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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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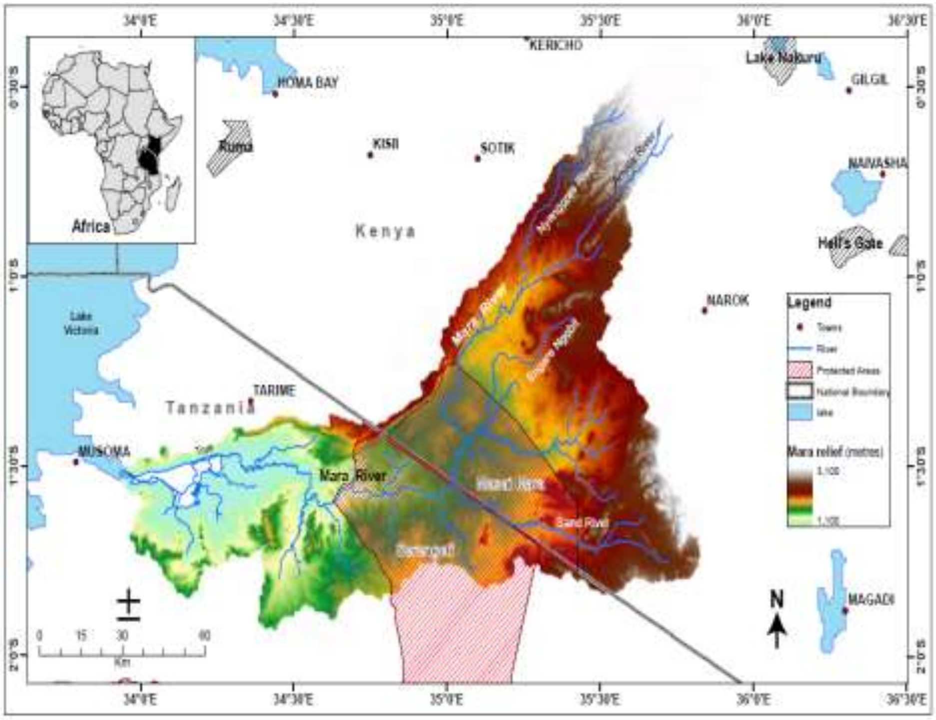

Figure 1. A map of Mara River Basin.

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	-	-	-	-
Cd	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
	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	-	-	-	-
Se	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
	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
SRP	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]
	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
TP	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]
	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
Ammonium	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]
	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
Oxidized nitrogen	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]
	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
Nitrates	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]
	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
Nitrites	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]
	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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