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Full Length Research Paper

Influence of anthropogenic activities and seasons on heavy metals in spring water along Amala and Nyangores tributaries of the Mara River Basin

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Anthropogenic activities, including replacing natural forests with human settlements and increased agricultural activities have environmental impacts. The activities can contaminate aquatic ecosystems including spring waters that are sources of major rivers like the Amala and Nyangores, tributaries of Mara River in Mau Complex. In the complex, forestlands have been converted to human settlements and agricultural lands. Although residents of the Mara River Basin use the spring waters for domestic and animal watering purposes, evaluation of the impact the activities have on the spring water quality has not been done. This study evaluated the site and seasonal variations of zinc, copper, selenium, manganese, chromium, cadmium and lead concentrations in spring waters within the Mau Complex where forests have been cleared and converted to anthropogenic activities. The study covered areas along Amala and Nyangores rivers. There were variations ($p \leq 0.05$) in the heavy metals levels with sites and seasons. Except for Mn, Cu and Cd which were lower, the levels of the other heavy metals in water from the control points (undisturbed forest areas) were higher in downstream areas that had undergone massive anthropogenic activities. Although there were seasonal variations ($p \leq 0.05$), the pattern was not clear. Some heavy metals levels were higher in wet seasons while others were higher in dry season. But the heavy metals levels were within the recommended international standards for domestic/animal use. These results demonstrate that the anthropogenic activities were not yet causing pollution of the spring waters. Maintaining the anthropogenic activities at present levels is recommended. However, periodic monitoring to ascertain the quality of the spring water is necessary to mitigate increase to detrimental levels with time. These results contribute knowledge helping regulatory agencies and management of Lake Victoria basin to formulate monitoring polices to curb water quality deterioration.

Key words: Anthropogenic activities, heavy metals, spring water, River Mara, Mau Complex.

INTRODUCTION

Mara River basin, especially on the high highlands, where the main tributaries (Rivers Amala and Nyangores) traverse used to be part of the Mau Forest (McCartney, 2010). The area has undergone massive deforestation (Defersha and Melesse, 2012, Mango et al., 2010, 2011). Between 1973 and 2008, the Mau Forest and range land conversion to agriculture was over 203% (Mati et al., 2008). Such conversion to anthropogenic activities cause environmental, soil and water quality degradation problems that affect human, animal and aquatic life (UNEP, 2006). Studies within the Mara River basin have demonstrated that deforestation and human settlement have increased soil erosion and sedimentation and caused extreme water flow events (Dessu and Melesse, 2012, 2013, Mango et al., 2011). The changes these anthropogenic activities can cause in the spring water quality, especially the levels of heavy metals in ground water have not been quantified.

Springs are susceptible to contamination since water feeding them flows through the ground for only a short distance, thus limiting possible natural filtering. Consequently, springs may not be good choice for a water supply if the area uphill has industrial, agricultural, or other activities that can be sources of pollution (Varol and Şen, 2012). In many parts of the world, decline in water quality has been associated with anthropogenic activities uphill of the waters sources. Examples of such incidences include decline in water quality in China (Huang et al., 2015; Yang et al., 2015); Turkey (Varol, 2011; Varol and Şen, 2012), Taiwan (Chen et al., 2015), India (Jain, 2004), Sweden (Loefgren et al., 2014), and Nigeria (Akintoye et al., 2014). The anthropogenic activities in water catchment areas destroy the forest cover necessary in preventing soil erosion and sediment deposition into the water bodies (Foley et al., 2005; Liu et al., 2007). The activities also cause deterioration of underground water quality (Almeida et al., 2007; Duruibe et al., 2007; Micó et al., 2006). Such quality deterioration can be high when the anthropogenic activities are close to springs. In the Mara River basin, forest lands have been converted into human use activities (McCartney, 2010; UNEP, 2006). The basin has witnessed increase in human settlement (McCartney, 2010), agriculture (Matano et al., 2015; McCartney, 2010), urban centers development (McCartney, 2010; UNEP, 2006) and tourist activities, which are possible sources of contamination (McCartney, 2010; Nyairo et al., 2015; UNEP, 2006).

The Mara River drains into Lake Victoria, which thereafter flows into the River Nile and the Mediterranean Sea. The water is a source of livelihood for many people in Kenya, Tanzania, Southern Sudan, Sudan and Egypt. Consequently, its water contamination/quality deterioration can affect lives of many people together with animals and aquatic life. Changes in the water quality of the Mara River water basin have been documented (McCartney, 2010; Nyairo et al., 2015; Wafula et al., 2017). The Mara River sources are mainly the rivers Amala and Nyangores, which are fed by springs in the Mau Forest and former Mau Forest areas within the River Mara basin. There has been no documentation of the contribution of the springs forming sources of Amala and Nyangores Rivers to the Mara River water quality. The objective of this study was to assess the levels on heavy metals in the spring waters feeding the Amala and Nyangores rivers.

Seasonal variations in anthropogenic activities usually influence quality of river water downstream (Ma et al., 2005; Chang, 2008; Li et al., 2009; Simeonov et al., 2003). The water quality changes can be variable where there are seasonal variations in agricultural (Micó et al., 2006), industrial (Ma et al., 2005, Simeonov et al., 2003) and tourist (Almeida et al., 2007) activities. Within the Mara River basin, these economic activities vary with seasons. Usually, tourist activities are high when it is winter season in the northern hemisphere. Agricultural activities within the basin are mainly rain fed and most agricultural activities are undertaken during the long rains in April-June and short rains in October-November (Jaetzold et al., 2007). The main industry within the Mau Complex, is tea production that runs throughout the year. Although, the influence of these activities on the water quality on Rivers Amala and Nyangores were recently demonstrated (Nyairo et al., 2015), their influence on spring water quality have not been established. This study also evaluated the variations in heavy metals (Mn, Cu, Zn, Pb, Cr, and Cd) and Se in springs at the catchment of Rivers Amala and Nyangores with site and seasons.

MATERIALS AND METHODS

Study area

The springs were randomly selected in the catchment of Nyangores and Amala rivers located in the Mau Forest Complex within Narok and Bomet counties, Kenya (Figure 1). Mara River basin is a trans-boundary basin shared by Kenya and Tanzania and is part o the larger Nile River Basin. The basin lies between latitudes 0°38' and1° 03' south and between longitudes 35° 01' and 35° 33' east(Figures 1 and 2). The area was heavily forested (UNEP, 2006,

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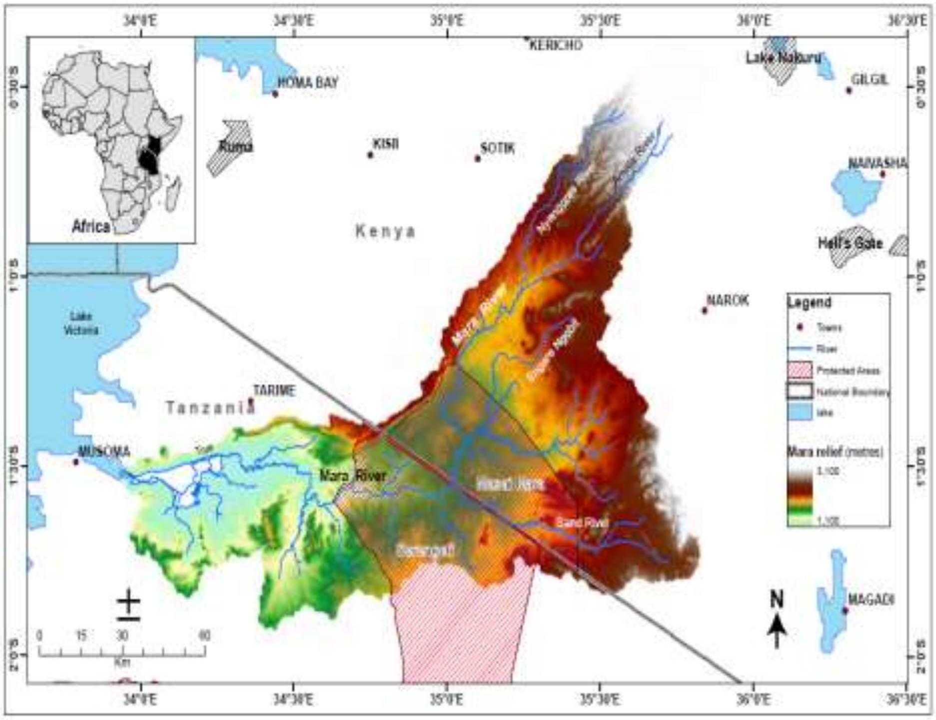

Figure 1. A map of Mara River Basin.

Figure 2. A Google earth map of Mara River Basin and sampling points.

2009) with typical equatorial natural forest trees, but parts have been converted to large and small scale farming and a buffer zone of tea plantation introduced by the government to stop encroachment into the forest. It is an important water tower for the Kenya (GOK, 2008a, b). The small scale farming crops in the area are dominated by maize, beans, peas, potatoes, tea, wheat and

Table 1. Coordinates and local names of springs.

Site	Local Name of Spring	Coordinates	Site	Local Name of Spring	Coordinates
M2	Teganda	S0 41.257 E35 24.964	M14	Kebenet	S0 49.580 E35 20.677
M6	Kapsosrurwa	S0 42.343 E35 21.878	M21	Chepudonge	S0 57.992 E35 21.303
M11	Silbwet	S0 47.327 E35 29.116	M22	Motiok	S1 02.221 E35 14.534
M12	Sotionik 1	S0 49.023 E35 31.270	M23	Chepkesoi	S0 55.368 E35 17.687
M20	Sotionik 2	S0 45.825 E35 34.659	M24	Kapangas	S0 55.004 E35 17.619
M15	Ainabsabet	S0 47.881 E35 32.762	M26	Kapangas	S0 49.740 E35 19.126
M17	Kapsoen 1	S0 54.197 E35 27.812	M27	Ndong Ndong	S0 47.408 E35 20.785
M18	Kapsoen 2	S0 53.159 E35 27.385	M28	Siongiroi	S0 44.788 E35 21.787

vegetables.

A total of sixteen (Table 1) springs were randomly selected, of which two (Tenganda (M2) and Kebenet (M14)) were located in the forest, were used as controls. Springs (Kapsosrurwa (M6), Silbwet (M11), Sotionik 1 (M12), Sotionik 2 (M20), Ainabsabet (M15), Kapsoen 1 (M17), Kapsoen 2 (M18), Chepudonge (M21), Motiok (M22), Chepkesoi (M23), Kapangas 1 (M24), Kapangas 2 (M26), Ndong Ndong (M27) and Siongiroi (M28)) were located in sections of the river where small scale farming of tea, maize and potatoes interspersed with agro-forestry and animal husbandry.

Sampling design and collection

Water sampling was done in two seasons, dry and wet season, using a pre-cleaned water sampler. The water samples were collected just below the water surface and stored in pre-cleaned amber colored 2.5 L glass bottles. The bottles had been pre-cleaned by soaking in 10% nitric acid overnight and rinsed with distilled water on the day of sampling. Each sample was treated with 10 ml of 6N HNO_3 solution for preservation. The samples were then transported to the laboratory and filtered immediately using Whatman filter paper then stored at -20°C pending extraction (AOAC, 2000; APHA, 1995).

Determination of parameters

The water samples were filtered through a 1 µm cellulose acetate millipore filter, acidified by 1% (2 ml) concentrated nitric acid, and then pre-concentrated by evaporating 200 to 30 ml on a hot plate at 60°C (Mzimela et al., 2003). The evaporated samples were transferred to a 50 ml volumetric flask and made-up to the volume with double distilled water after addition of 1.5 mg/ml of strontium chloride.

The extracts were analyzed for Pb, Cu, Zn, Mn, Se, Cd and Cr using an atomic absorption spectrophotometer, Shimadzu Atomic Absorption Flame Spectrophotometer, Model AA-6200 (Kyoto, Japan).

Statistical analysis

The data were subjected to statistical analysis of variance (ANOVA) using a two factor completely randomized design. SAS statistical package and GraphPad Prism for students't-test ($p \leq 0.05$) was used to check the variations.

RESULTS AND DISCUSSION

All the heavy metals (Tables 2 and 3) significantly ($p \leq 0.05$) varied with site for both springs flowing into Amala and Nyangores. Mn, Cu and Cd were lower ($p \leq 0.05$) in water from springs that water still under natural forest (Kebenet and Teganda) than springs in areas that had been subjected to anthropogenic activities. For some heavy metals, the levels in spring waters were similar to or higher than those of the control sites, which were in virgin forest areas. The spring water heavy metals ranged from 0.009 to 0.602 ppb for Pb in Chepudonge and Kebenet, 0.014 to 0.054 ppb Mn in Chepudonge and Ndong Ndong, 0.073 to 0.609 ppb Cu in Kapangas 2 and Kapangas 1, 0.004 to 0.602 ppb Zn in Kapangas 2 and Ndong Ndong, 0.035 to 0.465 ppb Se in Ndong Ndong and Chepkesoi, 0.448 to 0.946 ppb Fe in Kebenet and Motiok, 0.015 to 0.055 ppb Cr in Kebenet and Siongiroi and 0.093 to 0.819 ppb Cd in Motiok and Siongiroi, respectively, in springs flowing into Amala. For the spring flowing into Nyangores, the range of heavy metals ranges were 0.003 to 0.020 ppb Pb in Ainabsabet and Silbwet, 0.017 to 0.058 ppb Mn in Sotionik 2 and Silbwet, 0.137 to 0.257 ppb Cu in Kapsoen 1 and Teganda, 0.002 to 0.173 ppb Zn in Kapsosrurwa and Sotionik 2, 0.095 to 0.386 ppb Se in Kapsosrurwa and Ainabsabet, 0.439 to 0.577 ppb Fe in Ainabsabet and Sotionik 2, 0.064 to 0.410 ppb Cr in Kapsosrurwa and Teganda, and 0.013 to 0.042 ppb Cd in Teganda and Kapsoen 2, respectively. Apart from fluoride levels that had been reported to be high in some spring waters in Kenya (Gaciri and Davies, 1993), heavy metals levels in spring water in Kenya had not been reported. However, comparable in levels of some heavy metals of springs from the similar catchments had been observed in other countries such as India (Prasad and Bose, 2001), Mexico (Wyatt et al., 1998), and Jordan (Batayneh, 2010). But in Turkey, heavy metals levels were higher than acceptable limits in sediments from springs in Karasu creek demonstrating contamination (Yalcin et al., 2007). In this study, all the heavy metals exhibited low concentrations

Table 2. Heavy metals concentration levels in water from springs flowing in Amala (µg/L).

Spring		Kebenet	Chepudonge	Motiok	Chepkesoi	Kapangas	Kapangas	Ndong Ndong	Siongiroi	Mean season
Mn	Dry season	0.014	0.013	0.044	0.026	0.016	0.020	0.047	0.030	0.026
	Wet season	0.018	0.017	0.056	0.034	0.021	0.026	0.060	0.038	0.034
	Mean sites	0.016	0.015	0.050	0.030	0.019	0.023	0.054	0.034	-
	CV (%)	-	-	-	-	8.029	-	-	-	-
	LSD (p≤0.05)	-	-	-	-	0.003	-	-	-	0.001
	S.D	-	-	-	-	0.015	-	-	-	-
Cu	Dry season	0.690	0.173	0.161	0.266	0.278	0.064	0.173	0.376	0.273
	Wet season	0.083	0.223	0.208	0.344	0.940	0.082	0.223	0.485	0.324
	Mean sites	0.387	0.198	0.185	0.305	0.609	0.073	0.198	0.431	
	CV (%)	-	-	-	-	2.088	-	-	-	-
	LSD (p≤0.05)	-	-	-	-	0.005	-	-	-	0.002
	S.D	-	-	-	-	0.2193	-	-	-	-
Fe	Dry season	0.004	0.604	0.826	0.499	0.728	0.537	0.578	0.803	0.572
	Wet season	0.891	0.780	1.066	0.644	0.940	0.693	0.746	1.036	0.850
	Mean sites	0.448	0.692	0.946	0.572	0.834	0.615	0.662	0.920	
	CV (%)	-	-	-	-	3.483	-	-	-	-
	LSD (p≤0.05)	-	-	-	-	0.022	-	-	-	0.011
	S.D	-	-	-	-	0.252	-	-	-	-
Zn	Dry season	0.008	0.004	0.005	0.384	0.005	0.003	0.525	0.242	0.147
	Wet season	0.005	0.005	0.098	0.496	0.007	0.004	0.678	0.312	0.201
	Mean sites	0.007	0.005	0.052	0.440	0.006	0.004	0.602	0.277	
	CV (%)	-	-	-	-	0.846	-	-	-	-
	LSD (p≤0.05)	-	-	-	-	0.001	-	-	-	0.000
	S.D	-	-	-	-	0.197	-	-	-	-
Pb	Dry season	0.848	0.008	0.029	0.022	0.020	0.004	0.012	0.020	0.120
	Wet season	0.010	0.010	0.046	0.028	0.026	0.005	0.016	0.026	0.021
	Mean sites	0.429	0.009	0.038	0.025	0.023	0.005	0.014	0.023	
	CV (%)	-	-	-	-	8.865	-	-	-	-
	LSD (p≤0.05)	-	-	-	-	0.002	-	-	-	0.001
	S.D	-	-	-	-	0.208	-	-	-	-
Cr	Dry season	0.013	0.032	0.035	0.040	0.031	0.020	0.030	0.048	0.031

Table 2. Contd.

	Wet season	0.017	0.041	0.046	0.052	0.040	0.026	0.039	0.062	0.040
	Mean sites	0.015	0.037	0.041	0.046	0.036	0.023	0.035	0.055	
	CV (%)	-	-	-	-	6.018	-	-	-	-
	LSD (p≤0.05)	-	-	-	-	0.010	-	-	-	0.005
	S.D	-	-	-	-	0.013	-	-	-	-
	Dry season	0.144	0.188	0.081	0.404	0.481	0.863	0.266	0.715	0.393
	Wet season	0.186	0.243	0.105	0.521	0.621	1.113	0.344	0.923	0.507
Cd	Mean sites	0.165	0.216	0.093	0.463	0.551	0.988	0.305	0.819	
	CV (%)	-	-	-	-	10.870	-	-	-	-
	LSD (p≤0.05)	-	-	-	-	0.000	-	-	-	0.002
	S.D	-	-	-	-	0.318	-	-	-	-
	Dry season	0.690	0.173	0.081	0.404	0.481	0.026	0.039	0.062	0.245
	Wet season	0.047	0.173	0.578	0.525	0.012	0.083	0.030	0.266	0.214
Se	Mean sites	0.369	0.173	0.330	0.465	0.247	0.055	0.035	0.164	
	CV (%)	-	-	-	-	0.399	-	-	-	-
	LSD(p≤0.05)	-	-	-	-	0.001	-	-	-	0.001
	S.D	-	-	-	-	0.229	-	-	-	-

in the spring waters across the sites. Indeed, these levels were lower than the water quality limits for domestic/animal use purposes (USEPA, 2014; WHO, 2014). These results suggest that the effect of the anthropogenic activities were not yet causing significant spring water heavy metals pollution in the upper Mau River complex.

All the heavy metals (Tables 2 and 3) varied significantly (p≤0.05) with seasons, with the exception of Cd on the Nyangores River sode. For the springs flowing into Amala River Mn, Cu, Fe, Zn, Cr, and Cd concentrations were higher in wet seasons while Pb and Se were levels were higher in the dry season. Only levels of Mn and Cu were higher while Fe, Zn, Pb, and Cr were lower in wet season than dry season in water flowing into the Nyangores River. Variations in the distribution of heavy metals appeared to be controlled by hydro-biological/geological conditions (Sankar et al., 2010) than the anthropogenic activities. Seasonal variations in heavy metals concentrations in the spring waters may have arisen from the rapid growth of population and increased agricultural activities (Abdel-Baki et al., 2011). The level of heavy metals recorded in water in this study are generally low when compared with the environmental limits suggested by WHO (WHO, 2014) (Table 5), and USEPA (USEPA, 2014). These results demonstrate that the anthropogenic activities in the upper Mau River Complex in the catchment of rivers Amala and Nyangores are not yet causing serious spring water quality deterioration.

Comparison of the mean data from Amala and Nyangores (Table 4) reveals that levels Mn, Cu, Zn, Pb, Cr and Se were not different (p≤0.05), while Fe and Cd were higher in spring waters draining into the Amala River than Nyangores River. The lack of differences in most heavy metals levels were attributed to the fact that these areas were deforested within the same time range and have been subjected to similar anthropogenic activities. Differences in Fe and Cd could have arisen from variations in hydro-biological/geological differences (Tables 6 to 8).

In conclusion, the anthropogenic activities at the catchment of Amala and Nyangores, tributaries of Mara River have not caused serious increase in

Table 3. Heavy metals concentration levels in water from springs flowing into Nyangores River (µg/L).

Spring		Teganda	Kapsosrurwa	Silbwet	Sotionik 1	Sotionik 2	Ainabsabet	Kapsoen 1	Kapsoen 2	Mean season
Mn	Dry season	0.013	0.012	0.039	0.023	0.014	0.018	0.041	0.026	0.023
	Wet season	0.032	0.027	0.076	0.021	0.020	0.022	0.026	0.018	0.030
	Mean sites	0.023	0.020d	0.058	0.022	0.017	0.020	0.034	0.022	-
	CV (%)	-	-	-	-	9.435	-	-	-	-
	LSD (p≤0.05)	-	-	-	-	0.003	-	-	-	0.002
	S.D	-	-	-	-	0.016	-	-	-	-
Cu	Dry season	0.057	0.154	0.143	0.237	0.247	0.057	0.153	0.334	0.173
	Wet season	0.456	0.183	0.214	0.367	0.265	0.285	0.121	0.026	0.240
	Mean sites	0.257	0.169	0.179	0.302	0.256	0.171	0.137	0.180	
	CV (%)	-	-	-	-	43.010	-	-	-	-
	LSD (p≤0.05)	-	-	-	-	0.104	-	-	-	0.052
	S.D	-	-	-	-	0.118	-	-	-	-
Fe	Dry season	0.613	0.537	0.733	0.443	0.647	0.477	0.513	0.713	0.585
	Wet season	0.268	0.508	0.388	0.628	0.507	0.400	0.544	0.256	0.437
	Mean sites	0.441	0.523	0.561	0.536	0.577	0.439	0.529	0.485	
	CV (%)	-	-	-	-	3.095	-	-	-	-
	LSD (p≤0.05)	-	-	-	-	0.019	-	-	-	0.009
	S.D	-	-	-	-	0.139	-	-	-	-
Zn	Dry season	0.003	0.004	0.005	0.341	0.005	0.003	0.467	0.215	0.130
	Wet season	0.002	0.002	0.006	0.004	0.002	0.002	0.002	0.002	0.003
	Mean sites	0.003	0.002	0.006	0.173	0.003	0.003	0.235	0.109	
	CV (%)	-	-	-	-	0.901	-	-	-	-
	LSD (p≤0.05)	-	-	-	-	0.001	-	-	-	0.000
	S.D	-	-	-	-	0.144	-	-	-	-
Pb	Dry season	0.007	0.007	0.026	0.020	0.018	0.003	0.011	0.018	0.016
	Wet season	0.019	0.013	0.014	0.011	0.002	0.002	0.025	0.019	0.013
	Mean sites	0.013	0.010	0.020	0.016	0.010	0.003	0.018	0.019	
	CV (%)	-	-	-	-	9.602	-	-	-	-
	LSD (p≤0.05)	-	-	-	-	0.002	-	-	-	0.001
	S.D	-	-	-	-	0.008	-	-	-	-
Cr	Dry season	0.753	0.072	0.063	0.093	0.083	0.096	0.074	0.064	0.162

Table 3. Contd.

	Wet season	0.067	0.056	0.076	0.068	0.081	0.091	0.078	0.089	0.076
	Mean sites	0.410	0.064	0.070	0.081	0.082	0.094	0.076	0.077	
	CV (%)	-	-	-	-	2.147	-	-	-	-
	LSD (p≤0.05)	-	-	-	-	0.003	-	-	-	0.002
	S.D	-	-	-	-		-	-	-	-
Cd	Dry season	0.012	0.028	0.031	0.036	0.028	0.018	0.027	0.042	0.028
	Wet season	0.013	0.017	0.025	0.040	0.013	0.032	0.037	0.041	0.027
	Mean sites	0.013	0.023	0.028	0.038	0.020	0.025	0.032	0.042	
	CV (%)	-	-	-	-	11.933	-	-	-	-
	LSD (p≤0.05)	-	-	-	-	0.004	-	-	-	NS
	S.D	-	-	-	-	0.169	-	-	-	-
Se	Dry season	0.128	0.167	0.072	0.359	0.427	0.766	0.237	0.635	0.349
	Wet season	0.190	0.023	0.128	0.168	0.083	0.006	0.030	0.071	0.087
	Mean sites	0.159	0.095	0.100	0.264	0.255	0.386	0.134	0.353	
	CV (%)	-	-	-	-	0.439	-	-	-	-
	LSD (p≤0.05)	-	-	-	-	0.001	-	-	-	0.001
	S.D	-	-	-	-	0.222	-	-	-	-

Table 4. Comparison of Water quality parameters of springs flowing in Amala and Nyangores (Student t test of Amala and Nyangores data for heavy metals in water samples).

Table analyzed	Mn Paired t test data	Cu Paired t test data	Fe Paired t test data	Zn Paired t test data	Pb Paired t test data	Cr Paired t test data	Cd Paired t test data	Se Paired t test data
Column B	Amala	Amala	Amala	Amala	Amala	Amala	Amala	Amala
vs.	vs.	vs.	vs.	vs.	vs.	vs.	vs.	vs.
Column A	Nyangores	Nyangores	Nyangores	Nyangores	Nyangores	Nyangores	Nyangores	Nyangores
Paired t test								
P value	0.400	0.120	0.008	0.073	0.303	0.106	0.007	0.879
P value summary	NS	NS	**	NS	NS	NS	**	NS
Significantly different? (p≤0.05)	No	No	Yes	No	No	No	Yes	No
One- or two-tailed P value?	Two-tailed	Two-tailed	Two-tailed	Two-tailed	Two-tailed	Two-tailed	Two-tailed	Two-tailed
t, df	t=0.8962, df=7	t=1.768, df=7	t=3.704, df=7	t=2.109, df=7	t=1.113, df=7	t=1.856, df=7	t=3.763, df=7	t=0.1578, df=7
Number of pairs	8	8	8	8	8	8	8	8

Table 4. Cont'd.

How big is the difference?								
Mean of differences	0.003	0.092	0.200	0.107	0.057	-0.083	0.422	0.012
SD of differences	0.010	0.147	0.153	0.144	0.145	0.127	0.318	0.206
SEM of differences	0.003	0.052	0.054	0.051	0.051	0.045	0.112	0.073
95% confidence interval	-0.005 to 0.011	-0.031 to 0.215	0.0722 to 0.327	-0.013 to 0.227	-0.064 to 0.179	-0.189 to 0.023	0.157 to 0.688	-0.161 to 0.184
R squared	0.103	0.309	0.662	0.388	0.150	0.330	0.670	0.004
How effective was the pairing?								
Correlation coefficient (r)	0.766	0.564	0.555	0.998	0.008	-0.699	0.362	-0.196
P value (one tailed)	0.013	0.073	0.077	< 0.0001	0.492	0.027	0.189	0.321
P value summary	*	NS	NS	****	NS	*	NS	NS
Was the pairing significantly effective?	Yes	No	No	Yes	No	Yes	No	No

Table 5. Permissible limits for heavy metals of drinking water set by WHO.

Parameters	WHO's Permissible Limits (mg l^{-1})
Mn	0.02
Cu	0.02
Fe	0.30
Zn	3.00
Pb	0.01
Cr	0.003
Cd	0.05
Se	0.02

the heavy metals levels in spring waters within the catchment area. Thus, the spring water in and around Mau Forest water towers are suitable for domestic/animal use. The contribution of the springs to the heavy metal load to the River Mara from water from springs flowing into the tributaries of the Amala and Nyangores are minimal and insignificant. The anthropogenic activities within the area should be maintained at the current levels, but there is need for continuous surveillance since long term activities could alter the status. Periodic monitoring of the spring waters for heavy metal is recommended.

CONFLICT OF INTERESTS

The authors have not declared any conflict of

Table 6. Levels of physicochemical parameters of water from springs of Amala and Nyangores Rivers.

Item		Nyangores springs			Sotionik 1	Sotionik 2	Ainabsabet	Kapsoen 1	Kapsoen 2	Mean season
		Teganda	Kapsosrurwa	Silbwet						
Temperature (°C)	Wet season	12.57	12.90	13.07	13.13	12.90	13.07	13.13	13.23	13.00^{b}
	Dry season	14.70	15.78	16.05	16.07	15.44	16.06	16.10	16.15	15.79^{a}
	Mean Sites	13.64^{a}	14.34^{b}	14.56^{a}	14.60^{a}	14.17^{b}	14.56^{a}	14.61^{a}	14.69^{a}	-
	CV (%)	-	-	-	-	1.17	-	-	-	-
	LSD (p≤0.05)	-	-	-	-	0.20	-	-	-	0.10
pH	Wet season	6.37	6.90	6.24	6.23	6.15	6.42	6.47	6.90	6.46^{b}
	Dry season	6.51	6.10	6.37	6.67	6.14	6.44	6.48	6.10	6.35^{a}
	Mean Sites	6.44^{d}	6.50^{a}	6.31^{f}	6.45^{c}	6.15^{g}	6.43^{e}	6.48^{b}	6.50^{a}	-
	CV (%)	-	-	-	-	0.00	-	-	-	-
	LSD (p≤0.05)	-	-	-	-	0 .00	-	-	-	0 .00
		Amala springs		Motiok	Chepkesoi	Kapangas	1Kapangas2	Ndong Ndong	Siongiroi	Mean season
			Chepudonge							
Temperature (°C)	Wet season	13.13	29.70	8.81	13.87	13.77	14.09	14.11	14.21	13.13^{a}
	Dry season	16.20	32.34	9.81	16.94	16.97	16.38	16.73	16.21	16.20^{b}
	Mean Sites	14.67^{c}	31.02^{a}	9.31^{d}	15.40^{b}	15.37^{b}	15.24^{b}	15.42^{b}	15.21^{b}	-
	CV (%)	-	-	-	-	-	1.36	-	-	-
	LSD (p≤0.05)	-	-	-	-	-	0.26	-	-	0.13
pH	Wet season	6.24	6.20	6.23	6.66	6.83	6.83	6.27	6.27	6.24^{a}
	Dry season	6.37	7.59	6.67	6.30	6.11	6.79	6.72	6.44	6.37^{b}
	Mean Sites	6.31^{h}	6.90^{a}	6.45^{f}	6.48^{d}	6.47^{e}	6.81^{b}	6.50^{c}	6.33^{g}	-
	CV (%)	-	-	-	-	-	0 .00	-	-	-
	LSD (p≤0.05)	-	-	-	-	-	0 .00	-	-	0 .00

*Means with the same letters are not significantly (p≤0.05) different.

interests.

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Table 7. Concentration levels of Nutrients in water from springs flowing into Amala (ppb).

Spring		Kebenet	Chepudonge	Motiok	Chepkesoi	Kapangas	Kapangas	Ndong Ndong	Siongiroi	Mean season
	Dry Season	33.440	42.010	22.010	24.860	33.430	26.290	36.290	22.000	30.040
	Wet Season	31.540	19.550	64.110	31.540	29.840	26.410	46.960	31.540	35.190
SRP	Mean sites	32.490	30.780	43.060	28.200	31.640	26.350	41.630	26.770	-
	CV (%)	-	-	-	-	0.021	-	-	-	-
	LSD(p≤0.05)	-	-	-	-	0.008	-	-	-	0.004
	Dry Season	52.010	82.010	63.430	50.570	86.290	122.010	362.000	130.570	118.610
	Wet Season	105.250	48.690	561.250	197.840	134.410	91.540	607.540	563.140	288.710
TP	Mean sites	78.630	65.350	312.340	124.210	110.350	106.780	484.770	346.860	-
	CV (%)	-	-	-	-	0.000	-	-	-	-
	LSD(p≤0.05)	-	-	-	-	0.000	-	-	-	0.000
	Dry Season	57.670	34.330	21.000	36.000	122.670	82.670	77.670	69.330	62.670
	Wet Season	33.200	33.200	67.200	115.210	63.210	27.210	25.210	43.210	50.960
Ammonium	Mean sites	45.440	33.770	44.100	75.610	92.940	54.940	51.440	56.270	-
	CV (%)	-	-	-	-	0.013	-	-	-	-
	LSD(p≤0.05)	-	-	-	-	0.009	-	-	-	0.005
	Dry Season	155.540	431.610	114.640	114.940	407.360	138.270	434.330	132.520	241.150[b]
	Wet Season	157.930	145.200	557.560	62.660	519.020	301.560	233.560	975.390	369.110[a]
Oxidized nitrogen	Mean sites	156.740	288.410	336.100	88.800	463.190	219.920	333.950	553.960[a]	-
	CV (%)	-	-	-	-	0.000	-	-	-	-
	LSD(p≤0.05)	-	-	-	-	0.000	-	-	-	0.000
	Dry Season	28.663	59.256	31.420	31.420	50.896	45.384	64.860	28.663	42.536[b]
	Wet Season	27.745	24.437	188.150	161.324	57.694	31.052	44.465	17.731	69.086[a]
Nitrates	Mean sites	28.204[g]	41.893[e]	109.785[a]	96.372[b]	54.295[d]	38.218[f]	54.663[c]	23.243[h]	-
	CV (%)	-	-	-	-	0.000	-	-	-	-
	LSD(p≤0.05)	-	-	-	-	0.000	-	-	-	0.000
	Dry Season	3.120	6.450	3.420	3.420	5.540	4.940	7.060	3.120	4.630[b]
	Wet Season	3.020	2.660	20.480	17.560	6.280	3.380	4.840	1.930	7.520[a]
Nitrites	Mean sites	3.070[g]	4.560[e]	11.950[a]	10.490[b]	5.910[d]	4.160[f]	5.950[c]	2.530[h]	-
	CV (%)	-	-	-	-	0.148	-	-	-	-
	LSD(p≤0.05)	-	-	-	-	0.011	-	-	-	0.005

*Means with the same letters are not significantly (p≤0.05) different.

Table 8. Concentration levels of nutrients (ppb) in water from springs flowing into Nyangores.

Spring		Teganda	Kapsosrurwa	Silbwet	Sotionik 1	Sotionik 2	Ainabsabet	Kapsoen 1	Kapsoen 2	Mean season
	Dry season	26.280	16.290	53.420	26.290	24.860	22.010	39.140	26.290	29.320^{a}
	Wet season	40.120	50.420	26.410	29.830	40.120	31.550	43.550	26.400	36.050^{b}
SRP	Mean sites	33.200^{d}	33.360^{c}	39.920^{b}	28.060^{f}	32.490^{e}	26.780^{g}	41.350^{a}	26.350^{h}	-
	CV (%)	-	-	-	-	0.022	-	-	-	-
	LSD(p≤0.05)	-	-	-	-	0.008	-	-	-	0.004
	Dry season	87.710	40.570	467.710	164.860	112.010	76.290	506.290	469.280	240.590^{a}
	Wet season	62.410	98.410	76.120	60.680	103.540	146.410	434.400	156.680	142.330^{b}
TP	Mean sites	75.060^{g}	69.490^{h}	271.920^{c}	112.770^{d}	107.78^{f}	111.350^{e}	470.350^{a}	312.980^{b}	-
	CV (%)	-	-	-	-	0.005	-	-	-	-
	LSD(p≤0.05)	-	-	-	-	0.011	-	-	-	0.006
	Dry season	131.610	27.670	56.000	96.010	52.670	22.670	21.010	36.010	42.460^{b}
	Wet season	69.210	41.190	25.200	43.200	147.200	99.200	93.200	83.190	75.200^{a}
Ammoniu m	Mean sites	100.410^{a}	34.430^{h}	40.600^{g}	69.600^{b}	99.940^{a}	60.940^{c}	57.110^{e}	59.600^{d}	-
	CV (%)	-	-	-	-	0.012	-	-	-	-
	LSD(p≤0.05)	-	-	-	-	0.008	-	-	-	0.004
	Dry season	131.610	121.000	464.640	52.210	432.520	251.300	194.640	812.820	307.590^{a}
	Wet season	186.650	517.930	137.560	137.920	488.830	165.930	521.200	159.020	289.380^{b}
Oxidized nitrogen	Mean sites	159.130^{g}	319.470^{d}	301.100^{e}	95.070^{h}	460.68^{b}	208.620^{f}	357.920^{c}	485.920^{a}	-
	CV (%)	-	-	-	-	0.000	-	-	-	-
	LSD(p≤0.05)	-	-	-	-	0.000	-	-	-	0.000
	Dry season	28.663	59.256	31.420	23.151	20.303	156.730	134.498	48.140	25.815^{a}
	Wet season	27.745	24.437	188.150	34.359	71.107	37.667	37.667	61.094	54.479^{b}
Nitrates	Mean sites	28.204^{g}	41.893^{e}	109.785^{a}	28.755^{b}	45.751^{d}	97.198^{f}	86.082^{c}	54.663^{h}	-
	CV (%)	-	-	-	-	0.000	-	-	-	-
	LSD(p≤0.05)	-	-	-	-	0.000	-	-	-	0.004
	Dry season	2.520	2.210	17.060	14.640	5.240	2.810	4.030	1.610	6.270^{a}
	Wet season	3.740	7.740	4.100	4.100	6.650	5.930	8.470	3.740	5.560^{b}
Nitrites	Mean sites	3.130^{g}	4.980^{e}	10.580^{a}	9.370^{b}	5.950^{d}	4.370^{f}	6.250^{c}	2.680^{h}	-
	CV (%)	-	-	-	-	0.158	-	-	-	-
	LSD(p≤0.05)	-	-	-	-	0.011	-	-	-	0.006

*Means with the same letters are not significantly (p≤0.05) different.

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Full Length Research Paper

Influence of land use practices on water physicochemical parameters and nutrients loading along the Mara River of East Africa

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Mara River originates from the Mau Forest and traverses through landscapes with varying activities. Over the years, Mara River Basin has witnessed population increase, accompanied with conversion of forestlands into agricultural farms, human settlements, industrial and tourist activities and development of urban centres. Land uses along riverine areas have influence on water quality and may affect health of surrounding ecosystems. The objective of this study was to investigate the influence of land use activities on the river water quality using samples collected along the river. A spring within the Mau Forest (Ainabsabet spring) and a stream emanating from forested land draining into the river after the mine site were controls. The samples were analyzed for water physicochemical parameters, which registered the following ranges of results; water pH (5.23 ± 0.01 to 8.04 ± 0.01), temperature (11.5 ± 0.06 to 23.73 ± 0.06°C), turbidity (65.77 ± 21.58 to 369.47 ± 15.69 NTU), dissolved oxygen (6.14 ± 1.55 to 8.18 ± 0.03 mg/l), total dissolved solids (45.22 ± 0.65 to 308.33 ± 2.08 mg/l), total soluble solids (6.33 ± 2.31 to 110.56 ± 1.50 mg/l), electrical conductivity (34.32 ± 0.45 to 252.00 ± 5.57 µS/cm), water nutrient loads; total nitrogen derivatives (223.57 ± 2.22 to 1630 ± 96.56 µg/l), total phosphates (42.32 ± 0.34 to 681.23 ± 68.8 µg/l) and silicates (up to 65.77 ± 0.65mg/l). Levels of most parameters increased ($p \leq 0.05$) downstream the river. Emarti site, close to large-scale maize farms, registered highest nutrient levels. Water from livestock and wildlife grazing areas (Tarime sites) that had gullies and bare soils, registered the highest levels of total soluble solids. The Kirumi wetland reduced ($p \leq 0.05$) nutrients concentrations entering Lake Victoria. Although land uses along the river contribute to nutrients loading into the water system, nutrient levels were within acceptable limits. There is need to conserve and protect the wetland and control activities along the Mara River, to mitigate future contamination of the Mara River which would pollute the Lake Victoria water.

Key words: Mara River basin, land use, water physicochemical parameters, nutrients loading.

INTRODUCTION

Increase in human settlement, agricultural activities, urban and industrial development in former forest lands cause a decline in water quality and ecological health of ecosystems (Johnson et al., 2001). The rise in human populations increases diversity of their activities in fragile areas, which within river basins often reduce the river water quality (Hawkins et al., 1993). Major water pollution problems from agriculture have been reported in developed countries as, arising from intensified farming systems and use of agrochemicals (FAO, 1994). The increasing climatic stresses in developing countries also have led to changes in land use (Olesen and Bindi, 2002; Foley et al., 2005). These activities are being extended to developing countries. In East Africa, land use changes due to rapid urbanization and forests clearing to create room for agriculture and human settlement are the major stressors of streams and rivers (Kobingi et al., 2009). Water physicochemical parameters that is, water pH, temperature, dissolved oxygen (DO), turbidity, total suspended solids (TSS), total dissolved solids (TDS), water electrical conductivity (EC), concentrations of nitrates, nitrites, ammonium nitrogen, total nitrogen (TN), soluble reactive phosphorous (SRP) and total phosphorous (TP) are useful snapshots in evaluating water quality (APHA, 1980). The water bodies are home of different biodiversity which have optimal conditions that favour their existence (Ward and Tockner, 2001; Cardinale, 2011). Therefore adverse changes in ecosystem composition may lead to serious threats to biota (Dallas and Day, 2004). The evaluations of these parameters are necessary in water quality assessment.

The Mara River that forms the upper part of the Nile Basin is considered as one of the pristine rivers draining into Lake Victoria (Mati et al., 2005). Over recent years, the Mara River basin has undergone major land use/cover changes (Mango et al., 2010). The Mau Forests with savannah grasslands which used to be the sources of Mara River have been converted to human settlement and agricultural plantations such as Nyayo Tea Zones (Awiti et al., 2001). Other activities within the river basin include forestry, livestock keeping, fisheries, tourism, urban centres development, conservation areas and mining activities (Mango et al., 2010; Nyairo et al., 2015; Owuor et al., 2017). These activities decrease the environmental quality of the adjacent riverine lands as reservoirs, making them susceptible to pollution (Nyairo et al., 2015; Owuor et al., 2017). The Mara River water quality parameters were evaluated, to determine the need for policy intervention measures on livelihoods activities, in the area to mitigate water pollution and sustain aquatic ecosystem in the river and Lake Victoria.

MATERIAL AND METHODS

This study was conducted along Mara River, between longitudes 33°47'E and 35°47'E and latitudes 0°38'S and 1°52'S (Figure 1). The altitude of the basin ranges from 2,932 m above mean sea level (amsl) around Mau Escarpment to 1,134 m amsl around Lake Victoria. Water samples were collected in different areas along the Mara River (Table 1). The upstream of Ainabsabet Spring, within the Mau Forest, having least anthropogenic activities within its vicinity was used as control site 1. The Nyahenda stream emanating from forested land and draining into the river after the mine site was used as control site 2. Sampling points were selected based on dominant land use activities within the areas, accessibility and safety of the area (part of the area had wildlife on land or hippopotamus in the river).

Grab samples of surface water, were collected in three replicates of about 10 meters apart, along the Mara River area at each sampling site, using a clean beaker. The beaker was rinsed with the river water prior to each sample collection. Each sample was transferred into 500 ml plastic bottle, containing 0.2 g of $HgCl_2$ a preserving agent, and stored in an icebox before being transported to laboratory for analysis.

The water pH, temperature, turbidity, dissolved oxygen, and electrical conductivity were measured *in-situ* using a multi parameter-water quality meter (WQC-24-TOACOK). The total dissolved solids and total soluble solids were determined according to standard methods (APHA, 1989). For each sample, 20 ml was drawn and filtered through 0.45 μm GF/C filter paper using a filtering apparatus (Suction Pump P18990). The collecting beakers and filter papers had been dried in the oven at 90°C for 24 h and cooled to room temperature in desiccators and their weights were recorded before use. The collected residues were dried in the oven at 90°C for 8 h while the filtrate in the beaker were evaporated to dryness at the same temperature, then cooled in desiccators to room temperature before weighing.

TDS was calculated as:

$$(((B+S)-B) \times 1000 \times 1000) \div 20 \text{ ml}$$

Where B = weight of beaker (gm), S = weight of sample (gm)

TSS was calculated as:

$$((F+R)-F) \times 1000 \times 1000 \div 20 \text{ ml}$$

Where F= weight of filter (gm), R=weight of residue (gm).

Chemical analysis

Ammonium-nitrogen was determined by the indophenol blue photometric method (Koroleff, 1996). Accurately 17.5 g of phenol and 0.2 g of sodium nitroprusside were dissolved in Millipore milli Q water to a final volume of 500 ml (Reagent 1). Trisodiumcitrate-dihydrate (140 g) and 11 g of sodium hydroxide were dissolved in 300 ml of Millipore milli Q water. After complete dissolution, 20 ml of sodium hypochlorite was added followed by distilled water to a final volume of 500 ml (Reagent 2). Exactly 3 ml each of reagents 1 and 2 were added to 50 ml water, with vigorous shaking following addition of each reagent. Samples were then kept at room temperature for 24 h thereafter subjected to spectroscopic reading and the absorbance was read at 630 nm using a Genesys10s

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#Posthumous

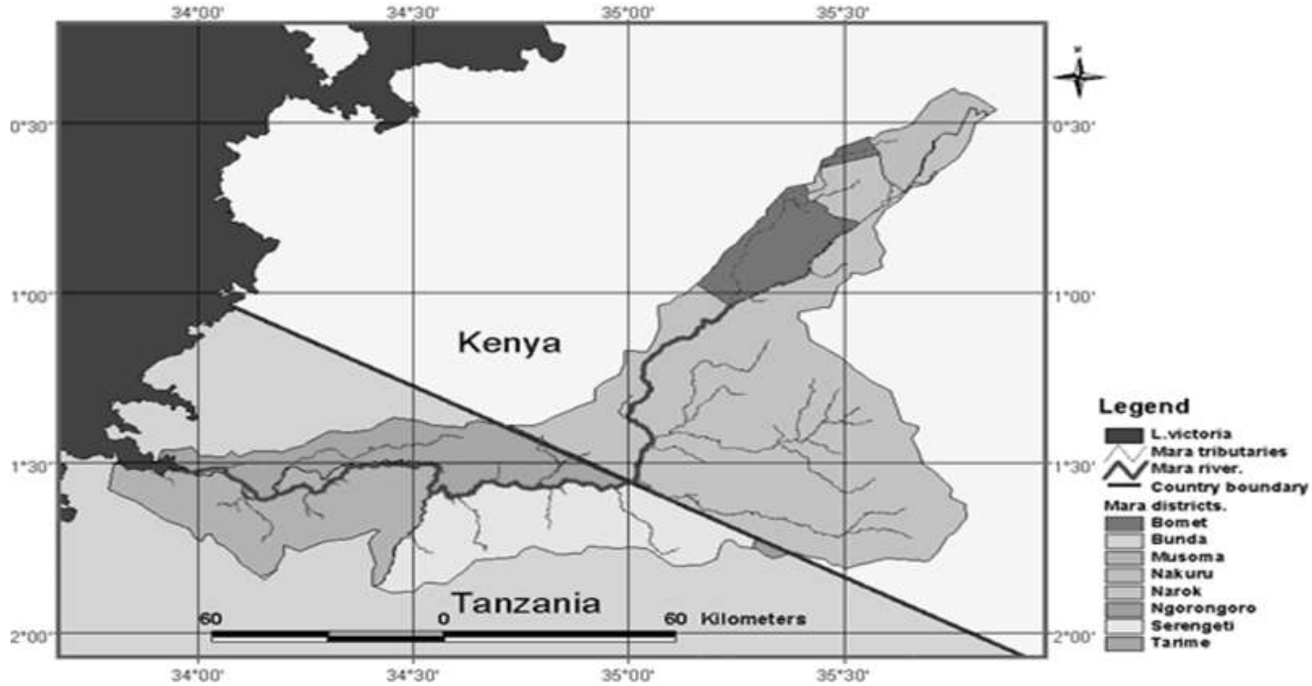

Figure 1. Map of the Mara River Basin (http://nowater-nolife.org/watersheds/Mara/Map .Accessed on 25th June 2013).

UV-Vis Spectrophotometer. The concentration of ammonium nitrogen was quantified using calibration curve prepared from a sub stock solution of 10 mg NH_4-N from anhydrous ammonium chloride (NH_4Cl) (Analar (AR)).

The levels of nitrite, nitrate and total nitrogen were determined using standard methods (Wetzel, 1991). For nitrites, 25 ml of each filtered water sample was added with 1 ml of sulphanilamide followed by vigorous shaking and standing for 5 min, before addition of further 1 ml N-I-napthylethylene diamine dihydrochloride. Absorbance of the solutions was then read against distilled water as a blank at 543 nm using a Genesys 10s UV-Vis Spectrophotometer. Nitrite concentration was quantified using a calibration curve prepared from a sub stock solution of 1000 µg NO_3-N/l from potassium nitrate (Analar).

Nitrates levels were determined as nitrites by, first passing the water sample through a copper cadmium column to reduce the nitrates to nitrites (Wetzel, 1991). The first 25 ml of each sample were discarded and the final 25 ml was analyzed as described for nitrite determination. The levels of total nitrogen (TN) were determined using the unfiltered sample which involved the addition of sulphanilamide and N-1-napthylethylene diamine dihydrochloride (Wetzel, 1991). The samples were digested for 3 h in an autoclave steam sterilizer at 93 to 120°C, using Electric Model no.25x. The samples were allowed to cool, and then passed through copper cadmium column and the absorbance read as described in the nitrite analysis.

Soluble reactive phosphorus (SRP) was determined by the ascorbic acid reduction method (Murphy and Riley, 1962). A mixed reagent of ammonium molybdate, sulphuric acid, ascorbic acid and potassium antimonyl titrate in the ratio of 2:4:2:1 respectively was prepared. Unfiltered samples (50 ml) was added to 5 ml mixed reagent and within 3 h, the extinction of the solutions were measured using a Genesys 10s UV-Vis spectrophotometer at a wavelength of 885 nm. The soluble reactive phosphorous concentration was quantified using calibration curve prepared from a sub stock solution of 1mg PO_4^-P/l which was prepared from potassium dihydrogen phosphate (KH_2PO_4) (Analar (AR). Total phosphorous was determined using the ascorbic acid reduction method (Murphy and Riley, 1962). Unfiltered samples (50 ml) was added to 5 ml of the mixed reagent, followed by digestion in an autoclave pressure steam sterilizer at 90 to 120°C of Electric Model no.25x for 2 h. The solutions were allowed to cool and absorbance read at 885 nm (Genesys 10s UV-Vis Spectrophotometer). The levels were quantified using a calibration curve from a sub stock solution of potassium dihydrogen phosphate (KH2PO4).

Silicates were analyzed according to a standard procedure (Wetzel, 1991). Each filtered sample (25 ml) was added to 5 ml of 0.25 M HCl, followed by swirling, 5 ml of 5% ammonium molybdate was then added with further swirling, thereafter 5 ml of 1% disodium EDTA was added followed by vigorous swirling. After 5 minutes, 10 ml of 17% sodium sulphite was added in each sample solution and these were allowed to stand for 30 min. The sample solutions were introduced to Genesy 10s UV-Vis spectrophotometer and the absorbance read at 700 nm. The silicates concentrations were quantified using calibration curve from a stock solution of 100mg SiO_2/l prepared from (AR) sodium hexafluorosilicate (Na_2SiF_6) (Analar (AR).

Data analysis

The data were subjected to a one-way analysis of variance using Statistical Analysis System (SAS) version 9.2 SAS Inc, 2002. The standard deviations were calculated using Microsoft excel programme.

RESULTS AND DISCUSSIONS

The results from 10 sites along Mara River Basin are presented in Tables 2 and 3. The World Health

Table 1. Sample sites, sampling coordinates land use and riverside characteristics.

Name	Sampling coordinates		Land use and riverside characteristics within the sampling site
Ainabsabet	0.658°S	35.544°E	Dense forested tress, thick grasslands and shrubs
Emarti site	1.043 °S	35.240°E	Large scale wheat and maize farming
Ngerende 1	1.109°S	35.166°E	Wildlife conservation-pools of hippopotamus upstream of the sampling point, isolated shrubs and trees within the river bank
Ngerende 2	1.137°S	35.142°E	Wildlife conservation- tourist lodges (Ngerende Campsites), game animals (Zebras, Gazelle, Hippos, Crocodiles, buffalos).
Old Mara Bridge	1.246°S	35.032°E	Isolated pockets of tall grasses, wildlife browsers and livestock (Maasai cattle and sheep).
New Mara Bridge	1.529°S	35.021°E	Wildlife Conservation, evidence of intense browsing. Presence of trenches and gullies used as paths by game animals assessing drinking water points
Tarime before mines	1.616°S	34.531°E	Pockets of human settlement, livestock, human domestic activities, excavated heaps of soils neighbouring the mining industries.
After mine	1.510°S	34.465°E	Sand harvesting, human settlement, small scale maize and banana farming
Nyahenda stream	1.476°S	34.414°E	It's a stream of clear water draining into the main Mara River. Emanating from a small forested land upstream, thick grasslands/shrubs.
Kirumi wetland	1.493°S	34.258°E	Fishing activities, pockets of human settlement, the water mass covered by aquatic vegetation(wetland)

Organization (WHO, 2004) and National Environmental Management Agency (NEMA, 2006) standards for comparison are presented in Tables 4 and 5, respectively. The water pH at Ainabsabet Spring (Control Site 1) was 5.4 ± 0.01 while in areas after the Tarime mine site was 8.04 ± 0.01. The result shows there was a significant ($p \leq 0.05$) increase of pH downstream. Abundance of organic acids due to natural decomposition of organic matter tends to increase water acidity (Chapman, 1996; Watanabe et al., 2006; Reuss and Johnson, 2012). The low pH at Ainabsabet Spring might be a result of no human habitation or anthropogenic activity hence attributed to the abundance of decomposition of leaves, twigs and natural weathering processes due to high rainfall in the site.

The areas adjacent to Tarime Mine site recorded the highest pH compared to all sites in the study area. Similar, high pH adjacent to to mining site had been observed in Western United States where, use of cyanide in leaching gold ores contributed significantly to the increase of water pH (Vladmir and Robert, 2006). Despite the observed increase, all sites in the study area along the river registered pH levels that were within the standard limits surface water of 6.5 to 9.2 (WHO., 2011) and 6.5 to 8.5 (NEMA., 2006). The pH results of this study were within the same range with another studies whereby the results from Mara River water ranged between 4.8 and 7.6 (Glows, 2005) and that of Mara River tributaries ranged from 5.7 to 7.4 (Nyairo et al., 2015).

The dissolved oxygen (DO) concentration along the Mara River water ranged from 6.14 ± 1.55 mg/l at the wetland to 7.94 ± 0.01 mg/l before the mine and 7.56 ± 0.10 mg/l after the mine site (Table 4). Nyahenda Stream (Control Site 2) which was off the main river registered DO level of 8.18 ± 0.03 mg/l. The data from this site of unpolluted water was not used to evaluate the land use effects, but to determine changes in water quality downstream entering the main river. Cold flowing water generally has more oxygen with many particles of moderate plants compared to stagnant and slow flowing water (Wetzel, 1983). At Ainabsabet Spring (control site 1), the water was slow flowing with pockets of natural decaying vegetative matter on the surface. This caused an increase in oxygen demand by decomposer species and possibly leading to the observed decrease of dissolved oxygen. However, the decrease was within acceptable standard limits (WHO., 2011, Williamson et al., 1998). In an earlier study, the DO levels ranged from 0.49 mg/l before draining into the Kirumi wetland to 7.35 mg/l at the Mara mines sites (Glows, 2005). With exception of the wetland, all the DO levels were above the recommended guideline set by the

Table 2. *In-situ* water physicochemical parameters at different sites along the Mara River.

Names	pH	DO (mg/l)	EC (µS/cm)	Turbidity (NTU)	Temperature (°C)
Ainabsabet Spring	5.23±0.01	6.45±0.01	34.32±0.45	98.45±1.15	11.53±0.06
Emarti site	7.48±0.01	7.28±0.05	67.00±0.01	160.37±29.21	18.83±0.15
Ngerende 1	7.53±0.06	7.62±0.38	66.30±5.03	143.17±48.97	19.73±0.32
Ngerende 2	7.56±0.02	7.53±0.09	65.00±2.65	109.87±1.86	19.70±0.1
Old Mara	7.47±0.01	7.28 ±0.05	67.00±0.01	176.20±28.19	18.83±0.06
New Mara	7.27±0.01	6.92±0.15	81.00±3.60	280.97±2.54	23.73±0.06
Before mine	7.75±0.01	7.94±0.01	108.00±6.08	364.17±29.56	23.50±0.29
After mine	8.04±0.01	7.56±0.10	112.00±3.0	369.47±15.69	23.03±0.15
Nyahenda Stream	7.47±0.06	8.18±0.03	42.33±0.6	90.55±0.90	18.07±0.12
Kirumi(Wetlands)	7.58±0.12	6.14±1.55	252.00±5.57	65.77±21.58	23.26±0.13
CV (%)	0.68	6.98	3.91	12.61	0.73
LSD, (p ≤ 0.05)	0.08	0.87	5.97	39.92	0.25

SE = Standard error.

Table 3. Total dissolved solids and total suspended solids in water at different sites, along the Mara River.

Site name	TDS(mg/l)	TSS(mg/l)
Ainabsabet Spring. (Control Site1)	45.22 ±0.65	9.22±0.13
Emarti site	129.33 ± 4.04	6.33±2.31
Ngerende 1	183.33 ± 4.93	41.67±1.15
Ngerende 2	180.68 ±1.15	42.00±2
Old Mara bridge	183.68 ±1.15	73.33±2.89
New Mara bridge	106.67 ±10.4	11.67±2.89
Tarime-(Before Mines)	193.24 ± 0.17	107.33±0.19
Tarime-(After Mines)	221.33 ±12.66	110.56±1.50
Nyahenda Stream(Control Site 2)	59.00±1	9.33 ±1.15
Kirumi(Wetlands)	308.33±2.08	24.67±1.53
CV (%)	3.50	4.18
LSD (P≤0.05)	9.60	3.11

SE= standard error.

Tanzania Government for surface water, suitable for fisheries and domestic use of 6 mg/l (Bitala, 2008). But the levels were within acceptable standards and guidelines (NEMA, 2006, WHO, 2011), demonstrating sustainability of dissolved oxygen concentration in Mara River. The DO levels at the wetland were slightly above 6 mg/l. The low level could be due to the biological activities taking placewithin the wetland (Wetzel, 1983, Gagnon et al., 2007, Kadlec and Reddy, 2001).

The electrical conductivity of water along the Mara River ranged from 34.32 ± 0.45 to 252.00 ± 5.57 µS/cm (Table 2). There was significant ($p \leq 0.05$) increase of electrical conductivity downstream of Ainabsabet Spring water (control site 1). Nyahenda Stream water (control site 2) showed a significant ($p \leq 0.05$) low electrical conductivity. Farm inputs that avail ions into surface water are primary causes of increased electrical conductivity within agricultural lands (Williamson, 2001). The high electrical conductivity registered at Emarti site might have resulted from farm inputs via surface runoff and leaching into the river. Livestock herding that was evident before the mining site also contributed to soil erosion, enhancing the ionic inputs into the water. Mining operations accelerate the chemical oxidation processes of the earth crust, releasing acids, metals and sulphates into surface and ground water (Lupankwa et al., 2004). Along the Mara River, the most significant input of ions was the mining activities as demonstrated by higher conductivity registered downstream the mine site. All the electrical conductivity levels were within acceptable standard limits of 400µS/cm in surface water (WHO, 2011). The anthropogenic activities within the Mara River basin were therefore not releasing excessive ions into the river water system.

Table 4. National Environment Management Authority (NEMA)-permissible quality standard limits for domestic and surface water.

Parameter	Domestic water	Surface water
pH (Fresh water)	6.5 - 8.5	6.5-8.5
pH in Marine waters	No set guideline	5.0 -9.0
Dissolved oxygen	Above 6 mg/l	Above 6 mg/l
Total Suspended solids	30 mg/l	30 mg/l
Total Dissolved Solids	1200 mg/l	1200 mg/l
Ec (water conductivity)	No set guideline	400 µS/cm
Turbidity	Below 10NTU	300 NTU
Nitrate (NO_{3-})	10 mg/l	10 mg/l
Ammoniacal- N (NH^{4+}-)	0.5 mg/l	0.5 mg/l
Nitrite (NO_{2-})	3 mg/l	3 mg/l
Dissolved Iron	0.3 mg/l	10 mg/l

(NEMA., 2006).

Table 5. World Health Organization (WHO)-permissible quality standard limits for domestic and surface water.

Parameter	Domestic water	Surface water
pH (Fresh water)	Below 8.0	6.5-9.2
pH in Marine waters	No set guideline	5.0 -9.0
Dissolved oxygen	No set guide	Above 6 mg/l
Total Suspended solids	5 mg/L	30 mg/l
Total Dissolved Solids	500 mg/l	1200 mg/l
Ec (water conductivity)	No set guideline	400 µS/cm
Turbidity	10NTU	300 NTU
Nitrate (NO_3^-)	3 mg/l	10 mg/l
Ammoniacal- N (NH^{4+}-)	No set guideline	Below 0.2 mg/l
Nitrite (NO_2^-)	0.05 mg/l	0.05-0.01 mg/l
Silicates	No set guide	100 mg/l.

(WHO, 1984; WHO, 1996; WHO, 2004; WHO, 2011).

Water turbidity along the Mara River ranged from 65.77 ± 21.58 NTU at Kirumi wetland to 369.47 ± 15.69 NTU after the gold mine site (Table 2). Apart from Kirumi wetland, all sites sampled registered higher turbidity ($p \leq 0.05$) compared to Ainabsabet Spring (control site 1). Normally, high turbidity results are from surface runoffs and from both non-point and point sources. The poor soil conservation practice is one entry source of sediment loads into surface water (Bugenyi and Balirwa, 2003). The increase in turbidity downstream along the Mara River might be a result of sediment loading resulting from diversified land use practices. The mining activities were major contributors of turbidity along Mara River, but other contributors included land tillage from agricultural farms, livestock herding and wildlife descending to drinking water points. The Ngerende sites showed a predominant land use of game conservancy with higher water turbidity. The turbidity levels after the mine site exceeded the standard limits of 10 NTU for drinking water and 300 NTU for domestic use and some aquatic life forms (WHO., 2011). This higher level of turbidity than accepted level might pose health risk to consumers of water. The Kirumi wetland and downstream, showed a reduced turbidity to acceptable level, before water was discharged into Lake Victoria. The water temperature of Mara River ranged between 11.53 ± 0.06°C to 23.73 ± 0.06°C (Table 2). All sites recorded significantly ($p\leq0.05$) higher temperatures than Ainabsabet Spring (control site 1). The temperatures in all sites in the study were below NEMA upper limit of 35°C for natural surface water (NEMA, 2006).

Ainabsabet Spring (control site 1) registered the lowest TDS (45.22 ± 0.65 mg/l) level closely followed by Nyahenda Stream (control site 2) (59.00 ± 1mg/l) (Table 3). Low total dissolved solids are often characteristic of forested rivers (Chapman and Chapman, 2003). Both control sites were emanating from forested riverbanks, which probably filtered dissolved solids before discharging to downstream. All sites sampled had higher ($p \leq 0.05$) TDS than control sites. The Kirumi wetland site recorded the highest level of TDS (308.33 ± 2.08 mg/l). The increased TDS levels downstream might be a result of soluble salts from land use practices such as agricultural and mining activities, and vegetative destruction due to over grazing. The wetlands usually have high TDS retention (Tanner et al., 1998). These activities enhance availability and entry of salts through surface runoff and leaching into the river. The pattern was similar to that of electrical conductivity. Despite the observed increase of TDS in Kirumu wetland, the values were within acceptable limit of 1200 mg/l (WHO., 2011), thus may not have considerable effects on water quality to the Mara River water users.

The highest TSS level of 110 ± 1.50 mg/l was recorded from streams passing through the mining site while the lowest TSS level of 6.33 ± 2.31 mg/l recorded around Emarti site which had large wheat and maize farming within its vicinity (Table 3). The large-scale wheat and maize farming around Emarti site area were therefore not contributing to the influx of TSS. The levels of TSS at Emarti site were not significantly different from that at Ainabsabet Spring (control site 1) which was recorded to be 9.22 ± 0.13 mg/l. Insufficient soil conservation practices in agricultural regions increase TSS values (Nightingale and Bianchi, 1980; Bugenyi and Balirwa, 2003).

The soil conservation practices in the study area were adequate to contain the TSS at low levels in the water. Increase in TSS levels along the Mara River was higher in mining sites than agricultural areas. The Mara River water recorded high level of TSS exceeding the 5 mg/l permissible limits (WHO., 2011) while Kirumi wetland recorded TSS level of 24.67 ± 1.53 mg/l before the water drained into Lake Victoria which was below the 30 mg/l permissible limit (NEMA., 2006).

The dominant derivatives of the inorganic nitrogen along the Mara River was the nitrate nitrogen (NO_3^--N) followed by the ammonium nitrogen (NH_4^+-N) and then the nitrite nitrogen (NO_2^--N). The highest NO_3^--N level of 243.65 ± 5.26 µg/l was at Emarti site, which was the nearest site to large-scale agricultural plantations. The farming activities might be the main source of these nutrients. Similar result had been observed on the lower portion of the Mara River in Tanzania where high concentrations of NO_3^- and $P0_4^3$ were originating from the nearby agricultural soils (Kihampa and Wenaty, 2013). Within the Nyando River Basin of Kenya, agricultural land use was the major contributing factor in variations of water quality particularly the nutrients levels (Raburu et al., 2002).

Livestock and wildlife animals increased nitrates levels in adjacent waters (McCartney, 2010). Similar rise in the inorganic derivatives was registered at the Ngerende Site, which was near the section inhabited by hippopotamus and crocodiles. Aquatic vegetation utilizes phosphate and nitrates as nutrients thereby lowering their concentrations in ecosystem (Belke, 2007). This explained the observed low levels of nitrates (3.16 ± 0.20 µg/l) and soluble reactive phosphates (5.53 ± 1.22 µg/l) at Karimi wetland. All the nutrients levels (Tables 4 and 5) in the Mara River water were within acceptable limits with permissible level of total nitrogen of 19 mg/l (NEMA, 2006; WHO, 2011).

SRP and total phosphorous (TP) levels are presented in Table 6. The SRP levels were highest around the Ngerende sites, which were inhabited by a pool of hippopotamus and crocodiles upstream during the sampling period. A previous study (McCartney, 2010), recorded high SRP levels along the Mara River at the New Mara Bridge. This was attributed to the presence of large herds and livestock wastes within the area. Other than the natural phosphate, human and animal excreta are some of the most important sources of phosphate inputs into surface water (Golterman, 1993). Along the Mara River, both wildlife animals and livestock were sources of nutrient loadings particularly phosphorous in water. However the total phosphorous levels in surface water fell within the permissible WHO limit of 10 mg/l (WHO, 1984).

All sites along the Mara River recorded an increase of silicates from the control sites, while the Kirumi wetland site recorded highest concentrations (Table 6). Studies elsewhere show that mining activities and dust were inseparable and the main dust component was silica (Ogola et al., 2001). The increase in silicates levels downstream mining sites were attributed to the mining activities. Vegetative destruction due to mining activities, which result in heaps of sandy soil within the mining sites, accelerates routes of silica dust into the Mara River water. The silicates levels in Kirumi wetland water were above the standard limits of 1 to 30 mg/l in surface water. Therefore, Mara River can be noted as one of the sources of silicate pollution in Lake Victoria. However the silicate concentration in the Mara River water was within acceptable limit of 100 mg/l in surface water (WHO., 2011). The Kirumi wetland reduced ($p \leq 0.05$) all the nutrients concentrations other than the silicates. The wetland is therefore a purification site used in reducing and controlling pollutants nutrients from entering Lake Victoria.

Conclusion

The anthropogenic activities in and around the Mara River Basin have been changing the physiochemical parameters of the river. Despite the changes of water quality, the levels of the physiochemical properties recorded were within acceptable quality standards (NEMA, 2006; WHO, 2011).The Kirumi wetland reduces the nutrients levels hence mitigating pollutant loads from upstream from entering into Lake Victoria. The anthropogenic activities within the Mara River basin

Table 6. Nutrients concentrations in water at different sites along the Mara River.

Site name	Silicates (mg/l)	NO_3^- (µg/l)	NO_2^- (µg/l)	$NH4^+$(µg/)l	SRP (µg/l)	TN (µg/l)	*TP (µg/l)*
Ainabsabet Spring (Control Site 1)	Nd	111.97±1.50	3.20 ±0.1	56.57 ±0.91	32.95 ±1.37	923.24 ±5.77	52.00 ±0.01
Emarti Site	29.50± 1.70	243.65±5.26	15.58±3.96	15.26 ±4.18	78.40 ±1.48	1515.67±7.63	581.00±25.35
Ngerende 1	30.00± 0.00	142.97±2.17	32.03±1.05	30.33 ±0.58	122.68±0.58	1209.33±3.06	479.33±15.14
Ngerende 2	30.33± 0.58	141.73±2.06	33.06±0.96	30.43 ±0.81	123.33±0.58	1206.33±1.53	483.67±4.72
Old Mara Bridge	29.02± 2.89	149.14±6.49	30.50±0.81	31.95 ±1.92	79.46 ±1.94	1309.33±61.85	681.23±68.8
New Mara Bridge	28.83± 1.31	145.36±3.11	13.83±2.81	15.48 ±2.68	69.10 ±1.73	1630.00±96.56	373.47±8.66
Tarime (Before Mines)	26.08± 0.10	41.41 ±2.05	21.73±6.35	24.23 ±1.97	46.38 ±2.28	1285.13±4.39	456.00±2
Tarime(After Mines)	32.50± 3.83	8.08 ±2.35	8.07 ±1.79	13.15 ±0.27	17.78 ±2.92	1093.40±24.48	505.33±3.05
Nyahenda Stream (Control Site 2)	21.47± 0.33	5.37 ±0.30	0.10 ±0.01	5.73 ±0.46	6.13 ±0.42	223.57 ±2.22	42.32 ±0.34
Kirumi(Wetlands)	65.80± 0.65	3.16 ±0.20	0.37 ±0.46	8.18 ±0.57	5.53 ±1.22	442.07 ±5.25	95.19 ±2.50
CV (%)	5.76	3.19	16.70	8.06	2.82	4.70	6.38
LSD (p≤0.05)	2.88	5.39	4.51	3.17	2.78	86.69	40.76

Nd = not detected, SE = Standard error.

needed to be control with appropriate policy strategies to mitigate water pollution in future. In addition, the Mara River water quality needs periodical monitoring and evaluation, to determine any possible adverse increase of physiochemical downstream. The Mara River basin should have land use planning and strategies to discourage inhabitants from land tilling, up to the banks of the river in order to conserve the bank vegetation to reduce erosion and sediment loading in the Mara River. The Kirumi wetland should be conserved and integrate the wise use aspect, due to its significance in the reducing of nutrients concentration entering the Lake Victoria.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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Perception and mitigation preferences on climate change among residents of Nairobi City County

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As result of compounding factors related to environmental, social, economic and political pressures, it is feared that the impacts of climate change and variability may overwhelm resilience of urban systems in developing countries if adaptation and mitigation strategies are not strengthened. Understanding how the urban residents perceive and respond to climate change is necessary for the purpose of formulating informed adaptation and mitigation strategies. This study was designed to assess the level of awareness, knowledge, attitude and mitigation preferences among residents of Nairobi City County. A cross-sectional survey design was adopted where 404 households were selected through random sampling from different administrative villages in Nairobi city. Though majority of the respondents had heard about climate change before, a knowledge gap in understanding specific issues of climate change in cities was evident. Study respondents had a greater understanding of climate change signs and effects that are directly related to weather patterns such as changes in temperatures and rainfall patterns compared to the more complex and indirect environmental issues related to climate change in cities. A similar behavior was observed in the choice and preference for long term climate management strategies. Educational status emerged as top social demographic attribute that influenced respondents' level of awareness, knowledge, worry and concern towards climate change in cities. In order to build resilience to climate change effects for urban communities, these critical factors must be considered when developing or reviewing policies and programs, and the study suggests for more public awareness programs to boost understanding of these factors among residents of Nairobi.

Key words: Climate change, cross-sectional survey, knowledge, mitigation, preferences and resilience.

INTRODUCTION

The debate on climate change has been surrounded by a lot of controversies though the evidence presented in the Fourth Assessment Report of IPCC suggest that climate change is experienced all over the world and the

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influence of anthropogenic activities are very significant (IPCC, 2001; Sheppard, 2005; IPCC, 2007; OECD, 2010; Grover, 2011; Falaye and Okwilagwe, 2016).

Climate change may potentially damage every natural and human resource on earth (Garnaut et al., 2008) and the third world countries are most affected by the climate change as they have low-level response strategies to climate change (Ashraf and Wahaband, 2006; Feiden, 2011). Gleeson (2008) and Govindarajulu (2014) argued that urban systems are a constantly evolving spatial product of the flow of the social-economic, infrastructural and ecosystem systems and as a result they are seen as the key drivers of climate change and; while being principle emitters of greenhouse gases (GHGs), cities are the most vulnerable to the impacts of climate change (Dreyfus, 2013; Govindarajulu, 2014). The poor in developing nations will be more vulnerable as they tend to live in informal settlements that are more exposed to the ravages of extreme weather patterns (Feiden, 2011).

Mitigation and adaptation strategists are the only solutions to build resilience to climate change impacts in cities (Sheppard, 2005; IPCC, 2007; Semenza et al., 2008; OECD, 2010; Sheppard, 2005 and Mathews, 2011). Perception is the process by which individuals receive stimuli or information from the environment and modify it into psychological awareness (Vedwan and Rhoades, 2001). Notably, people often act based on their perception and as so studying people's perception is critical component of socio-political contexts within which policymakers in cities operate (Leiserowitz, 2006; Yu et al*.,* 2013; Crona et al., 2013). Public support or opposition of climate change policies and strategies that include treaties, regulations, taxes, subsidies among others will be influenced significantly by how people perceive the dangers and risks of climate change (Leiserowitz and Pidgeon, 2006).

Climate change awareness in African is poor as many people are poorly informed about climate change (Godfrey et al., 2009; Tadera, 2010; Barimah, Kwadwo and David, 2015) compared to developed countries where studies have shown that people in these countries are likely to perceive climate change as a threat compared to people living the developing nations despite people living in these nations been more vulnerable to climate change impacts (Otieno et al., 2009). While the principles of public inclusion in Kenya are supported by various policies, legislation and initiatives such as the National Constitution of 2010, Environmental Management Coordination Act (EMCA)1999/2015, the National Climate Change Response Strategy (NCCRS) 2010, National Climate Change Action Plan (NCCAP) 2013 to 2017, and National Adaptation Plan (NAP) 2015 to 2030, which describe the actions to be taken by all players to adapt, mitigate and build climate change resilience, the status of climate change awareness among city resident's in Kenya is largely unknown (Otieno et al., 2009). On the contrary, many studies in Kenya have focused on assessing climate change perception of farmers and pastoral communities in various parts of the country (Adimo et al., 2012, 2016 Silvestri et al*.,* 2012; Ndambiri et al., 2013). Additionally, With the rapid urbanization currently taking place in most African cities (Hope, 1999; Chirisa, 2008), such as Nairobi city, it is important for city managers and policymakers to understand how urban residents experience climate change impacts and their responses in order help them provide informed strategies for building resilience to climate change in cities. This paper has therefore, examined household awareness, perception, and preference to long-term adaptation and mitigation strategies of climate change through cross-sectional approach among Nairobi city residents towards building policy framework and management options of climate change. Lastly, the paper has examined how different socio-demographic attributes such as gender, age, educational status and number of years lived in Nairobi could have influenced perception towards different climate issues in the city.

MATERIALS AND METHODS

Study area

The study was carried out in Nairobi the capital city of Kenya. Geographically, Nairobi extends between longitudes 36° 40' and 37° 10' E and latitudes 1° 09' and 1° 28' S, covering an area of about 689 km^2. The average altitude is approximately 1795 m above sea-level with a mean biannual rainfall of about 900 mm. The vegetation varies from grassland to scattered acacia trees in the east to remnants of hardwood forests in the higher areas to the west. Land use within the study area is divided roughly into urban use, agriculture, rangeland and remnants of tropical forests. Large areas of the forests, however, have been deforested as a result of both the agricultural and urban expansions. Nairobi City has a population of about four million people with population densities varying widely within the city. On average, Nairobi has a population density of 4, 515 people/km^2, though, population distribution differs significantly with low- income areas having high population density compared to high-income areas (Kenya National Bureau of Statistics, 2015).

Sampling and data collection procedures

The study targeted all the households in Nairobi City County. According to the 2009 population census, there were 985,016 households within a population of 3.5 million people in Nairobi (KNBS, 2009). According to 2009 KNBS population data, Nairobi city was stratified into four districts (strata); namely Nairobi West, Nairobi East, Nairobi North and Westland. From each stratum, systematic sampling was done to select administrative units (villages) where data was collected. Within the villages, simple random sampling was done to select households for questionnaires. The sample size was determined using Krejcie and Morgan formula and table (Krejcie and Morgan, 1970) and 404 participants were considered for the study while later 397 questionnaires considered for analysis as presented in Table 1. A response rate of 98.26% was considered adequate for this study as

Table 1. Sample size distribution.

S/N	Location (Strata)	Total population	Formula	No of questionnaires
1.	Nairobi West	212.295	$\frac{Total\ no\ households}{Total\ no.of\ households\ in\ Nairobi} * 404$	87
2.	Nairobi East	369.866	$\frac{Total\ no\ households}{Total\ no.of\ households\ in\ Nairobi} * 404$	152
3.	Nairobi North	327.428	$\frac{Total\ no\ households}{Total\ no.of\ households\ in\ Nairobi} * 404$	134
4.	Wetlands	75.427	$\frac{Total\ no\ households}{Total\ no.of\ households\ in\ Nairobi} * 404$	31
Total		985.016	404	

Table 2. Main themes of survey questionnaires.

Criterion	Groups of questionnaires survey	Type of response	Description and role
The demographic characteristics	Respondents personal information	Choice and open	To understand the social demographic characteristics of the respondents
Climate change knowledge	Have you heard or read about climate change	Choice (yes, no, I don't know)	To assess respondent's awareness
Climate change impacts	How well you understand climate change?	Likert scale (very well, fairly well, not very well, not at all)	To assess how respondents understand climate change in cities
	Climate change contributors in cities	Likert scale (high, moderate, not sure)	
	Signs of climate change in cities	Likert Scale (1-5)	
	Climate Change threat to personal health and safety	Likert scale rating	To assess how respondents relate climate change to life
Adaptation and mitigation strategies	Worry about climate change	Likert scale rating	To identify issues of concern to help formulate response strategies
	Concern about climate change	Likert scale rating	
	Agreement with policy and legislation statements	Likert scale rating	

it fell above the 75% response rate recommended by Kelley et al. (2003).

Initially, enumerators were trained on contents of the questionnaires tool including how to select households, how to approach the respondents and inform them the purpose of the survey and ethical issues related to the study including the provision of true information as well as seeking the consent of respondents before administering questionnaires to them. The data collection exercise started on July 15, 2018, to July 28, 2018, with pretesting of questionnaires with the enumerators after which arising issues were addressed. During the data collection exercise, the principal researcher ensured quality control of data collected by monitoring performance of data collectors and regular checks of data collected to evaluate completeness. These checks helped ensuring that no data was missing and to detect errors. It took five to seven minutes for the participants to answer the questionnaire and ensure that it truly reflected their immediate experience on climate change. The surveys were conducted on weekdays between 9 a.m. and 5 p.m. (Table 1).

The response format is as outlined in Table 2 with 8 detailed questions that gauged the respondents' awareness, knowledge and attitude on climate change in cities as well as their preference on different adaptation and mitigation plans The socio-demographic information about the respondents was also collected including their names, gender, age, educational status, number of years lived in Nairobi, location as well as their occupations. A set of questions assessed climate change awareness among respondents, sources of climate information, perceived causes of climate change, signs of climate change in their environment, concerns of respondents on climate change as well as perception on different policy statements drawn from different urban sectors (Table 2).

Statistical analysis

The researcher used computer-aided statistical packages to analyze data obtained from the study. Particularly, Statistical Package for Social Scientists (SPSS) series 24 was used for data

Table 3. Overall socio-demographic characteristics.

Characteristic	Category	Frequency	Percentage
Gender	Males	219	55.2
	Females	178	44.8
Age group	< 24	130	32.7
	25-34	125	31.5
	35-44	87	21.9
	45-54	36	9.1
	> 55	19	4.8
Educational status	Primary	42	10.6
	Secondary	139	35
	Tertiary	216	54.4
Years lived in Nairobi	< 5	127	32
	6-10	85	21.4
	11-15	40	10.1
	16-20	62	15.6
	> 20	83	20.9

analysis. Firstly, all completed questionnaire were investigated for completeness and consistency, then a numerical coding of qualitative responses was done for ease of storage and analysis. The numerical codes were entered into SPSS and analysis commands ran to test hypothesis on climate awareness, perception and preference to long-term mitigation strategies for climate change impacts. Data analysis involved both simple descriptive such as frequency counts, percentages, means and standard deviations to summarize the data and inferential statistics such as correlation analysis, chi- square, Kruskal and Mann-Whitney tests to determine statistical significance of respondents' social-demographic characteristics to major issues that were investigated in this study. The hypotheses were tested at statistical confidence level of 95%.

RESULTS AND DISCUSSION

Table 3 presents a result summary of the socio-demographic characteristics of respondent households. The sampled population consisted of 55.2% (n = 291) males and 44.8% (n= 178) female. Gender is a good predictor of climate change because different genders are affected by climate change differently and hence both groups could have different perspective on climate change issues (McCright, 2010). Majority of the respondents were below 24 years (32.7%) and between 25 to 34 years (31.5%) of age. Age is a critical predictor of respondent's familiarity with weather events and studies have shown a positive correlation between age and climate change familiarity (Saroar and Routray, 2010; Ochieng and Koske, 2013). Majority of the respondents (54.4%) had attained tertiary education (colleges and universities) followed by 35% of those had achieved secondary education. Educational status is seen as another major predictor of public knowledge and attitude. Studies on climate change have shown that people with high level of education were likely to be informed on climate change issues (Aquah, 2011; Adebayo et al., 2013). Majority (32%) of the residents had lived in Nairobi for less than 5 years followed by 21.4% for about 6 to 10 years. The number of year lived in a certain area could probably reflects individual's experience with climate change events in that area.

Level of awareness about climate change among respondents

As a guiding question on respondent's awareness, the first question sought to determine whether the respondent had heard about climate change previously. Results of this analysis revealed that majority (91.7%; n =364) of the respondents had heard about climate change while 7.8% (n= 31) had not heard about it as presented in Table 4.

The findings of this study support numerous studies that have been done in the past decades. For instance, a study conducted by Lorenzoni and Pidgeon (2006) to collect public views on climate change in Europe and USA found that public awareness had increased tremendously from 65% in early 1990's to over 72% in early 2000's. Thus, 91.7% awareness level among Nairobi residents could mean that the both international and local climate change awareness is on rise and more

Table 4. Climate change awareness among the respondents.

Response category	Frequency	Percentage
Heard about climate change	364	91.7
Never heard about Climate change	31	7.8
Don't Know whether they heard	2	0.5
Total	397	100.0

Table 5. Differences in climate change knowledge among different socio-demographic groups.

Social-demographic groups		Knowledge status		
		Yes (%)	No (%)	I don't know (%)
Gender	Male (n =219)	89.0 (195)	10.5 (23)	0.5 (1)
	Female (n =178)	94.9 (169)	4.5 (8)	0.9 (1)
	Chi-square		0.085	
Educational status	Primary (n =42)	78.6 (33)	21.4 (9)	0 (0)
	Secondary(n =139)	91.4 (127)	8.6 (12)	0 (0)
	Tertiary(n=216)	94.4 (204)	4.6 (10)	0.9 (2)
	Kruskal test		$\chi^2(2) = 11.384$, $p = 0.003$	
Age group	< 24 (n =130)	93.1 (121)	6.2 (8)	0.7 (1)
	25-34 (n =125)	89.6 (112)	10.4 (13)	0.0 (0)
	35-44 (n =87)	92.0 (80)	6.9 (6)	1.1 (1)
	45-54 (n = 36)	91.7 (33)	8.3 (3)	0.0 (0)
	> 55 (n = 19)	94.7 (18)	5.3 (1)	0.0 (0)
	Kruskal test		$\chi^2(4) = 1.232$, $p = 0.873$	
Number of Years lived in Nairobi	< 5 (n = 127)	89.8 (114)	8.7 (11)	1.6 (2)
	6-10 (n =85)	92.9 (79)	7.1 (6)	0.0 (0)
	11-15 (n =40)	90.0 (36)	10.0 (4)	0.0 (0)
	16-20 (n =62)	90.3 (56)	9.7 (6)	0.0 (0)
	> 20 (n =83)	95.(79)	4.8 (4)	0.0 (0)
	Kruskal test		$\chi^2(4) = 4.782$, $p = 0.31$	

people are becoming aware of climate change (Table 4). Table 5 presents a statistical summary showing the differences in climate change knowledge between different demographic groups.

A positive climate change awareness was found across all groups outlined in Table 5. There was no statistical differences in age group (χ^2 *(4) = 1.232, p* = 0.873) and the number of years some had lived in Nairobi (χ^2 (4) = 4.782, p = *0.31) and* level of climate change awareness. However, a statistical difference (χ^2 (2) = 11.384, p = 0.003) was found between the level of awareness and the educational status of the respondents. These results can be supported by study conducted by Oruonye (2011) which found that students in tertiary levels of education were more aware of climate change based on the question that asked whether the respondents had heard about climate change before. The results of this study also support other studies by Aquah (2011) and Adebayo et al. (2013) which singled out educational status as main predictor of climate change awareness.

While results of this study may be taken to mean that majority of Nairobi's residents are extremely aware of climate change such as conclusion might be misleading because hearing about climate change does not translate to understanding deep issues related to it. This can be attested by a study done by Oruonye (2011) which revealed that majority of college/university students were aware of climate change based on the survey question whether they heard of it before. A further probe of same respondents revealed that majority (89%) them did not

Table 6. Frequencies of climate change understanding among respondents.

Response	Frequency	Percentage
Very well	113	28.5
Fairly well	206	51.9
Not very well	43	10.8
Not at all	35	8.8

understand deep issues of climate change thus arriving into a conclusion that majority of students in high levels of education in Jalingo Metropolis had low awareness on climate change. To overcome this challenge, respondents of this study were subjected to more focused and objective questions in order to reveal their level of awareness and perception on climate change in order to make a more informed decision about their perception and understanding of climate change in cities.

Understanding climate change

The assumption of this study was that the respondents who heard about climate change previously should be able to understand deep issues of climate change compared to those who had not heard about it. Therefore, to test consistency of climate awareness, survey participants were requested to provide their feedback on a likert-scale tool ranging from 1 to 4, where 1 represented *very well,* and 4 denoted *not at all* indicating their level of understanding of climate change in cities.

Table 6 presents the descriptive statistics of the responses obtained. An overwhelming majority of 28.5 and 51.9% felt that they understood climate change very well and fairly well respectively. While a minority of 8.85% felt that they did not understand at all (Table 6). To understand how different demographic attributes affected level of understanding of climate change, a cross-tabulation was done and the statistics are as shown in Table 6 (Table 7).

The results of this analysis show that there was statistical difference (χ^2 *(2) = 6.802, p* = 0.033) between the educational status of the respondents and level of understanding climate change. This could be translated to mean that educational status improved individual's understanding of climate change compared to other social demographic attributes where no statistical differences were found between age of the respondent (χ^2 *(4) =8.837, p* = 0.065) and number of years the respondent had lived in Nairobi (χ^2 *(4) = 0.493, p* = 0.974) and their level of understanding climate change in the city.

The findings of this study support the studies done by Aquah (2011) and Adebayo et al. (2013) which attributed education as a major predictor of level of awareness and knowledge on climate change. Thus, according to this study, it highly probable that someone who had achieved high level of education was more likely to have some deep understanding of climate change issues as well as management practices that can be used to control climate change in urban setting. Additionally, these group are more likely going to embrace and support any mitigation strategies and policy framework that sought to find short and long-term solution to climate change.

Perception on causes of climate change

Apart from knowing how well respondents understood climate change in cities, knowledge on specific factors that are responsible for climate change in cities is another measure of public awareness on urban climate change. This was achieved by presenting respondents with a list of factors that majorly contribute to climate change in cities for them to indicate their level of agreement with each factor. Results of the analysis of the responses are presented in Table 8.

Results of this study revealed that respondents were unaware of the causes of climate change in urban areas though knowledge gaps between different causes were evident. Vehicular emission emerged as the most significant cause of climate change supported by 75% (n= 301) of the respondents followed closely by destruction of green spaces and forests that was supported by 74% (n = 295) of the respondents. Industrial emission received an approval of 71% followed by population growth and urbanization rates received an approval of 70% from the respondents.

On global context, a study by Lorenzoni and Pidgeon (2006) revealed that most citizens in the US and Europe had no clear understanding of various causes of climate change as many respondents indicated deforestation and air pollution as main causes despite them being secondary to burning of fossil fuels. However, this study indicated that majority of residents in Nairobi were aware of the contribution of fossil fuel burning and deforestation in driving climate change.

Locally, these results reaffirm the results of Otieno Pauker and Maina (2009) and Ochieng and Koske,

Table 7. Differences in climate change understanding among different socio-demographic groups.

Social-demographic groups		Level of understanding climate change			
		Very well (%)	F. well (%)	Not v. well (%)	Not at all (%)
Gender	Male (n =219)	32.0 (70)	48.9 (107)	37.0 (34)	3.7 (8)
	Female (n =178)	24.2 (43)	55.6 (99)	18.5 (33)	1.7 (3)
	P value	0.182			
Educational status	Primary (n =42)	23.8 (10)	42.9 (18)	33.3 (14)	0.0 (0)
	Secondary(n =139)	26.6 (37)	48.2 (67)	20.9 (29)	4.3 (6)
	Tertiary(n=216)	30.6 (66)	56.0 (121)	11.1 (24)	2.3 (5)
	Kruskal Test	$\chi^2(2) = 6.802$, $p = 0.033$			
Age group	< 24 (n =130)	21.5 (28)	59.2 (77)	15.4 (20)	3.8 (5)
	25-34 (n =125)	33.6 (42)	44.0 (55)	19.2 (24)	3.2 (4)
	35-44 (n =87)	35.6 (31)	52.9 (46)	11.5 (10)	0 (0)
	45-54 (n = 36)	19.4 (7)	61.1 (22)	16.7 (6)	2.8 (1)
	> 55 (n = 19)	26.3 (5)	31.6 (6)	36.8 (7)	0.5 (1)
	Kruskal Test	$\chi^2(4) = 8.837$, $p = 0.065$			
Number of years lived in Nairobi	< 5 (n = 127)	29.1 (37)	53.5 (68)	14.2 (18)	3.1 (4)
	6-10 (n =85)	31.8 (27)	47.1 (40)	15.3 (13)	5.9 (5)
	11-15 (n =40)	37.5 (15)	45.0 (18)	12.5 (5)	5.0 (2)
	16-20 (n =62)	21.0 (13)	61.3 (38)	17.7 (11)	0 (0)
	> 20 (n =83)	25.3 (21)	50.6 (42)	24.1 (20)	0 (0)
	P (value)	$\chi^2(4) = 0.493$, $p = 0.974$			

(2013) which showed that majority of Kenyans viewed destruction of forests and pollution as major drivers of climate change. The authors further opined that Kenyans understood climate change based on their daily environmental experiences and thus global aspects of climate change like GHG emissions remain abstract in their understanding.

Evidently, respondents expressed limited knowledge on the role of land use and zoning policies, and drainage control with an approval rating of 51.5 and 55.7% respectfully in relation to climate change in cities indicating that respondents were unware of the role of these factors in driving climate change in cities. These result could be interpreted to mean that most Nairobi residents are only aware of climate change drivers which are directly linked with pollution (industrial and vehicular emissions), population and urbanization growth. Also, these result show limitation in knowledge about different causes of climate change because, for instance, land policies stand at the heart of climate change in cities as they influence all other critical sectors linked with climate change in cities such transport orientation and resource management.

In addition, poor land use policies could mean unprioritised land allocation including green spaces, poor transport networks meaning more traffic problem and as result more emissions among others (OECD, 2010). On the other side, poor drainage systems may also lead to flooding in cities due to blocked drainage channels and result more casualties and spread of waterborne diseases such cholera.

Perception on signs and effects of climate change

A study by Lorenzoni and Pidgeon (2006), revealed that most studies on climate change perception have indicated some shared views across the world. In particular, the study found that there is a widespread awareness and concern about climate issues; limited understanding of causes of and solution to climate change, perceived psychological, temporal and spatial distant threats on climate change and some willingness to address the perceived threats through defined measures as well as ascription of individual responsibility to take measures against climate change. To test these factors, residents' awareness and perception was examined through their knowledge of specific signs and of climate change. It was assumed that residents who were more familiar with various contributing factors should know at least little about signs of climate change. Results of this analysis are presented in Table 9.

Table 8. Respondents perception on causes of climate change among respondents.

Factor	Category	Frequency	Percentage
	High	278	70.0
Population growth	Moderate	86	21.7
	Not Sure	33	8.3
	High	295	74.3
Destruction of green spaces	Moderate	73	18.4
	Not Sure	29	7.3
	High	268	67.5
Poor solid waste management	Moderate	107	27.0
	Not Sure	22	5.5
	High	221	55.7
Poor drainage systems	Moderate	141	35.5
	Not Sure	35	8.8
	High	279	70.3
Rate of urbanization	Moderate	102	25.7
	Not Sure	16	4.0
	High	301	75.8
Vehicular emissions	Moderate	79	19.9
	Not Sure	17	4.3
	High	282	71.0
Industrial emissions	Moderate	98	24.7
	Not Sure	17	4.3
	High	206	51.9
Poor land planning policies	Moderate	130	32.7
	Not Sure	61	15.4

The outcome of these results show that majority of the residents perceived temperature fluctuations 92.2% (strongly agree and agree moderately) as the main sign of climate change. This was followed by 90 and 85.2 % of residents who perceived extended dry seasons and change of rain patterns as the key signs respectively. Similar to the results of the causes of climate change, it was confirmed that residents perceived signs that seemingly interfered with their day-to-day activities as major signs of climate change. A study by Hares, Dickinson and Wilkes (2010) support this observation as it found that the most dominant understanding of climate change was linked to changes in weather patterns that survey participants had personally observed in their lifetime

Perception and understanding on effects of climate change revealed that majority of the residents perceived water scarcity as the major effect of climate change with an approval rating of 84.3% (strongly agree and agree moderately) followed by 79.4 and 75.4% spread of diseases and price fluctuations of agricultural commodities. On the lower end, human-human conflict, human-animal conflicts and migrations from one area to another due to limited resources received an approval rating of 47.8, 48.9 and 63.0% respectively. Again, these results revealed the constant knowledge gap and low interpretation of deep issues related to climate change among residents of Nairobi.

In essence, respondents seem to constantly rate issues that affected them on daily basis high compared to those which affected them based on the season of the year. For instance, due to water scarcity in 2017 many cholera cases were reported in Nairobi (GoK, 2017; Daily Nation, 2017a,b; WHO, 2017) implicating spread of

Table 9. Respondents agreement level with various signs and effects known to relate to climate change.

Factors		Responses									
		Strongly agree		Agree moderately		Somewhat agree		Not agree		Strongly disagree	
		F	%	F	%	F	%	F	%	F	%
Signs	Temperature fluctuations	244	61.5	122	30.7	23	5.8	7	1.8	1	0.3
	Extended dry seasons	246	62.0	111	28.0	24	6.0	13	3.3	3	0.3
	Extended cold seasons	207	52.1	117	29.5	44	11.1	22	5.5	7	1.8
	Change in rain pattern	258	65.0	80	20.2	38	9.6	15	3.8	6	1.5
	Flooding in rainy seasons	187	47.1	113	28.5	49	12.3	35	8.8	13	3.3
Effects	Spread of diseases eg cholera	208	52.4	107	27.0	36	9.1	35	8.8	11	2.8
	Water scarcity	232	58.4	103	25.9	38	9.6	19	4.8	5	1.3
	Price fluctuations	201	50.6	99	24.9	48	12.1	35	8.8	14	3.5
	Human-human conflicts	105	26.4	85	21.4	70	17.6	96	24.2	41	10.3
	Human- animal conflicts	108	27.2	86	21.7	78	19.6	94	23.7	31	7.8
	Migrations	166	41.8	84	21.2	74	18.6	49	12.3	24	6.0

infectious waterborne diseases. Also, there has been significant fluctuations in prices of basic agricultural food commodities (Agricultural and Food Authority, 2018; Daily Nation, 2017a,b; The Star News, 2017) due to poor rains that have been experienced in the country. Although climate change factors could have played a significant contribution to varied pricing, other pressing issues such as unemployment and political situation could have masked this influence.

Individual attitude towards on climate change among Nairobi's residents

Over the past decades, studies undertaken to examine the trend in worry and concern about climate change have served to provide a general indication of how people view matters of climate change. Notably, studies conducted in 1988 in the 12 EC member states showed that 76% of the respondents were very/somewhat worried about climate change. Similar studies within the same area showed an increase in concern to 89% 1992 though a decline to 84% in 1992 and 39% in 2002 (Lorenzoni and Pidgeon, 2006). Another study in 2002 showed that Europeans were worried about future changes in climate change though despite the high level of concern detected in these studies, the importance of climate change remained a secondary compared other environmental, personal and social issues (Lorenzoni and Pidgeon, 2006). This study noted some consistency with these studies as 47.1% of respondents were worried to great deal and 34.8% to a fair deal.

Similarly, 49.6% were very concerned and 37.5% were fairly concerned about climate change. Both the results for level of worry and concern showed some consistency meaning that both factors influenced the respondent's response to some extent. Descriptive statistics for these analyses are provided in Tables 10 and 11. To further understand how demographic characteristics influenced individuals' worry and concern towards climate change a cross-tabulation was done and statistical summaries are presented in Tables 12 and 13.

Results of personal worry analysis revealed that both educational status (χ^2 *(2) =10.015, p* = 0.007) and age group (χ^2 *(4) =14.142, p* = 0.007) of the respondents were statistically significant. Similarly, results of level of concern versus educational status were statistically significant *(χ^2* (2) =7.592, p = *0.022),* thus, supporting findings of other studies that have singled out level of education as key predictor of climate change awareness. Even though age did not influence one's level of concern *(χ^2* (4) =7.230, p = 0.124) as some studies have previously indicated, the findings of this study are consistent the findings of Owolabi et al. (2012) and Saroar and Routray (2010) indicating that age group influenced personal worry and concern on climate change on the respondents. Also, studies have shown that age influences personal experience with different climatic conditions and as such old people are likely going to view climate change differently from young inexperienced people.

On the contrary to a study by McCright (2010) which compared different studies that had been done previously on public views on climate change indicating that women were more worried and concerned about climate change compared to males; this study did not find any statistical

Table 10. Level of personal worry about climate change in Nairobi.

Level of worry	Frequency	Percentage
Great deal	187	47.1
A fair deal	138	34.8
Only a little	61	15.3
Not at all	11	2.8
Total	397	100.0

Table 11. Level of concern to climate change in Nairobi among respondents.

Level of concern	Frequency	Percentage
Very concerned	197	49.6
Fairly concerned	149	37.5
Not very concerned	42	10.6
Not at all concerned	4	1.0
I don't know	5	1.3
Total (n)	397	100.0

Table 12. Differences in level of personal concern on climate change among different socio-demographic groups.

Social-demographic groups		Level of personal worry			
		Great deal (%)	A fair deal (%)	Only a little (%)	Not at all (%)
Gender	Male (n =219)	47.0 (103)	33.8 (74)	15.1 (33)	4.1 (9)
	Female (n =178)	47.2 (84)	36.0 (64)	15.2 (27)	1.7 (3)
	P value		0.564		
Educational status	Primary (n =42)	35.7 (15)	35.7 (15)	21.4 (9)	7.1 (3)
	Secondary(n =139)	41.7 (58)	35.3 (49)	19.4 (27)	3.6 (5)
	Tertiary(n=216)	52.8 (114)	34.3 (74)	11.1 (24)	1.9 (4)
	Kruskal-Wallis		$\chi^2(2)=10.015$, p = 0.007		
Age group	< 24 (n =130)	58.5 (76)	27.7 (36)	13.1 (17)	0.8 (1)
	25-34 (n =125)	42.4 (53)	34.4 (43)	17.6 (22)	5.6 (7)
	35-44 (n =87)	46.0 (40)	40.2 (35)	12.6 (11)	1.1 (1)
	45-54 (n = 36)	33.3 (12)	52.8 (19)	11.1 (4)	2.8 (1)
	> 55 (n = 19)	31.6 (6)	26.3 (5)	31.6 (6)	10.5 (2)
	Kruskal-Wallis		$\chi^2(4)=14.142$, p = 0.007		
Number of years lived in Nairobi	< 5 (n = 127)	50.4 (64)	37.8 (48)	10.2 (13)	1.6 (2)
	6-10 (n =85)	38.8 (33)	37.6 (32)	17.6 (15)	5.9 (5)
	11-15 (n =40)	52.5 (21)	30.0 (12)	15.0 (6)	2.5 (1)
	16-20 (n =62)	53.2 (33)	32.3 (20)	11.3 (7)	3.2 (2)
	> 20 (n =83)	43.4 (36)	31.3 (26)	22.9 (19)	2.4 (2)
	Kruskal-Wallis		$\chi^2(4)=4.964$, p = 0.291		

difference among its respondents ($p = 0.564$ and > 0.05) and ($p = 0.681$ and > 0.05) respectively. Similarly, contrary to studies that have indicated that the amount of time one has lived in an area could probable influence their level of worry and concern, this study found no statistical difference (χ^2 (4) =4.964, p = *0.291*) and (χ^2 *(4)* =3.137, p = 0.535) between number of years the respondents had stayed in Nairobi and their level of worry

Table 13. Differences in level of concern on climate change among different socio-demographic groups.

Social-demographic groups		Level of concern				
		Very concerned (%)	**F. concerned (%)**	**Not v. concerned (%)**	**Not at all concerned (%)**	**I don't know (%)**
Gender	Male (n =219)	48.4 (106)	38.8 (85)	11.0 (24)	0.9 (2)	0.9 (2)
	Female (n =178)	51.1 (91)	36.0 (64)	10.1 (18)	1.1 (2)	1.7 (3)
	Mann-Whitney			0.681		
Educational status	Primary (n =42)	38.1 (16)	33.3 (14)	21.4 (9)	4.8 (2)	0.5 (1)
	Secondary(n =139)	46.8 (65)	39.6 (55)	12.9 (18)	0.7 (1)	0.0 (0)
	Tertiary(n=216)	53.7 (116)	37.0 (80)	6.9 (15)	0.5 (1)	1.9 (4)
	Kruska Wallis			$\chi^2(2)$ =7.592, *p* = 0.022		
Age group	< 24 (n =130)	58.5 (76)	32.3 (42)	6.9 (9)	0.0 (0)	2.3 (3)
	25-34 (n =125)	47.2 (59)	38.4 (48)	10.4 (13)	2.4 (3)	1.6 (2)
	35-44 (n =87)	47.1 (41)	37.9 (33)	14.9 (13)	0 (0)	0 (0)
	45-54 (n = 36)	36.1 (13)	50.0 (18)	13.9 (5)	0.0 (0)	0.0 (0)
	> 55 (n = 19)	42.1 (8)	42.1 (8)	10.5 (2)	5.3 (1)	0.0 (0)
	Kruskal Wallis			$\chi^2(4)$ = 7.230, *p* = 0.124		
Number of Years lived in Nairobi	< 5 (n = 127)	48.8 (62)	40.9 (52)	9.4 (12)	0.0 (0)	0.8 (1)
	6-10 (n =85)	45.9 (39)	36.5 (31)	14.1 (12)	2.4 (2)	1.2 (1)
	11-15 (n =40)	47.5 (19)	45.0 (18)	7.5 (3)	0.0 (0)	0.0 (0)
	16-20 (n =62)	59.7 (37)	35.5 (22)	3.2 (2)	1.6 (1)	0.0 (0)
	> 20 (n =83)	48.2 (40)	31.3 (26)	15.7 (13)	1.2 (1)	3.6 (3)
	Kruskal Wallis			$\chi^2(4)$ =3.137, *p* = 0.535		

and concern respectively.

Preferences to long-term mitigation climate change management strategies

To examine the level of policy awareness among respondents, a set of mitigation and adaptation strategies were put together cutting across different sectors concerned with climate change management in cities. Participants were then asked to indicate their level of agreement or support to each strategy statement and rank based on a Likert-scale tool ranging from 1 to 5, where 5 represented *strongly agree* and 1 denoted *I don't know*. Table 14 shows the calculated mean scores per tested strategy. A mean of *1 to 2.5* indicates that the element in intervention has been adapted to a small extent while a mean of *2.6 to 5* shows that the factor has been employed to a large extent.

The results of this study show that Nairobi residents are aware of different adaptation and mitigation strategies though gaps on their knowledge are evident. The respondents recorded an overall mean score of 4.37 meaning that they were aware of different mitigation strategies. Most of the study respondents had a tendency to agree or strongly agree with the strategies presented in the questionnaire, but still, there some substantial minority who disagreed or said "don't know" with various strategies, thus, indicating limited knowledge on climate change issues in cities.

Comparing the nature of strategies presented to respondents, majority of them seemed to agree with strategies that directly linked with their daily environmental issues such as, protection of sensitive areas such as Nairobi's river bank, forests, watersheds and other reserved areas from encroachment" which received their highest approval with a mean of 4.66 (SD= 0.684. This was followed closely by "Encouraging proper maintenance of drainage systems to manage flooding in rainy seasons" (M= 4.59, SD=0.759) and "Promoting proper waste management techniques to reduce drainage blockages and emissions from wastes" **(**M=4.56, SD= 0.804). "Encouraging water management technologies among city residents such as water harvesting, good water usage in households" was represented with a mean of 4.52 (SD= 0.787). Evidently, waste management, drainage issues after light rain showers, water scarcity, and destruction of protected areas have been affecting Nairobi residents more often the reason as to why manage strategies related to them could have received high approval from the residents. The study established a knowledge gap in among mitigation management strategies majorly because their action plans could be indirect and thus difficult for an

Table 14. Calculated mean score as assigned by respondents on their rating of response strategies to the effects of climate change.

Policy statement	N	Mean	Std. Deviation
Protecting sensitive areas such as wetlands and forests	397	4.66	0.684
Encouraging maintenance of drainage systems in the city	397	4.59	0.759
Promoting proper waste management techniques	397	4.56	0.804
Encouraging water management technologies such as water harvesting	397	4.52	0.787
Embracing green planning in streets, parks, open spaces, gardens etc.	397	4.47	0.883
Promote low carbon technologies in cities	397	4.44	0.935
Encourage use of public/transit mass transport	397	4.43	0.809
Encouraging research to enhance climate change understanding and appreciation	397	4.40	0.92
Promoting waste-energy capture technologies	397	4.39	0.977
Encouraging public participation in matters related to environment and climate	397	4.38	0.969
Embracing effective traffic management technologies	397	4.38	0.831
Doing housing reforms in informal settlements	397	4.35	0.904
Encouraging use of Liquid Propane Gas (LPG) stoves	397	4.34	0.911
Encouraging solar installation and water heaters in buildings	397	4.34	0.92
Embracing use of weather and climate information in developments	397	4.32	0.949
Encouraging compliance with existing policies and legislation	397	4.28	1.027
Strengthening the capacity of national and county institutions responsible for climate change	397	4.27	1.114
Encouraging research to identify design and materials that enhance the resilience of infrastructure	397	4.26	1.065
Encourage use of non-motorized modes of transport	397	4.23	0.914
Promoting construction of climate-proof infrastructure, for example, roads	397	4.21	1.098
Adopting SMART building technologies such as green buildings	397	4.18	1.085
Encouraging mixed land use planning	397	4.16	0.999
Overall mean		4.37	

average person to interpret. For instance, “Mixed *land use development”* with a mean of 4.16 (SD 0.999) was the least preferred management strategy despite its immense role in climate change intervention in cities. For example, effective land use and zoning policies and strategies would ensure effectiveness of the transport sector by encouraging mixed developments plans thus reduced trips translating to reduced vehicular emissions and general reduction in GHG emission.

Also, these management strategies would ensure adaptation strategies are affected including preserving of land resources such as forests, providing for more open spaces and green spaces within the cities (OECD, 2010). Other mitigation management strategies such as use of green building technologies, construction of climate-proof infrastructure, use of non-motorized modes of transport among other indirect management strategies also reviewed a low rating thus attesting low understanding of the immeasurable role these strategies can play in climate management in cities.

Conclusion

The results of this study is a true reflection of resident perception on various issues related to climate change and policies including public awareness and understanding, perception on causes and effects, concern and their preference on management policies related to climate change in cities. Majority of the respondents had heard about climate change in the past though most of them were only familiar climate change issues directly linked with environmental issues such as change of rain pattern and extended dry periods were perceived as major signs of climate change while water scarcity and spread of infectious diseases such as cholera were perceived as major effects of climate change. However, there was knowledge gap to indirect issues related to climate change. Residents also expressed significant levels of worry and concern about climate change thus reflecting their likelihood to take individual responsibility towards taking necessary actions towards management climate change. This was attested by their aggregate mean score of 4.37 preference to different strategies that if embraced could help to manage climate change perceived effects in Nairobi. Educational status emerged as top social demographic attribute that influenced respondents’ level of awareness, knowledge, worry and concern towards climate change. We, therefore, recommend that the national government through the relevant departments and the county government of Nairobi should expand publicity on climate change in order to improve climate change awareness among the residents in order to improve individual willingness, actions and support to different climate change policy framework.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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