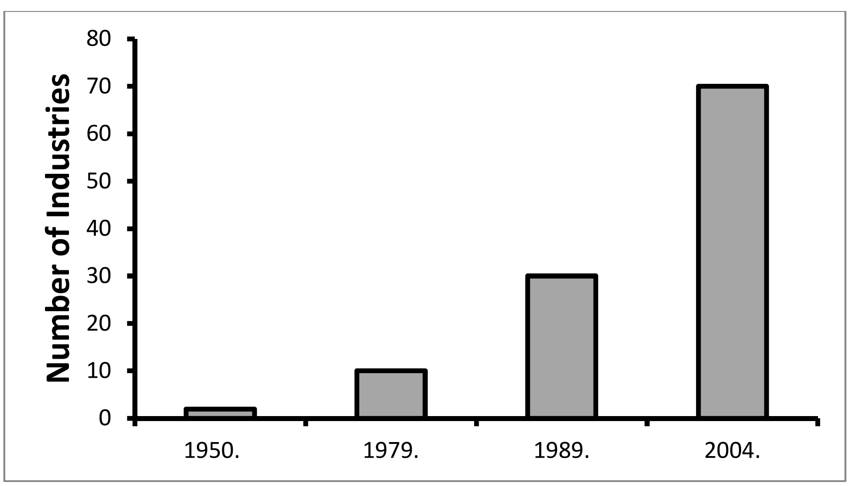

Fig. 1. Industrial development in Athi River/ Mavoko from 1950-2004
(Source: UN-HABITAT, 2006)

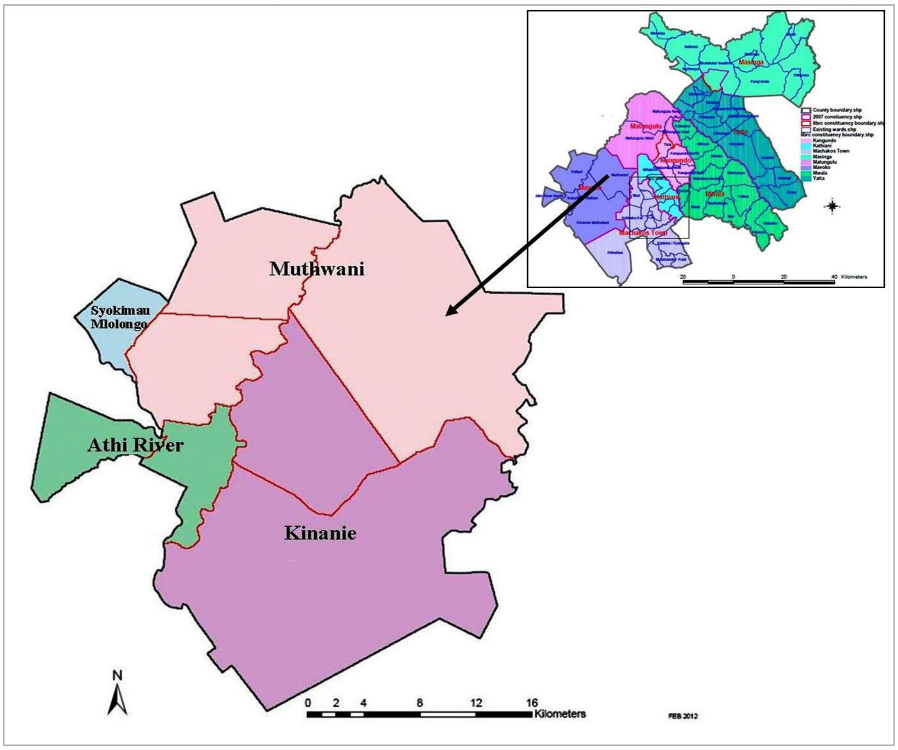

Fig. 2. Map of Mavoko constituency showing County Ward boundaries (inset) Machakos County

Fig. 3. The study transect highlighting the sampling points

2. MATERIALS AND METHODS

2.1 Research Design

The study design was purposive. Sampling points were deliberately chosen to assess the water quality of the Athi River within the study area. The surrounding conditions at various sampling points that make them susceptible to pollution are shown in Table 1. Seven sampling points were selected along the study transect. The first sampling point was located within the Nairobi National Park, North West of the Athi River town (see Fig. 3) and it served as the control point.

Table 1. Sampling points and their surrounding conditions

Sampling point	Surrounding activities
Sampling point 1	Inside Nairobi National Park. Control point
Sampling point 2	At Bridge 39. Main Sewer line and sewer manholes. The manholes were blocked and leaking
Sampling point 3	Near Mombasa road and Athi River Steel Plant. Construction activities in close vicinity.
Sampling point 4	Susceptible from runoff from the Athi River Tannery
Sampling point 5	Near Sewerage treatment ponds from residential estates (apartments)
Sampling point 6	Near flower farms and residential houses.
Sampling point 7	Before Mto wa Mawe tributary.

NB: All points had vegetable plots under irrigation

2.2 Sampling and Analysis of River Water

Water samples were collected from each sampling point once every week from 21st January 2015 to 6th March 2015. The water samples collected were analyzed for sodium (Na^+), Magnesium (Mg^{2+}), Calcium (Ca^{2+}), Electrical Conductivity (EC), alkalinity, acidity (pH), *E. coli*, Total Dissolved Solids (TDS) and heavy metals (lead and Chromium). At every sampling point, three water samples ten meters from each other were collected in 500 ml bottles. The 500 ml bottles were rinsed three times with the sample water before filling. The collected water samples were then mixed in a 1.5 Liter bottle. A 500 ml sample was then taken from the mixture for laboratory analysis. The samples were kept under ice to maintain a temperature of 4°C and then they were transported to the laboratory where they were refrigerated. The analysis of the samples was done at Central Water Testing Laboratory, WRMA and at the Government Chemist Laboratories.

pH, Total Dissolved Solids (TDS) and conductivity were measured on delivery of the samples using a conductivity meter with a p^H and TDS probe. After measuring the samples for conductivity and pH, part of the sample was acidified with 10% HNO3 to a pH of less than 2 for analysis of Calcium (Ca), Magnesium (Mg), Sodium (Na), Chromium (Cr) and lead (Pb). The analysis of the metals was done using CONTR AA 700 analytik-jena device by Flame Atomic Absorption Spectrometry (FAAS) in air acetylene flame. Total alkalinity was measured in un-acidified sample by titrating with sulphuric acid to pH 4.5 using phenolphthalein indicator.

E. coli was analyzed using Multiple Tube Fermentation Technique (MTFT), a three- stage procedure (presumptive stage, confirmed stage and completed stage) in which the results were statistically expressed as Most Probable Number (MPN).

2.3 Sodium Hazard and Magnesium Hazard

The values of Sodium, Calcium and Magnesium analyzed were used to calculate the Sodium Adsorption Ratio (SAR) of the water using the following formula [17].

$$\text{S.A.R.} = \frac{Na^+}{\sqrt{\frac{1}{2}(Ca^{2+} + Mg^{2+})}}$$

Where

Na^+ = Sodium in mmol / L
Ca^{2+} is Calcium in mmol / L
and Mg^{2+} is Magnesium in mmol / L

The following formula was used to calculate the magnesium hazard at various sampling points [18].

$$MH = \frac{Mg}{Mg + Ca} * 100$$

Where Ca and Mg ions are expressed in mmol / L. MH= Magnesium hazard.

2.4 Participant Observation

Field observations and documentation of the likely sources of pollution was done, still photographs of the prevailing conditions were taken and a visit made to eight of the ten (10) major companies listed in the Machakos County Integrated Development Plan of 2015 for observations on their potential to pollute the Athi River [19]. Seven (7) plots were randomly selected at every sampling point. Within each plot, six (6) sub-plots measuring approximately 25 m by 25 m were then randomly selected and observations were made on the percentage of crops that were stunted. It was assumed that the stunting was due to the water quality of the irrigation water.

2.5 Interviews

Interviews were mainly done on respondents who were particularly knowledgeable about water and sanitation in the Athi River area (key informants). Water Resources Management Authority (WRMA) officials from the regional office at Machakos and a representative from the Environmental Department from Mavoko Sub-County and Machakos County were interviewed. This was to seek the respondent's opinion on pollution of Athi River and on the likely sources of pollution and the mitigation measures being put in place as well as obtaining available monitoring records.

Ten (10) farmers from seven (7) different plots at every sampling point were also interviewed to document their experiences and perceptions in using the water for irrigation and effect on the crop yield.

The following simplified formula for proportions by was applied to get the number of plots to be observed, the number of 25 m by 25 m sub-plots to be observed under every plot and the number of farmers to be interviewed at every sampling point [20].

$$n = \frac{N}{1 + N(e)^2}$$

Where n= Sample size, N= Population size and e=level of precision.

2.6 Secondary Data Sources

Secondary data was obtained from review of relevant published and unpublished literature including books, journals, online materials, and reports. Relevant official and non-official documents within WRMA and Mavoko Sub-County environmental department were also examined to obtain data and information. Environmental audit reports of various industries in the area were also reviewed.

2.7 Data Analysis

Statistical Package for the Social Sciences (SPSS) version 16 for Windows and Microsoft Office Excel 2007 were used to analyze the data obtained.

3. RESULTS

3.1 Sources of Water Pollution at Athi-River

A review of the 2004 audit reports of ten factories listed in the Machakos County Integrated Development Plan, 2015 as the major factories within Mavoko revealed that four of them discharged their effluent waste into the municipal main sewer line while six had either sewerage treatment plants or septic tanks. However, only three out of the ten had complied with WRMA's effluent monitoring requirements of submitting quarterly effluent monitoring records to WRMA.

44.3% of farmers (as shown in **Table** 2) were of the view that the main source of pollution was municipal effluent.

The views of the farmers on water pollution varied from station to station (Table 3). Sampling point 7 had the highest percentage (19.2%) of farmers who perceived that the waters were polluted while sampling point 1 had the highest number of those who perceived the river not to be polluted (66.8%).

Table 2. Percentages of farmers' response of perceptions on the sources of water pollution (N=70)

	Sources of water pollution				
	Industrial	**Municipal**	**Street runoff**	**Others**	**None**
Sampling point 1	1.43	4.29	2.86	2.86	2.86
Sampling point 2	1.43	11.43	0	1.43	0
Sampling point 3	4.29	7.14	1.43	1.43	0
Sampling point 4	5.71	7.14	0	0	1.43
Sampling point 5	0	5.71	1.43	2.86	4.29
Sampling point 6	1.43	4.29	4.29	0	4.29
Sampling point 7	1.43	4.29	1.43	0	7.14
Total (%)	**15.72**	**44.29**	**11.44**	**8.58**	**20.01**

Note: The percentages were calculated using the total number of farmers interviewed

Table 3. Percentages of response by farmers on their perception on water quality (polluted or not) at each sampling point (N=70)

	SP1*	SP2	SP3	SP4	SP5	SP6	SP7
Yes (%)	6.38	17.02	17.02	12.77	17.02	10.64	19.15
No (%)	66.67	11.11	-	11.11	-	11.11	-
Not Sure (%)	7.14	7.14	14.29	21.43	14.29	28.57	7.14

Note: Yes: The water is polluted, No: The water is not polluted, Not Sure: Do not know whether the water is polluted or not. SP1-sampling points*

3.2 Physico-chemical Parameters and Bacteriological Characteristics

The pH values for all the sampling points were within the NEMA range (6.5-8.5) with an exception of sampling point 7 which had a mean of 8.7 (Fig. 4). However, there was an increasing trend in the pH from sampling point 1 to 7. The highest value (9.3) was recorded at sampling point 7 while the lowest value (6.6) was recorded at sampling point 4. There was a significant statistical difference in the pH values between sampling point 1 and sampling point 7 at the $P>0.05$ level for the seven sampling points ($F(6, 35) = 5.88$, $P=.00$)

The highest mean TDS (mg/L) concentration was recorded at sampling point 7 (1731 ± 327 mg / L) while sampling point 3 had the lowest mean value (497.57 ± 71.5 mg / L) The mean TDS values for all sampling points were below the NEMA threshold (1200 mg/L) with the exception of sampling point 4 (1321.7 ± 696.9 mg/L) and sampling point 7 (1731 ± 327 mg/L). The maximum value (2058mg/L) was recorded at sampling point 4 while the lowest value (403 mg/L) was recorded at sampling point 3. There was an increasing trend in the concentration of TDS from sampling point 1 to sampling point 7 and there was significant statistical difference in TDS means between sampling point 1 to sampling point 7 at the $P>0.05$ level for the seven sampling points ($F(6, 35) = 10.04$, $P=1.89x10-6$).

Electrical Conductivity varied with a general increasing trend from sampling point 1 to sampling point 7 (See Fig. 5). Sampling point 7 had the highest mean EC (2.47 ± 0.47 dS / m.) while sampling point 3 had the lowest mean conductivity (0.72 ± 0.11 dS/m). There was significant statistical difference in conductivity between the seven sampling points at the $P>0.05$ level ($F(6, 35) = 11.25$, $P=5.63x10-7$).

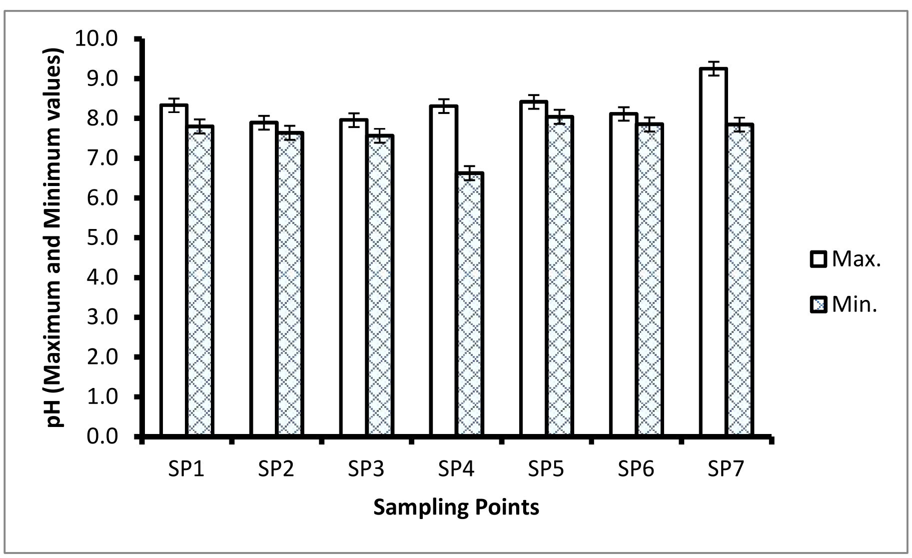

Fig. 4. Mean and standard error of pH (Maximum and minimum values) for the sampling points along the study transect

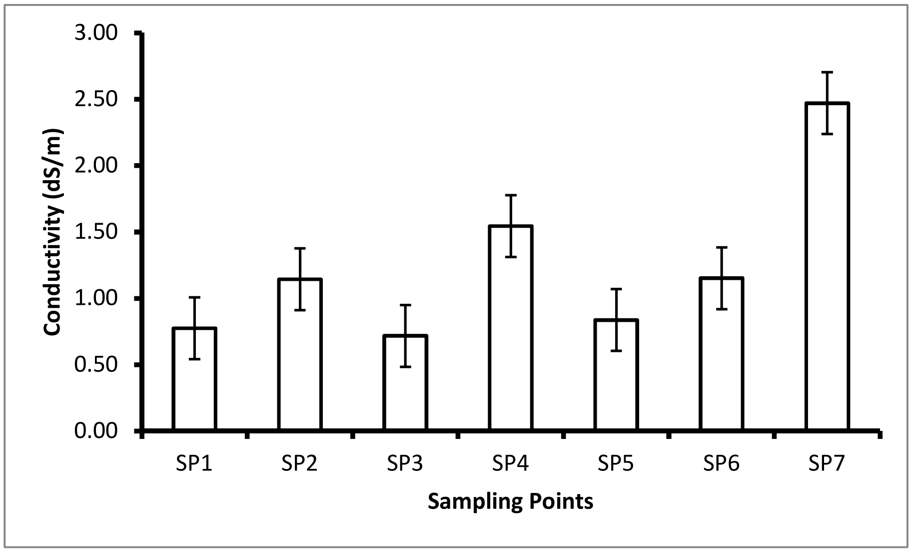

Fig. 5. Mean and standard error of conductivity values for the sampling points along the study transect

The mean calcium concentration varied with a decreasing and increasing spatial trend from SP1 to SP7 (Fig. 6). There was significant statistical difference in calcium concentration between sampling point 1 and sampling point 7 at the $p>0.05$ level (F (6, 35) = 1.16, p=0.34).

The magnesium concentration varied between 0.11 ± 0.32 mmol / L (SP1) and 1.67 ± 0.37 mmol / L (SP7) with the mean magnesium concentration showing a decreasing and increasing spatial trend but there was no significant statistical difference in the concentration between sampling point 1 and sampling point 7 at the *P*=.05 level (F (6, 35) = 1.55, *P*=.15).

SP4 had the highest mean concentration of sodium (0.8478 ± 0.4389 mmol / L) while SP 3 had the lowest concentration (0.2826 ± 0.1044 mmol / L). A general increasing trend of mean sodium concentration was observed along the study transect and there was significant statistical difference in the concentration of sodium between sampling point 1 and sampling point 7 at the *P*=.05 level for the seven sampling points [F (6, 35) = 3.47, *P*=.00].

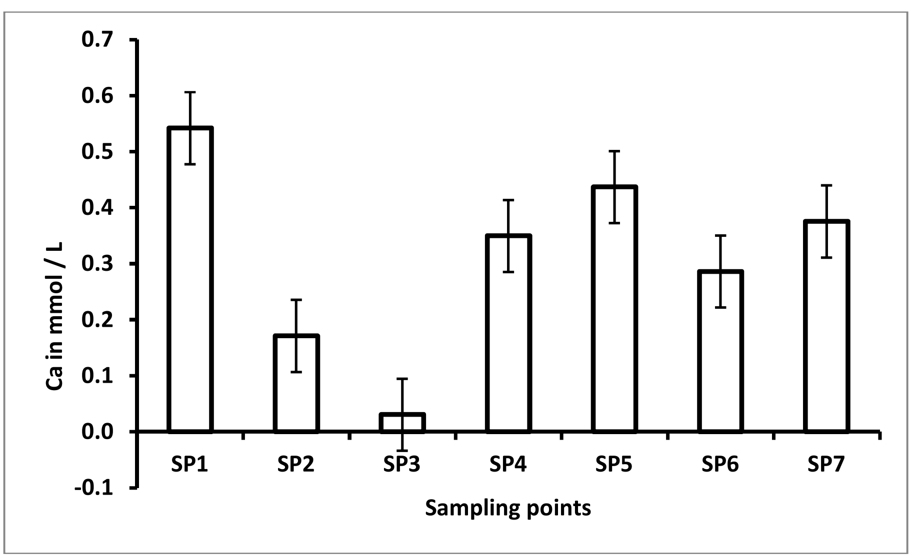

Fig. 6. Mean and standard error of calcium concentration along the study transect

The mean chromium concentration along the study transect was between 0.02 mg / L (SP2, SP5 and SP6) and 0.11 mg /L (SP1) (Fig. 7). There was no significant statistical difference in the concentration of chromium between the sampling points (sampling point 1 to sampling point 7) at the $P=0.05$ level ($F(6, 35) = 0.82$, $P=0.56$). The mean chromium concentration in the sampling points was below the NEMA recommended threshold value of 1.5 mg / L.

Mean lead concentration varied between 0.08 mg / L at SP 6 and 0.25 mg/L at SP4. The mean lead concentration was below the NEMA recommended threshold value for irrigation water (5 mg/L) for all sampling points. There was no significant statistical difference between the sampling points (sampling point 1 to sampling point 7) at the $p>0.05$ level ($F(6, 35) = 0.85$, $p=0.54$).

The mean *E. coli* count varied between sampling stations with the lowest count (1073 ± 355 MPN/100ml) recorded at SP4 while SP5 had the highest mean count (2203 ± 433 MPN/100ml,). The mean *E. coli* count showed an increasing trend and was above the NEMA recommended value (0 MPN/100 ml) at all sampling points (Fig. 8). There was significant statistical difference in the counts of *E. coli* between the seven sampling points (sampling point 1 to sampling point 7) at the $P>0.05$ level ($F(6, 28) = 2.5$, $P=0.46$).

3.3 The Effect on the Crops

Observations made on the quality of kales showed that the percentage of stunted growth in kales ranged from 3.33 to 4.1, with SP2 and SP4 having the lowest and highest percentages respectively. There was no significant statistical difference in the percentage of stunted kales at the $P>0.05$ level for the seven sampling points ($F(6,287) = 0.38$, $P=0.89$).

When asked if they had observed reduction in the size of the leaves of the kales during the dry season for the last 5-10 years, 74% of the respondents gave a negative reply (NO) while 19% confirmed (YES) and 7% were not sure.

When asked if they had experienced a reduction in yields over time, 77.1% of the farmers gave a negative response while 22.9% of the farmers gave a positive response (Table 4).

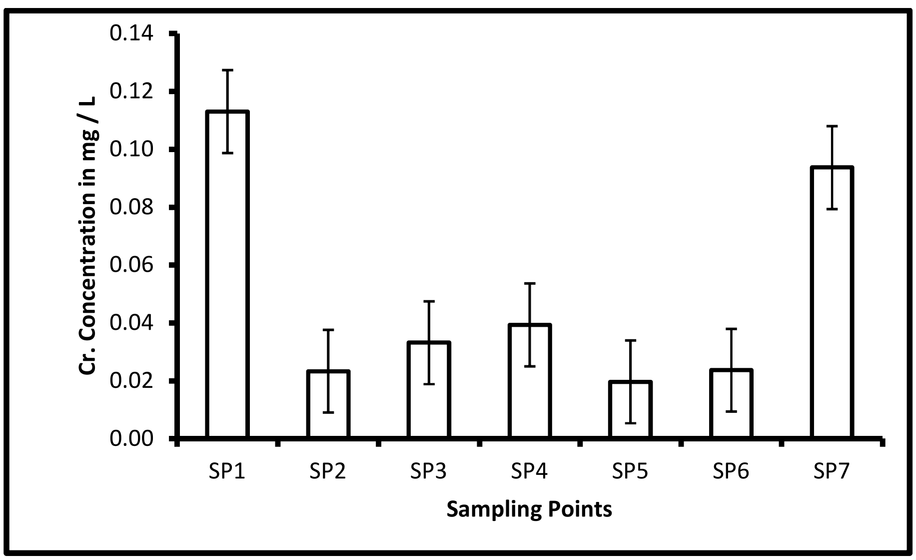

Fig. 7. Mean and standard errors of chromium concentration along the study transect

Table 4. Farmers' responses on yield reduction (N=70)

	SP1	SP2	SP3	SP4	SP5	SP6	SP7	Average
Yes (%)	30	20	20	10	40	30	10	**22.9**
No (%)	70	80	80	90	60	70	90	**77.1**

Note: Yes: Those who had observed reduction in yield over time, No: Those who did not observe any reduction in yield

The mean Sodium Adsorption Ratio (SAR) values along the study transect ranged from 0.44 in SP1 to 1.31 in SP4 and followed an increasing and decreasing tread along the transect from SP1 to SP7 (Fig. 9). The SAR for all sampling points was below the NEMA threshold value of 6.

Comparison of the study results (SAR and EC) and the FAO general guidelines for assessment of sodicity of irrigation water [16] show that the sodicity hazard for the water within the research area had a moderate sodicity hazard for the first three sampling sites and had no sodicity hazard for the last four sampling sites (Table 5).

The mean magnesium hazard values varied between 47.6 (SP1) to 86.8 in SP3. The most downstream station (SP7) had a mean value of 62.9 (See Fig. 10).

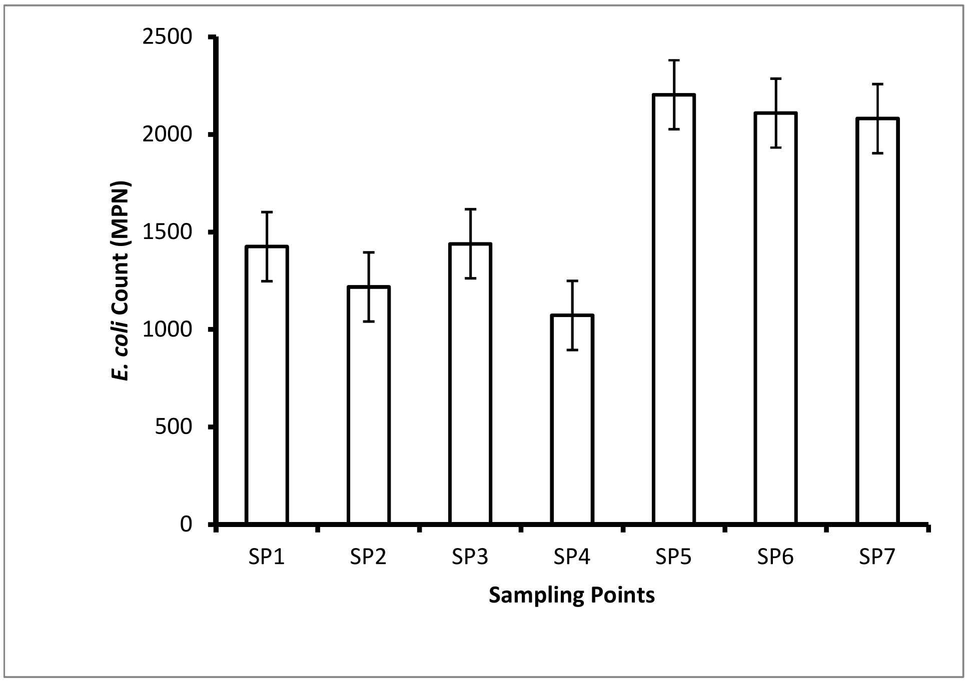

Fig. 8. Mean and standard error *E. coli* concentration (MPN/100 ml) along the study transect

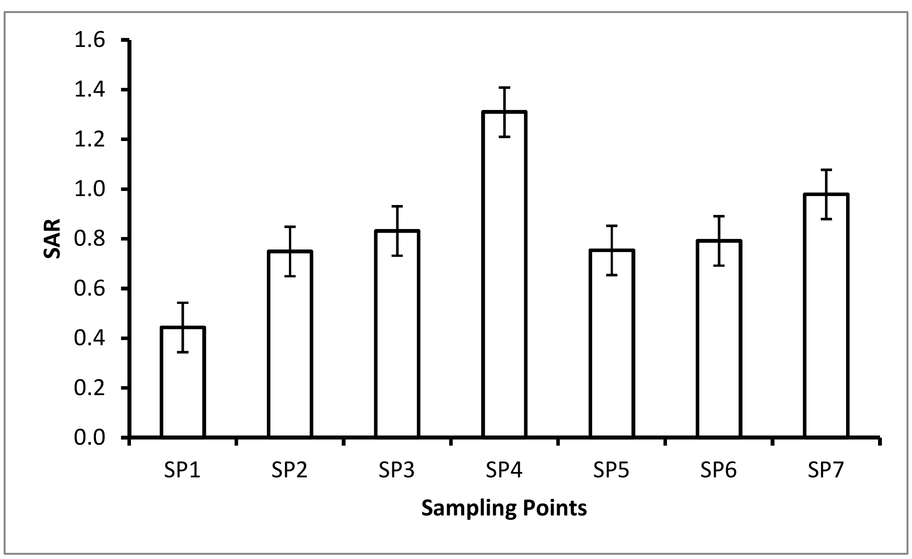

Fig. 9. Mean and standard error of sodium adsorption ratio (SAR) along the study transect

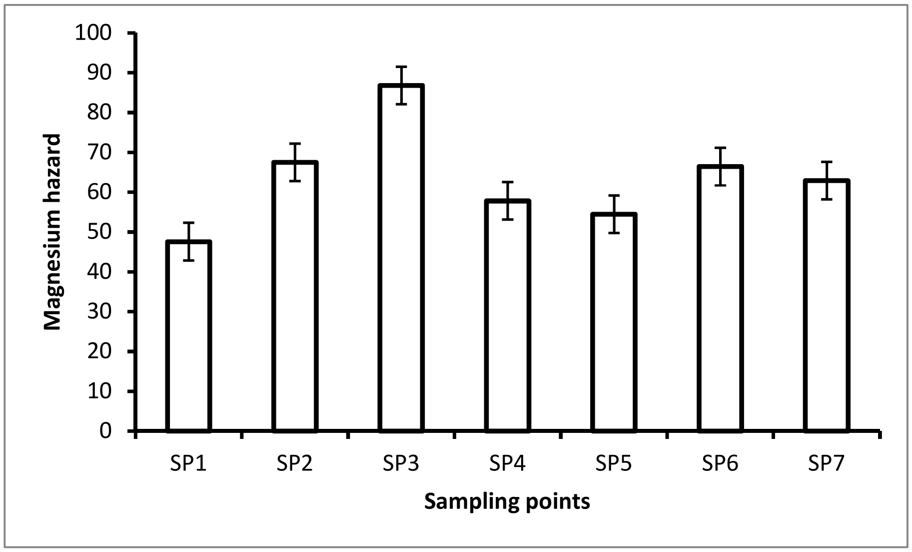

Fig. 10. Mean and standard error of magnesium hazard (MH) along the study transect

Table 5. Sodicity hazards of river water at different sampling stations, based on EC and SAR

Sampling point	SAR	EC (dS/m)	Sodicity hazard
SP1	0.44	0.77	Moderate
SP2	0.75	1.14	Moderate
SP3	0.83	0.72	Moderate
SP4	1.31	1.54	None
SP5	0.75	0.84	None
SP6	0.79	1.15	None
SP7	0.98	2.47	None

4. DISCUSSION

During the dry season, pollution input into the river was mainly from the municipal waste and industrial effluents. There are no monitoring arrangements as most of the effluent waste generators do not comply with NEMA's regulation. The farmers who had the opinion that the waters of Athi River within the Athi River area were polluted referred to pollution from the municipal sources. As such, the majority of those interviewed were of the opinion that the river is majorly polluted by municipal sources. This is corroborated by the high levels of *E. coli* in the water as indicated by the results in this study.

The normal pH range for irrigation water is from 6.5 to 8.4 [17]. Irrigation water with a pH outside the normal range may cause a nutritional imbalance or may contain a toxic ion, and low pH may cause accelerated irrigation system corrosion. Bauder et al. [16] also observed that high pH values above 8.5 are often caused by high carbonate (CO_3^{2-}) and bicarbonate (HCO_3^-) concentrations. All sampling points had pH values within the FAO range but high values of pH at sampling point 7 has a potential for pollution imbalance. The moderate salinity hazard reported in all sampling points is an indicator for a potential salinity problem in future if control measures are not put in place. The level of calcium might have been higher at the control point (sampling point 1) because of lack of adequate control measures for cement dust from nearby cement factories.

The results for the heavy metals (chromium and lead) corroborate with other findings [21] in which the concentration of lead downstream of Athi River was less than 0.01 mg/L. Studies done earlier had also showed that the concentration of lead in the tributaries of Athi River to range from 0.004 to 0.047 mg/L while that of chromium concentration ranged from ND (not detectable) to 0.068 mg/L [3]. However, due to bioaccumulation and biomagnification, the risk posed by heavy metals may be higher in the plant and animal tissues. The levels of chromium were high at sampling point one; this may be due to tanning activities that were reported by the respondents to be taking place nearby.

The level of *E. coli* within all the sampling points was higher than NEMA recommended values (0 MPN) with sampling point 5 having the highest count of 2203.25 MPN. This may be due to possible leakage from the nearby sewage treatment ponds or untreated discharge from the ponds into the river. Other research findings also revealed that microbial contamination of Nairobi River and Athi River was above the upper limits provided for by WHO and NEMA [6,11]. Sampling results by Karen and Langata District Association (KLDA) also showed that the level of *E.coli* in Mbagathi Rive (an upper tributary of Athi River) was above the NEMA threshold. Thus both the farmers and those who consume salads prepared from the vegetables grown in the study area risk getting infected with gastrointestinal illness (GI). In addition to gastrointestinal illness, illnesses such as eye infections, skin irritations, ear, nose, throat infections, and respiratory illness are also common in people who have come into contact with water contaminated with *E. coli* [22].

5. CONCLUSION

Though the mean values of the physico-chemical parameters were within the prescribed limits, there was an increasing trend in concentration for most of the parameters (e.g. pH, TDS, Conductivity, Magnesium, Sodium and Chromium and from sampling point 1 to sampling point 7. This is an indication that there is pollution input from the Athi River area. Of great concern is the level of microbial contamination (*E.coli*) which was higher than the recommended values and therefore poses a health risk to the users and the consumers of the vegetables which are grown in the area. In addition to that, all the points sampled had a moderate salinity hazard while 3 out of the seven sampled points had a moderate sodicity hazard. Should such a trend continue unabated, the quality of the river water and its potential for irrigation use will be compromised. Therefore there is need to take precautionary measures to arrest the pollution input before salinity and sodicity hazards become severe.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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Peer-review history:
The peer review history for this paper can be accessed here:
http://sciencedomain.org/review-history/17995