Asian Journal of Water, Environment and Pollution, Vol. 14, No. 3 (2017), pp. 19–26.
DOI 10.3233/AJW-170022

Variation in the Chemical Status of Water and Soil Sediments along Saiwa Swamp Ecosystem, Trans Nzoia County, Kenya

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Received January 11, 2017; revised and accepted May 3, 2017

Abstract: Saiwa Swamp National Park in west-northern Kenya presents a typical wetland, and is habitat to the rare sitatunga antelope (*Tragelaphus spekei*). The swamp is surrounded by farms making it an ecological island, thus threatening the very existence of this wetland. Agrochemicals released from these farms are channelled into the swamp and thus affecting its physico-chemical status. This study compared the chemistry of water and soil sediments at specific sites along the swamp gradient during the rainy season. pH of surface waters was nearly neutral (mean of 7.0) during the entire study period while that of the soil sediments was acidic (4.6 to 5.0). Elements Ca, Mg and Fe recorded higher concentrations in dry season compared to the wet season. Other elements including Cu, Mn and Zn were not detected in surface water during the dry season. There was an increase in concentrations of Cu and Mn in the swamp waters during the wet season. The findings of the study showed a large percentage of the nutrients removed from the subsurface water in filtering contaminants.

Key words: Riparian, sitatunga, chemical status, Saiwa Swamp National Park.

Introduction

Wetlands are areas whose soil is, either permanently or seasonally, saturated with moisture and have water tables that stand at or near the land surface and support aquatic plants (Mitsch and Gosselink, 2007). By trapping sediments and retaining excess nutrients and pollutants such as heavy metals, wetlands protect water quality. These functions are important especially when a wetland is connected to water sources (such as rivers and lakes) whose waters are used by humans. Since the beginning of the 20th century, more than half of the wetlands in the world may have disappeared, mostly in the developed world and this loss is on the rise especially in the tropics. Due to increase in human population, wetland conversions for agriculture, fishponds, and urban settlements have taken place in the developing world (Mitsch and Gosselink, 2007).

Saiwa Swamp wetlands are located in the Trans-Nzoia County about 400 km northwest of Nairobi and are fed by two rivers: Kipsaina and Saiwa. These types of wetlands are very productive and attractive for agriculture (Mohamed, 2000). The wetlands host important plant and animal species, remarkable being the endemic antelope sitatunga *Tragelaphus spekei* which is endemic to these wetlands and crowned cranes *Balearica regulorum* (Mohamed, 2000). Saiwa Swamp National Park, which forms a small part of these wetlands, was established in 1974 to protect the small population of the endemic sitatunga antelope (Mohamed, 2000). The vegetation in the park consists of three communities: gallery forest (39%), open grassland

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(24%) and wetland vegetation (37%). The principal vegetation of the Park wetland consists of large stands of bulrush *Typha domingensis*, reeds and sedges such as *Cyperus latifolius*, and tall swamp grasses including *Echinochloa pyramidalis* and *Pycreus lankecus*, interspersed with extensive patches of low vegetation, mainly *Hugrophila spiciformis*, *Ranunculus multifidus* and *Polygonum setulosum*. The wetland vegetation is bordered by remnants of tropical gallery forest composed of a variety of trees, shrubs and some patches of grasslands (Gichuki, 1998).

During the early 1960s, several ethnic groups migrated to this rich agricultural area from other parts of Kenya to benefit from the new settlement schemes. The rapid growth in human population in the area has resulted in substantial sub-division of the land leading to the draining and cultivation of much of the wetlands resulting in intensive erosion of the banks of Sinyerere and Kipsaina rivers. Therefore these intensive agricultural activities threaten the Saiwa wetland and its biodiversity. Moreover, to increase agricultural production, most farmers use agro-chemicals whose residues are carried by runoff into the wetland leading to, for example, vegetation succession (elephant grass has displaced the native *Typha* vegetation) and other ecological changes. The invasion of elephant grass into the riparian areas of the swamp may have led to the gradual deterioration of the wetland habitat including the decline in the population of the Sitatunga antelope inside the Park (Gichuki, 1998). Intensive agriculture in and around wetlands may lead to increased levels of pollution due to the reduction in riparian buffer zones, biodiversity and ecosystem goods and services supplied by these zones. However, only a few studies have been carried out in Kenya on the functional ecology of these wetlands. By comparing multiple sites along the swamp water course, the study aimed at characterizing the patterns of water quality along the gradient of water flow. Specifically, the study sought to establish the chemical status of water and soil sediments in Saiwa Swamp during the rainy season and how these may affect the wetland ecosystem quality in addition to understanding how the wetland functions in mitigating runoff contaminants from the surrounding farmlands.

Materials and Methods

Study Site

The study was conducted at the Saiwa Swamp National Park, which is the smallest park in Kenya with an area of about three square kilometres (Mohamed, 2000). The park is situated 25 km north-east of Kitale town (01° 05′ N, 35° 07′ E), at an elevation of about 1860 m above sea level. It is located at the confluence of rivers Saiwa, which originates from the Cherengani ranges (3371 m above sea level) to the north, and river Kipsaina which originates from Mt. Elgon (4321 m above sea level) to the west (Figure 1). The two rivers join to form river Sinyerere that flows into river Nzoia further downstream (Ogutu, 1996).

Water and Soil Sampling

Sampling points were selected based on their relative location within the swamp. Two sampling points, 1 (1° 7.015′ N, 35° 7.66′ E) and 6 (1° 4.53′ N, 35° 6.6.86′ E), were selected at the entry points of rivers Saiwa and Kipsaina respectively (Figure 1). Sampling points 4 (1° 5.73′ N, 35° 7.20′ E) and 2 (1° 6.84′ N, 35° 7.55′ E) were located within swamp along the main river Saiwa. Sampling point 3 (1° 6.86′ N, 35° 7.64′ E) was located outside the swamp next to an area used for livestock grazing while sampling point 5 (1° 5.73′ N, 35° 7.08′ E) was at a water spring located within the forest whose water flows into the swamp. Sampling point 7 (1° 3.80′ N, 35° 7.27′ E) was selected at the exit of the swamp's water (Figure 1).

Data were collected on monthly basis during wet (April to July and October to December) and dry (January to March and August to October) months from 2014 to 2016. At each sampling point, three water samples were collected randomly within an area of 1 × 1 m of the running river water using 300 ml sterilized plastic bottles. The sample bottles were tightly sealed, placed in an ice cooled container and transported to the laboratory for analysis. In the laboratory the samples were kept in a refrigerator at 4°C awaiting chemical analysis (APHA, 1998). Water samples from the same sampling point were thoroughly mixed and the composite samples were used for detailed analysis of pH, phosphorus (P), potassium (K), calcium (Ca), magnesium (Mn), iron (Fe), copper (Cu), zinc (Zn), manganese (Mn) and sulphur (S) as described by Okalebo et al. (2002). Sulphur (SO_4) was determined by the turbidity method (APHA, 1998). Likewise, three soil samples (at a depth of 20 cm) were collected randomly within an area of 1 × 1 m at the banks of the river but next to the water sampling points using a soil auger. Similarly, soil samples from the same sampling point were transported in a cooler to the laboratory, thoroughly mixed, air dried and sieved (through a 2 mm mesh) to remove stone pieces and large root particles.

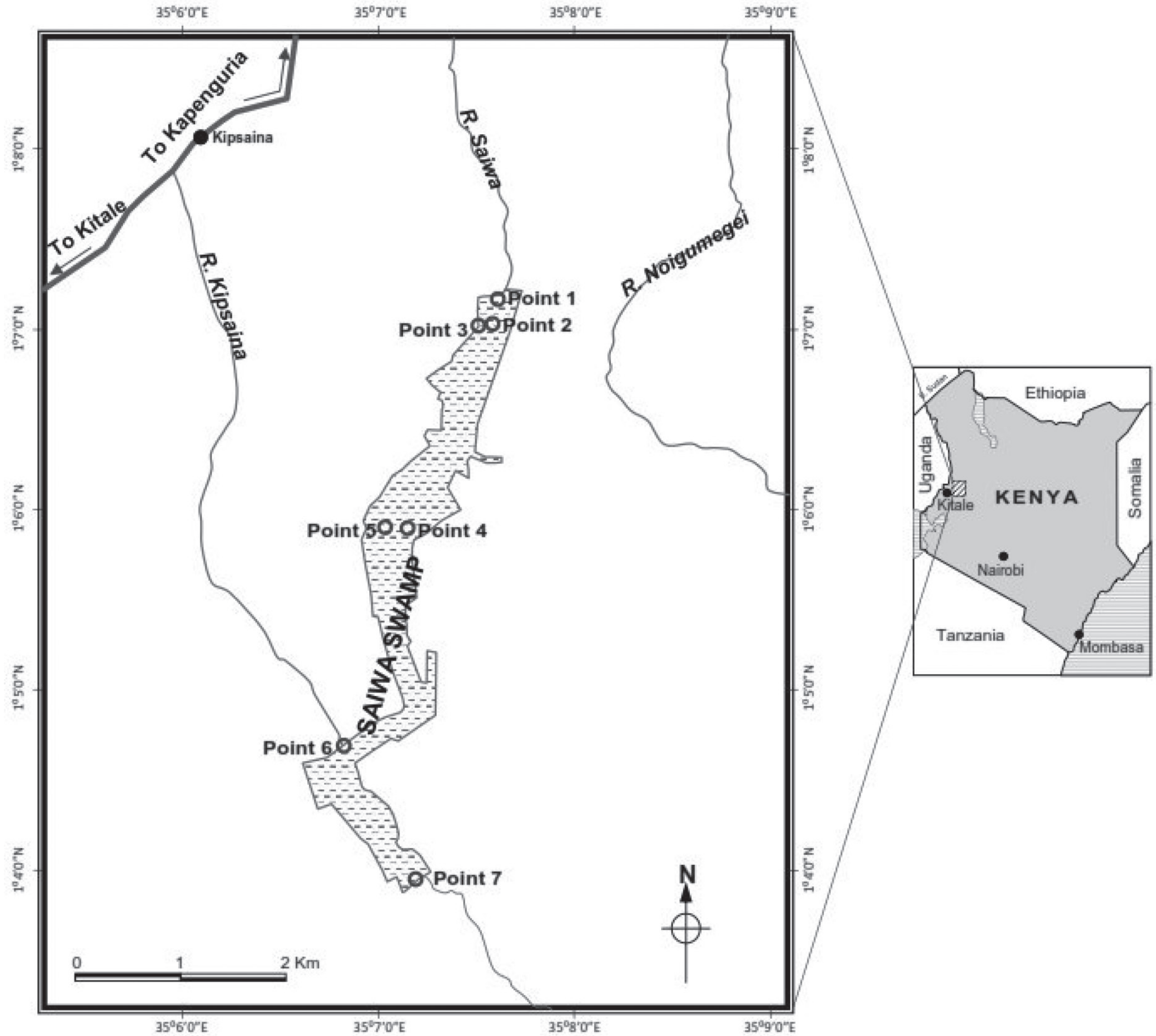

Figure 1: Sampling points along the Saiwa swamp.

The composite soil samples were then used for detailed analysis of the same variables as that of water samples.

Data were subjected to analysis of variance (ANOVA) procedure using the statistical software GenStat release 12.1 (Anonymous, 2009). Least significant difference (LSD) was used for mean separation at 5% significance level (Steel et al., 1997; Moore and McCabe, 1999).

Results

pH Values and Elements Concentrations in Waters

Comparisons of pH for surface waters showed no variation ($p \geq 0.05$) between the wet and dry seasons (Table 1). However, during the dry seasons, pH was slightly acidic (< 7) at sampling points 1 and 2 while it was neutral to alkaline (7.0 to 7.4) for the other sampling points. During wet seasons, sampling points 1, 2 and 4 recorded slightly lower pH whereas other points had neutral to alkaline pH (7.0 to 7.5). Lower *P* (0.3 to 0.6 mg/L) levels were recorded during dry seasons as compared to wet seasons (0.5 to 0.9 mg/L) (Table 1) with water entry point 1 recording the highest levels and water exit point 7 the lowest. For wet seasons, the lowest and highest *p* values were recorded at sampling points 4 (0.5 mg/L) and 7 (0.9 mg/L) respectively.

There were no significant ($p \geq 0.05$) variations in the concentrations of S between dry and wet seasons (Table 1). However, there were significant ($p \leq 0.05$) differences between the sampling points. During dry seasons, sampling point 7 registered the highest values (14.4 mg/L) while the lowest were observed in sampling point 3 (2.6 mg/L) which also had the lowest (3.9 mg/L) during wet season. Sampling point 2 had the highest value (8.5 mg/L). Significant ($p \leq 0.05$) differences were

Table 1: pH and elements concentrations in Saiwa swamp waters between seasons (mg/L except for pH)

Parameter	pH		K		Ca		Mg		P		S		Fe		Cu		Zn		Mn	
Seasons Sampling point	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet
P1	6.7 ± 0.29	6.3 ± 0.33	1.9 ± 0.92	1.7 ± 0.32	9.2 ± 3.28	4.0 ± 2.02	3.9 ± 0.30	0.8 ± 0.22	0.6 ± 0.19	0.6 ± 0.15	4.5 ± 0.00	4.6 ± 0.00	0.0 ± 0.00	5.4 ± 1.00	0.0 ± 0.00	0.0 ± 0.00	0.0 ± 0.00	0.0 ± 0.00	0.0 ± 0.00	7.6 ± 0.00
P2	6.9 ± 0.20	6.9 ± 0.17	2.2 ± 0.91	6.8 ± 3.70	11.7 ± 4.38	6.9 ± 1.80	4.6 ± 0.30	2.3 ± 0.37	0.5 ± 0.19	0.7 ± 0.07	7.7 ± 0.00	8.5 ± 0.00	0.0 ± 0.00	3.9 ± 0.80	0.0 ± 0.00	0.0 ± 0.00	0.0 ± 0.00	0.0 ± 0.00	0.0 ± 0.00	0.1 ± 0.00
P3	7.0 ± 0.25	7.0 ± 0.22	1.8 ± 0.83	5.7 ± 4.90	7.6 ± 2.99	5.1 ± 2.01	1.9 ± 0.60	0.9 ± 0.19	0.4 ± 0.22	0.6 ± 0.16	2.6 ± 0.00	3.9 ± 0.00	0.0 ± 0.00	3.3 ± 0.85	0.0 ± 0.00	0.0 ± 0.00	0.0 ± 0.00	0.0 ± 0.00	0.0 ± 0.00	0.1 ± 0.00
P4	7.1 ± 0.35	6.8 ± 0.26	1.8 ± 0.82	3.5 ± 2.34	7.8 ± 3.00	4.1 ± 1.10	2.3 ± 0.40	0.9 ± 0.20	0.5 ± 0.14	0.5 ± 0.16	2.9 ± 0.00	4.4 ± 0.00	0.0 ± 0.00	1.5 ± 0.40	0.0 ± 0.00	0.0 ± 0.00	0.0 ± 0.00	0.0 ± 0.00	0.0 ± 0.00	0.2 ± 0.00
P5	7.3 ± 0.62	7.1 ± 0.26	2.4 ± 0.76	5.6 ± 2.90	11.2 ± 3.03	7.4 ± 1.69	4.0 ± 0,50	2.1 ± 0.30	0.5 ± 0.22	0.7 ± 0.24	2.9 ± 0.00	6.7 ± 0.00	0.0 ± 0.00	0.6 ± 0.38	0.0 ± 0.00	0.0 ± 0.00	0.0 ± 0.00	0.0 ± 0.00	0.0 ± 0.00	0.1 ± 0.00
P6	7.4 ± 0.50	7.3 ± 0.17	2.3 ± 0.79	6.9 ± 4.66	7.9 ± 2.91	5.7 ± 1.53	4.2 ± 0.60	1.4 ± 0.20	0.5 ± 0.15	0.8 ± 0.17	9.3 ± 0.00	7.4 ± 0.00	0.0 ± 0.00	1.9 ± 0.81	0.0 ± 0.00	0.0 ± 0.00	0.0 ± 0.00	0.0 ± 0.00	0.0 ± 0.00	0.6 ± 0.00
P7	7.3 ± 0.56	7.5 ± 0.32	2.3 ± 0.66	5.3 ± 2.97	9.4 ± 3.29	6.5 ± 1.76	4.7 ± 0.70	1.7 ± 0.20	0.3 ± 0.17	0.9 ± 0.29	14.4 ± 0.00	6.8 ± 0.00	0.0 ± 0.00	1.1 ± 0.67	0.0 ± 0.00	0.0 ± 0.00	0.0 ± 0.00	0.0 ± 0.00	0.0 ± 0.00	0.1 ± 0.00

Table 2: pH and Nutrients concentrations in Saiwa swamp soils between seasons (mg/L except for pH)

Parameter	pH		K		Ca		Mg		P		S		Fe		Cu		Zn		Mn	
Seasons Sampling point	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet
P1	5.2 ± 0.35	5.0 ± 0.20	76.1 ± 39.7	161.7 ± 50.2	1647.7 ± 691.9	1497.4 ± 357.7	213.5 ± 51.8	429.1 ± 71.5	66.7 ± 5.2	78.2 ± 6.0	11.0 ± 1.8	78.0 ± 16.5	1387.2 ± 178.1	1352.7 ± 543.2	1.6 ± 0.8	3.6 ± 0.7	1.7 ± 0.3	75.0 ± 25.0	259.6 ± 81.6	516.3 ± 151.2
P2	4.7 ± 0.19	4.2 ± 0.11	148.3 ± 13.6	237.9 ± 54.4	2398.3 ± 203.8	1574.6 ± 326.6	303.6 ± 43.3	402.6 ± 52.1	11.4 ± 5.2	17.0 ± 2.5	32.9 ± 9.9	190.5 ± 49.0	4443.7 ± 1781.4	3492.8 ± 1097.4	5.8 ± 1.2	4.6 ± 1.2	4.9 ± 1.2	46.0 ± 27.9	641.5 ± 178.4	633.0 ± 167.2
P3	4.6 ± 0.18	4.3 ± 0.08	142.1 ± 33.8	319.0 ± 54.4	2343.2 ± 411.7	2439.9 ± 455.2	352.8 ± 85.3	608.6 ± 94.6	13.7 ± 2.1	16.8 ± 3.7	47.1 ± 16.7	144.1 ± 29.9	7116.7 ± 1222.1	4073.7 ± 1773.7	6.7 ± 0.5	5.1 ± 1.3	11.6 ± 3.6	85.2 ± 34.0	1141.6 ± 440.6	878.6 ± 216.5
P4	5.6 ± 0.31	5.2 ± 0.22	61.2 ± 11.5	183.9 ± 65.0	1144.1 ± 184.0	1334.4 ± 241.7	183.6 ± 55.4	307.3 ± 38.0	33.2 ± 9.2	59.2 ± 6.7	11.9 ± 1.9	61.5 ± 17.4	3225.3 ± 1995.4	1069.7 ± 489.9	3.3 ± 0.6	2.4 ± 0.9	2.2 ± 0.2	74.8 ± 23.0	352.9 ± 84.4	483.8 ± 188.9
P5	4.4 ± 0.39	3.9 ± 0.15	81.8 ± 23.0	245.2 ± 49.6	1646.4 ± 426.1	1771.2 ± 262.0	106.7 ± 34.3	342.1 ± 58.5	25.9 ± 8.6	19.7 ± 3.5	29.8 ± 8.0	121.6 ± 18.7	7592.4 ± 1071.9	5368.4 ± 1670.0	4.2 ± 1.0	7.0 ± 0.8	28.4 ± 7.5	163.1 ± 23.0	503.4 ± 8.4	790.1 ± 197.7
P6	5.0 ± 0.34	4.6 ± 0.19	163.3 ± 17.1	224.6 ± 83.2	1443.4 ± 383.1	1476.2 ± 228.9	277.0 ± 46.2	465.2 ± 103.8	13.7 ± 2.5	10.0 ± 1.9	26.1 ± 5.7	237.0 ± 89.0	12120.1 ± 1892.3	3917.2 ± 1165.4	5.5 ± 1.1	5.1 ± 1.1	5.1 ± 0.9	313.0 ± 30.0	1754.1 ± 164.9	2063.7 ± 463.1
P7	5.7 ± 0.35	5.3 ± 0.12	75.2 ± 18.0	187.8 ± 77.7	1705.5 ± 285.0	1516.2 ± 286.9	226.3 ± 16.0	338.1 ± 98.0	61.0 ± 8.9	60.2 ± 4.8	18.4 ± 3.5	104.1 ± 28.4	2234.1 ± 272.5	2456.1 ± 1020.2	3.0 ± 0.7	4.3 ± 1.1	11.4 ± 8.7	104.2 ± 24.0	755.7 ± 108.1	1034.4 ± 308.6

observed in the concentrations of K between the two seasons but only between the sampling points during wet seasons. Overall, the highest mean concentrations of K (5.07 mg/L) were recorded during wet seasons as compared to dry seasons (2.1 mg/L). During wet seasons, sampling points 1 and 6 had the lowest (1.7 mg/L) and highest (6.9 mg/L) levels of K respectively.

Significantly ($p < 0.05$) higher mean concentrations of Ca and Mg were recorded during dry seasons as compared to wet seasons. For Ca, sampling point 2 recorded the highest concentration of 11.7 mg/L and the lowest value of 4.0 mg/L at point 1 (Table 1). No traceable amounts of Cu, Zn and Mn were recorded in surface waters during both dry and wet seasons, although some amount of Fe was recorded in the wet seasons (Table 1). During wet seasons, Fe concentrations varied ($p \leq 0.05$) among the sampling points, with sampling point 1 recording the lowest (0.6 mg/L) and point 5 the highest (5.4 mg/L) values respectively.

pH and Elements Concentrations in Soils

Soils were more acidic (pH < 7) than surface waters with the mean pH values ranging from 5.02 during dry seasons to 4.64 for wet seasons (Table 2). In both seasons, sampling points 1 and 7 recorded the lowest pH levels of 4.4 (dry seasons) and 3.9 (wet seasons) while point 7 recorded the highest levels of 5.7 (dry seasons) and 5.3 (wet seasons). No significant ($p \geq 0.05$) variation was observed in P between the two seasons but significant differences were observed between the sampling points. During dry seasons, sampling point 3 recorded the lowest P value of 11.4 mg/kg while the highest was recorded at point 5 (66.7 mg/kg). During wet seasons, sampling point 6 had the lowest value (10.0 mg/kg) while point 5 had the highest (78.2 mg/kg). Mean concentrations of S were significantly ($p < 0.05$) higher (133.8 mg/kg) during wet seasons compared to dry seasons (25.3 mg/kg) with S content ranging from 11.0 mg/kg to 47.1 mg/kg during dry seasons and from 61.5 mg/kg to 237.0 mg/kg during wet seasons.

Significant differences ($p \geq 0.05$) were observed in K concentrations between dry and wet seasons. Wet seasons registered highest values of K varying between 161.mg/kg and 319.0 mg/kg for sampling points 4 and 5 compared to dry seasons when values ranged from 61.2 mg/kg to 163.3 mg/kg for sampling points 2 and 6 respectively. Sampling point 4 had highest K content (319.0 mg/kg) during wet seasons compared to all the other sampling points. However, no variability in Ca was recorded between the dry and wet seasons and between the sampling points. Mg was found to differ significantly ($p \leq 0.05$) between seasons, with dry seasons recording lower levels (106.7 mg/kg to 352.8 mg/kg) while wet seasons had higher levels (238.1 mg/kg to 608.6 mg/kg). Differences were also noted between sampling points with sampling point 4 recording the highest levels while sampling point 1 registered the lowest levels of Mg.

It can be noted that Fe showed significant ($p \leq 0.05$) seasonal variability, with dry seasons recording highest contents (1387.2 to 12120.1 mg/kg) than wet seasons (1069.7 to 5368.4 mg/kg). Sampling point 6 showed exceptionally high Fe content (12120.1 mg/Kg) during dry seasons compared to the other sampling points. In terms of Cu, levels did not vary much between seasons and between sampling points. Among the elements, Cu was found to have the least concentrations, mainly occurring in trace amounts. Zn concentrations did not differ significantly ($p \geq 0.05$) between seasons; however there were notable differences between the sampling points, During dry seasons, concentration varied from 1.7 to 28.4 mg/kg for sampling points 5 and 1 while during wet seasons these varied from 46.0 to 313.0 mg/kg at sampling points 3 and 6 respectively. In addition, sampling point 6 showed exceptionally high Zn concentration in the wet season compared to the other sampling points. Like with Zn, Mn did not differ between the seasons but differed between the sampling points. Dry seasons Mn levels varied from 259.6 to 1754.1 m/kg at sampling points 5 and 6 while wet season concentrations varied from 483.8 to 2063.7 mg/kg at sampling points 2 and 6 respectively. Moreover, sampling point 6 exhibited highest Mn concentrations during both dry and wet seasons compared to the other sampling points.

Discussion

pH represents the hydrogen ion (H^+) contents in water and it is a measure of the acidity or alkalinity (Katimon et al., 2004). pH of water determines the solubility and biological availability to organisms of chemical constituents such as phosphrous, potassium, sulphur and heavy metals such as copper, zinc and manganese (Guadet, 1979). It also determines the type of aquatic life of a water body. Saiwa swamp waters can be categorized as nearly neutral during both dry and wet seasons with mean pH values of 7.1and 7.0 respectively. Overall, during rainy seasons, water pH was comparatively lower than during dry seasons, suggesting that the swamp gets more inundated with acidic substances from surface runoff emanating from non-point sources during rainy seasons (Katimon et al., 2004). The swamp soils were found to be more acidic with mean pH of 5.0 and 4.7 for dry and wet seasons respectively. This is in line with findings of Katimon et al. (2004) who reported that many tropical soils located along the rivers are potentially acidic. Soil acidic conditions during the wet season could possibly be due to leaching of acidic substances into the water body from the swamp environs which later accumulate onto sediments due to the filtering effect of the swamp biota. Organic acids such as humic and fluvic acid are also produced during organic decomposition in these environments (Katimon et al., 2004).

Highest phosphorus levels were recorded during wet seasons compared to dry seasons for both waters and soils. These seasonal differences could indicate higher phosphate fertilizer leakages into the swamp waters from the surrounding crop farms. It has been reported by Muthuri and Jones (1997) that for most aquatic ecosystems, phosphorus is generally the limiting element for plant growth and therefore its availability from the farms causes eutrophication of water bodies. This could explain the observed higher phosphorus content in swamp soils compared to the surface water noted in this study.

Contrary to the waters, soils registered higher iron content during dry seasons compared to wet seasons. This could be explained by the weathering of the ferrasol and fluvisol rocks that dominate in the study area. The exceptionally high soil iron content (12120.1 mg/kg) recorded in dry season at sampling point 6, which is the entry point into the swamp of River Kipsaina, could be attributed to the agrochemicals from the horticultural activities from surrounding farms found on the banks of River Kipsaina.

Comparison of sulphur levels revealed that wet seasons had highest levels of sulphur than dry seasons, probably due to greater discharge of sulphur compounds into the water body during the wet season from the swamp environs. Sulphur levels (10-237 mg/L) found in the soil sediments, however, fell within the ranges reported in other tropical swamp sediments (Gaudet and Muthuri, 1981). However, soil sediments contained more sulphur compared to surface waters and this could be attributed to adsorption of sulphur compounds onto soil sediments. In addition, sampling point 6 recorded exceptionally high levels of sulphur (237.0 mg/kg) during wet seasons compared to the other sampling. This was perhaps due to deposition of sulphates from the environs as a result of the horticultural activities from surrounding farms found on the banks of River Kipsaina.

Potassium registered highest concentrations during wet seasons than dry seasons for both the waters and soils. Potassium is an alkali metal that forms highly soluble salts which are easily leached into the water. The point source of these metals could be linked to the excess potassium fertilizers (e.g. urea, NPK) used in the surrounding farms. If fertilizer application on crops exceeds their requirements, excess fertilizer is drained into the water (Divya and Belagali, 2012). This was particularly observed at points 1 and 6, which are entry points of rivers Saiwa and Kipsaina to the swamp, whose catchments are the extensive farms ranging from Kapenguria to Mt. Elgon. Sampling point 1 showed notably high potassium content (319.0 mg/kg) in the wet season compared to the other sampling points. Since sampling point 1 was the surface water entry point to the swamp, less or no filtration of nutrients took place at this point of sampling. During both seasons, potassium levels were highest in the sediments than surface waters at all sampling points probably due to deposition and the purification effect of the swamp.

In contrast to most of the other nutrients, calcium levels in surface waters were significantly ($p \leq 0.05$) higher during dry seasons compared to wet seasons at all sampling points (Table 2). This was presumably due to decreased water volume in the swamp during the dry season, hence higher calcium concentration. Calcium is one of the alkaline earth metals that are widely distributed in the earth's crust and present in almost all waters (Garg, 1987). It occurs in radicals of carbonates and bicarbonates in waters of high salinity, although calcium chloride and nitrates can also be found (Garg, 1987). Sampling point 4 recorded the lowest content of calcium in the soils in both seasons unlike surface waters. This could be explained by the location of sampling point in the middle of Saiwa River that experiences fast running waters, hence little deposition of the calcium salts. Similarly, magnesium levels were highest during dry seasons than wet seasons, possibly as a result of decreased water volume in the swamp during dry seasons. This is in line with study by Ndubi et al. (2015) in similar environments in Kenya. Magnesium resembles calcium in most of its chemical properties although its solubility is about ten times higher (Garg, 1987). Magnesium forms highly soluble salts which contribute to both carbonate and non-carbonate water hardness but to a lesser extent than the calcium component. The high values recorded for calcium and magnesium during dry seasons was possibly due to decreased volume of water in the swamp caused by less river flow and increased evapotranspiration in the swamp. The prevailing high temperatures in the area increase the concentration of calcium and magnesium salts (Medudhula et al., 2012). The low values of 1.4 mg/L and 5.7mg/L, recorded in the wet season for magnesium and calcium respectively, could be due to dilution by the increased inflow of water.

Traces of copper were recorded in sediments but not in the surface waters during both seasons. Among all the elements investigated, copper recorded the least amounts. These results are similar to those of Mwaniki et al. (2013). Copper is a heavy metal that is associated with pollution and was highest at sampling point 6 during wet seasons suggesting pesticide or fungicides source from surrounding agricultural farms. Dry seasons recorded lower trace amounts of manganese in water compared to rainy seasons. Like for iron, copper and zinc recorded highest amounts during wet seasons. This could be due to discharge of these elements into the waters during the rainy season from the swamp environs as opposed to the dry season.

Manganese pollution is linked to fossil fuels and oils from automobile exhausts (Guadet, 1979) and in this case it could have come from tractors that are used to prepare land prior to crop cultivation in the area. Sampling point 1 registered conspicuously high manganese levels (7.6 mg/L) in surface water during wet seasons compared to the other sampling points possibly due to the element being dissolved from the surrounding farms before water flows into the swamp. On the other hand, sampling point 6 exhibited conspicuously higher sediment manganese concentration during both seasons compared to the other sampling points. As noted earlier, River Kipsaina flows into sampling point 6, and drains from many small horticultural farms that are found on its banks. Therefore, manganese could be originating from agrochemicals (especially pesticide) used even during the dry seasons. As sampling point 6 was closer to sampling point 7, it perhaps influenced the high values at sampling point 7 as water had less residence time within the swamp for mopping up by the swamp. Levels of manganese during dry seasons were within the levels recommended by WHO guidelines of 0.1 mg/L for drinking water (Twort et al., 1994) but were above this value during the wet seasons. This makes the swamp water unsuitable for domestic purposes, hence the need to conserve the wetlands for filtration of manganese before it is discharged to the rivers and its subsequent use. Exit sampling point 7 recorded low values of manganese compared to the other sampling points, showing the critical function of cleaning up of such elements from polluted waters by wetlands. While the wet season registered very low trace amounts of zinc in both waters and soils, especially from sampling points 1, 2 and 3, no traceable amounts of Zn were recorded during dry seasons at all sampling points. This could be indicative of the purifying effect of the wetland.

In conclusion, many of the elements recorded higher levels during wet seasons as compared to the dry seasons in both water and soil sediments. Sediments, nutrients and toxic chemicals enter wetlands especially in rural areas where agricultural practices are common primarily by way of runoff. Where the runoff drains freshly-ploughed fields, as was the case around Saiwa swamp, it may carry a lot of pesticides and fertilizers applied on land. This probably explains the observed higher concentrations of elements in the wet season compared to the dry season in our study. Essentially, soil sediments recorded higher levels of mineral elements than in the surface water which is in agreement with Douglas and Considine (1984) and Mwaniki et al. (2013). Toxic chemicals reach surface waters in the same way as other elements, and can cause disease, death, or other problems upon exposure to plants and animals (including humans). Wetlands remove these pollutants by trapping the sediments, nutrients and toxic chemicals as they slow the velocity of waters and allow sediments to settle to the bottom where they are held in place (Garg, 1987). This demonstrates the vital role of wetlands in pollution control and the need to maintain and restore wetland vegetation along riparian zones. In general, this study found that swamps played this vital role of retention of chemicals and metal elements, especially during the dry season when water flow is low, slow and has longer residence times within the swamp to allow for filtration and mopping up of these chemicals and sediments. There is, therefore, need to conserve and restore these wetlands.

Acknowledgements

We wish to thank the Director, Kenya Wildlife Service, and his staff for allowing us to work within the Saiwa Swamp National Park and providing the necessary assistance we requested.

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