Journal of Agriculture and Ecology Research International

14(4): 1-19, 2018; Article no.JAERI.35588
ISSN: 2394-1073

Dwindling Wetland Ecosystems: A Survey of Impacts of Anthropogenic Activity on Marura Wetland, Kenya

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Authors' contributions

This work was carried out in collaboration between all authors. Author PMW designed the study, wrote the protocol and interpreted the data. Authors PMW and JMM anchored the field study, gathered the initial data. Author PMW performed preliminary data analysis. Authors NMM and RKA managed the literature searches. Author PMW produced the initial draft. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/JAERI/2018/35588
Editor(s):
(1) Normala Halimoon, Department of Environmental Sciences, Faculty of Environmental Studies, Universiti Putra Malaysia, Malaysia.
Reviewers:
(1) Siripavee Charoenwattanasak, Khon Kaen University, Thailand.
(2) Marcela Bianchessi da Cunha Santino, Universidade Federal de São Carlos, Brazil.
Complete Peer review History: http://www.sciencedomain.org/review-history/24364

Original Research Article

Received 20th July 2017
Accepted 9th August 2017
Published 28th April 2018

ABSTRACT

Many developed and developing member States to the Ramsar Convention on conservation of Wetlands have developed their national policies on wetlands conservation and management. Management systems that, on the global extent involve community based approaches have been developed. Nevertheless, many challenges in wetland conservation and management continue to determine the existence and survival of these ecosystems. Several unlike and intensely bad threats including undesirable anthropogenic activities, within the wetland catchment areas and in the wetlands, are a threat to these delicate ecosystems. The main objective of this study was to monitor the water quality using limnological variables from different sampling points of a swamp during the flood and drought period of the wetland. Nutrients such as nitrogen and phosphates were determined. Dissolved oxygen (DO), pH, turbidity, temperature, total solids and conductivity were determined using standard analytical procedures. There were six sampling points, Sampling

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point 1 was on Sergoit River before water enters Marura Wetland and acted as the control and the other five sampling points were within Marura Wetland, and were sampled in two seasons, wet and dry. The three replicas were collected four times in the dry season (December 2015 to March 2016) and four times during the wet season (April to July 2016). The findings revealed that there is a statistically significant difference between the control and test sample means of nitrates, phosphates, Dissolved oxygen, pH, Turbidity, Conductivity, and Total Solids. The results reveal that there is significance value of p = 0.000, which is below 0.05., and therefore, there is a statistically significant difference among the different parameters in test samples and control. There is a statistically significant difference in turbidity between test samples and control samples as determined by one-way ANOVA (F (11, 36) = 82.340, p = 0.000). There was a statistically significant difference in phosphates between study areas and control samples as determined by one-way ANOVA (F (11, 36) = 39.020, p = 0.000). There was a statistically significant difference in conductivity among the study areas and control samples as determined by one-way ANOVA (F (11, 36) = 651.859, p = 0.000). This study concludes that Marura Wetland is a polluted ecosystem as indicated by phosphorous, turbidity and conductivity that were above specifications by the Kenya National Water Quality Standards (KNWQS). The findings of this study provide an important baseline or insight from which to monitor future change in water quality of Marura Wetland. This study recommends that further studies should be conducted to establish the actual potential of the site and actual points of source pollution and the types of electrolytes dissolved in the waters of Marura Wetland. The study also recommends intervention by local and national authorities to safeguard this dwindling ecosystem.

Keywords: Socio economic importance; species diversity; point pollution; management options.

1. INTRODUCTION

Wetlands provide numerous, irreplaceable hydrological and ecological functions, including stabilization of water supplies, flood abatement, water purification, erosion control, recharge of groundwater aquifers and carbon sequestration [1,2,3]. Marura swamp originates from Sergoit River located in the northern part of Uasin Gishu County Kenya stretching a distance of 74kms wide to Katero. Marura swamp is a riverine wetland dominated by *Cyperus papyrus* and is faced with the problem of land use transformation from large scale ranching to small scale farming. The presence of Marura Wetland in a flat area makes it a point of concentrated human activities, which is slowly transforming into a cultivated area. This has been necessitated by the unreliable rainfall for rain-fed agriculture and the fact that the immigrants are crop cultivating communities as compared to the traditional use of the swamp by British settlers. Part of this wetland has now been drained for crop cultivation as a consequence of a study done by the colonial government between 1958-1961, which recommended the conservation of the swamp to absorb tons of heavy metals from large use of farm inputs upstream. Relationships between anthropogenic factors such as land use, point-source pollution, water management, and eutrophication parameters have been studied frequently [4,5]. Although this was the global view of wetlands at that time, the same recommendation is contained in the 1989-93 and 2005-15 Chepkiolel development plan. Understanding the influence of land use practices on water quality remains an important yet elusive goal for ecologists and resource managers alike. Numerous studies have demonstrated an association between watershed land use practices and pollution to surface waters. Before the 1970s, the dominant land use was large scale ranching and cash crop farming by the British settlers and colonialists. Since 1970, this has slowly been transformed into high density small scale farming. There has been a strong trend towards settlement along riverine and wetland areas due to their suitability for farming and easy availability of water for cultivation. Consequently, there is tendency of multiple source pollution from big as well as small farms. Marura swamp has rich species diversity over 100 birds' species, resident and migrant, over 100 plant species and it also provides an important wetland refuge for both domestic and wild animals. With continued pollution, there is likelihood of losing this biota. The swamp also provides socioeconomic products such as plant matter for building. The result of its land use transformation has been ecosystem alteration, habitat modification and destruction of wetland species. This diametrically contradicts the Ramsar convention of 1972 on wise use of wetlands which does not advocate drainage of wetlands. The general direction of river flow is northwards but even the main river, Sergoit, does not reach Lake Victoria basin as it disappears in the Yala Swamp through excessive evaporation. Wetlands, which cover about 2% of the land surface, are important sites for biological conservation because they support a rich biodiversity [2]. Wetlands are known to provide habitat to large number of aquatic organisms, offer ecosystem services such as water purification, nutrient cycling, carbon sequestration and also flood control. Some are a source of medicinal plants and cultural practices by the communities residing near the wetlands [6]. The rapid population growth has led to high demand for wetland products and need for settlement. Many communities, mostly in developing countries depend heavily on exploitation of the natural resources for their livelihood. Continuous use of natural resources together with an enormous increase in the amount of waste produced, are placing demands on aquatic ecosystems and thus, streams and rivers continue to bear the consequences of pollution [6]. This continued loss of habitat may lead to alteration of species of both plants and animals as well as loss of economic value of this scarce habitat. Kenya's wetlands are among the country's most important resources for social cultural and economic development [7]. However, increased demand for natural resources has resulted in their overexploitation thus affecting their structure, ecology and utilization [7].

1.1 Study Area

The study was carried out in Marura wetland, which is located near the University of Eldoret and about 7 Km from Eldoret town. Has catchment area of about 210 Km^2 [8]. The area, of bushy grassland, is characterized by moderate rainfall of more than 2000mm annually. Annual temperatures range between 8 and 27°C. Eldoret Municipality has an estimated population of 289,380 people [9].

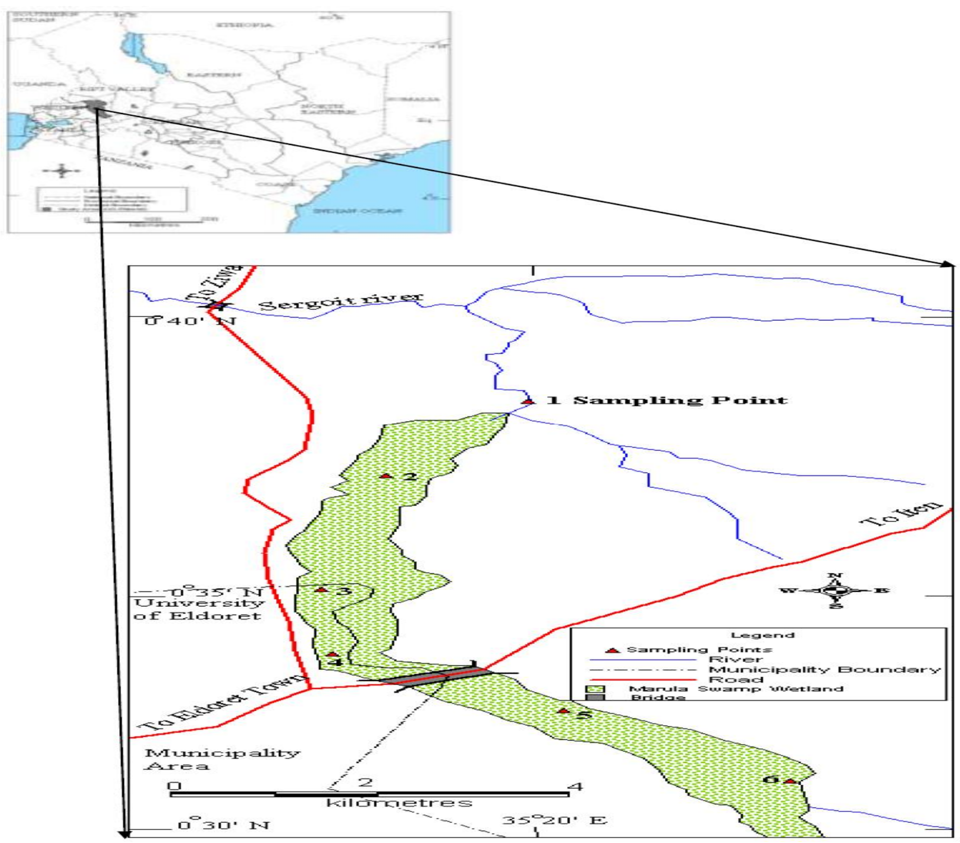

Fig. 1. Sampling points along Marura Wetland (By Luka C. Kanda; Moi university school of arts and social sciences)

2. METHODOLOGY AND DATA ANALYSIS

2.1 Sampling Method

During the months of December 2015 to July 2016, surface water quality measurement in Marura River was assessed by taking sample along the river, starting from the point where the wetland starts at Ilulla 30km east of point where the river crosses Iten Road. Survey was done in Marura area to identify suitable and representative sampling points, at places which were accessible on foot. Sampling points 1-4 were located West of Iten Road, while sampling points 5 and 6 were located to the east of Iten Road. Sampling point 1 is located 1km before the river enters Marura Wetland and acted as the control to determine the quality of the water before it enters into Murara Wetland. The sampling points were 15km apart from each other. Using a GPS system the coordinates (Ref: Table 1) of sampling points were determined. Sampling was carried out at each point in the mid-morning. Using sterilized sampling bottles, three samples were collected at each sampling point, to ensure that the data obtained was representative of the pollution level at the sampling station. The three replicas were collected four times in the dry season (December 2015 to March 2016) and four times during the wet season (April to July 2016). Using standard methods, the collected water samples were analyzed for turbidity, pH, dissolved oxygen, Total Dissolved Solids, nitrates, phosphates and electrical conductivity. The selected parameters was guided by the economic activities carried out in the area, which include; horticulture, dairy farming, wheat and maize farming, sports and tourism. This could involve heavy machines and farm inputs, which in turn can pollute the environment.

3. RESULTS AND DATA ANALYSIS

Quantitative analysis was done for the numerical data obtained from the field. Descriptive and inferential statistics were used to analyze the data. Means, standards deviations, variance, one way ANOVA and Pearson's correlation analysis were used to analyze the relationship between variables in relation to seasons. This was done using SPSS (version 24) statistical software. For solids and nutrients, one way ANOVA was used to analyze mean differences among the study samples and the control samples over the two seasons. Tukey test was used to analyze the significant differences between the test values and the control samples over the two seasons.

3.1 Results

This section provides different results after analysis. pH is reported as is (pH–log [H+]).

3.2 Water pH

In both the dry and wet seasons, the water pH of samples from in the three centers and control ranged from 6.32 to 7.32 over the dry season, and 6.96 to 7.62 over the wet season, where some values were below the required Kenya National Water Quality Standards (KNWQS) limits of 6.5-8.5 over the dry season (Table 4, Fig. 2). In all the sampling points, pH showed an increasing trend from the dry to wet season.

3.3 One Way ANOVA

Table 5 shows that the output of the ANOVA analysis where there is a statistically significant difference between the study areas and control sample means of nitrates, phosphates, dissolved oxygen, pH, Turbidity, Conductivity, and Total Solids. The results reveal that there is significance value of 0.000 (i.e., $p = 0.000$), which is below 0.05., and therefore, there is a ($p \le 0.05$) statistically significant difference among the different parameters in study area and control.

3.4 Water Temperature

There was a statistically significant difference in temperature between study areas and control samples as determined by one-way ANOVA ($F(11, 36) = 64.769$, $p = 0.000$). A Tukey post hoc test revealed that the temperature wetlands 3, 4 and 2 were not significantly different in the wet season, wetland 1 was not significantly different from the control in the wet season, wetlands 5 (wet season) control (dry) , wetlands 1, 2,3,4 and 5 (Dry season) were not significantly different. was significantly different from wetlands 1, 2, 3, 5 and the control (Table 6, Figure 3). Wetlands 2, 3 and 4 (wet) were significantly different from wetlands 1 and control during the wet season and was also significantly different from wetlands 5 (wet season), control dry season, and wetlands 2, 3, 1, 4 and 5 (Dry season). There was no statistically significant difference in pH in wetlands 1, 2, 3 and 5 during the dry season but there was a significant difference between the dry and wet season (Table 6, Fig. 3).

Table 1. GPS coordinates and altitude of the sampling points

	Units	ST1=Control	ST2=Wetland 1	ST3=Wetland 2	ST4=Wetland 3	ST5=Wetland 4	ST6=Wetland 5
	GPS Reading	N00º31'21" E035º21'32''	N00º31'07" E035º21'01''	N00º32'32" E035º20'88''	N00º33'35" E035º19'57''	N00º33'66" E035º19'21''	N00º35'10" E035º20'28''
Altitude	Altitude (m)	2193.04	2179.32	2176.58	2153.11	2150.06	2140.92

Table 2. Standard analytical procedures

Variable	Reference of standard method used
Determination of water pH	APHA, [10]
Determination of water turbidity	APHA, [10]
Determination of water temperature	APHA, [10]
Determination of total solids	APHA, [10]
Determination of nitrates	Andrew et al. [11], APHA, [10]
Determination of phosphates	Andrew et al. [11]
Determination of DO	APHA, [10]
Determination of conductivity	Faulkner et al. [12]

Table 3. Mean (±SEM) levels of physicochemical characteristics in samples from different sampling points during the dry and wet seasons

	N	(Dry season)				(Wet season)			
	Statistic	**Statistic**	**Std. error**	**Std. deviation**	**Variance**	**Mean statistic**	**Std. Error**	**Std. deviation**	**Variance**
Nitrate	24	0.6438	±0.04135	0.20257	0.041	1.0658	±0.05041	Statistic	Statistic
Phosphate	24	1.3142	±0.06417	0.31435	0.099	1.8604	±0.10354	0.24695	0.061
DO	24	11.8671	±0.98473	4.82418	23.273	14.4529	±0.69638	0.50722	0.257
Temperature	24	21.5775	±0.05550	0.27191	0.074	20.2450	±0.13626	3.41157	11.639
Turbidity	24	26.6904	±3.07095	15.04452	226.337	26.3638	±0.62665	0.66753	0.446
Conductivity	24	101.6658	±15.48315	75.85165	5753.474	67.3371	±8.68615	3.06993	9.424
TS	24	187.6250	±15.25874	74.75224	5587.897	199.7083	±8.78373	42.55326	1810.780

Table 4. Levels of pH–log [H+] in samples from different sampling points during dry and wet seasons

Sampling dates Dry season		DRY	Sampling dates Wet season	
	Variables	pH		pH
6th December 2015	W 1	7.14	6th April 2016	7.44
6th January 2016	W 1	7.32	6th May 2016	7.62
6th February 2016	W 1	7.28	6th June 2016	7.48
6th March 2016	W1	7.11	6th July 2016	7.51
6th December 2015	W2	6.88	6th April 2016	7.18
6th January 2016	W2	6.79	6th May 2016	7.29
6th February 2016	W2	6.99	6th June 2016	7.19
6th March 2016	W2	6.85	6th July 2016	7.15
6th December 2015	W3	6.71	6th April 2016	7.21
6th January 2016	W3	6.85	6th May 2016	7.25
6th February 2016	W3	6.74	6th June 2016	7.34
6th March 2016	W3	6.71	6th July 2016	7.27
6th December 2015	W4	6.89	6th April 2016	7.29
6th January 2016	W4	6.93	6th May 2016	7.19
6th February 2016	W4	6.84	6th June 2016	7.37
6th March 2016	W4	6.88	6th July 2016	7.28
6th December 2015	W5	6.32	6th April 2016	7.23
6th January 2016	W5	6.37	6th May 2016	7.12
6th February 2016	W5	6.49	6th June 2016	7.19
6th March 2016	W5	6.41	6th July 2016	6.98
6th December 2015	W6	6.89	6th April 2016	6.97
6th January 2016	W6	6.78	6th May 2016	6.99
6th February 2016	W6	6.87	6th June 2016	7.17
6th March 2016	W6	6.88	6th July 2016	6.96

Table 5. ONE-WAY ANOVA showing significance differences among the study areas

ANOVA						
		Sum of squares	**df**	**Mean square**	**F**	**Sig.**
	Within Groups	.213	36	.006		
	Total	4.125	47			
Temperature	Between Groups	31.656	11	2.878	64.769	.000
	Within Groups	1.600	36	.044		
	Total	33.256	47			
DO	Between Groups	869.579	11	79.053	208.877	.000
	Within Groups	13.625	36	.378		
	Total	883.203	47			
Turbidity	Between Groups	5216.468	11	474.224	82.340	.000
	Within Groups	207.337	36	5.759		
	Total	5423.805	47			
Nitrates	Between Groups	4.277	11	.389	67.598	.000
	Within Groups	.207	36	.006		
	Total	4.484	47			
Conductivity	Between Groups	187179.641	11	17016.331	651.859	.000
	Within Groups	939.756	36	26.104		
	Total	188119.397	47			
Phosphate	Between Groups	9.739	11	.885	15.684	.000
	Within Groups	2.032	36	.056		
	Total	11.771	47			
TS	Between Groups	159486.167	11	14498.742	39.020	.000
	Within Groups	13376.500	36	371.569		
	Total	172862.667	47			

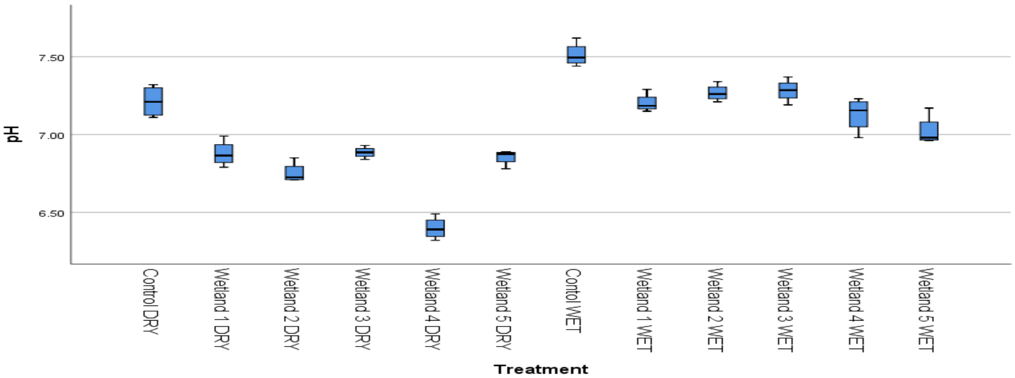

Fig. 2. Variation in pH down River Sergoit

Table 6. Levels temperature in samples from different sampling points during dry and wet seasons

Temperature				
Tukey HSD[a]				
Treatment	**N**	**Subset for alpha = 0.05**		
		1	**2**	**3**
Wetland 3 WET	4	19.4000[a]		
Wetland 4 WET	4	19.7100[a]		
Wetland 2 WET	4	19.9150[a]		
Control WET	4		20.4875[b]	
Wetland 1 WET	4		20.6500[b]	
Wetland 5 WET	4			21.3075[c]
Control DRY	4			21.3275[c]
Wetland 2 DRY	4			21.5525[c]
Wetland 3 DRY	4			21.5650[c]
Wetland 1 DRY	4			21.5950[c]
Wetland 4 DRY	4			21.5975[c]
Wetland 5 DRY	4			21.8275[c]
Sig.		0.054	0.993	0.050

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 4.000.
Different letters (s) are significantly different at p=0.05, One way ANOVA: Tukey test.

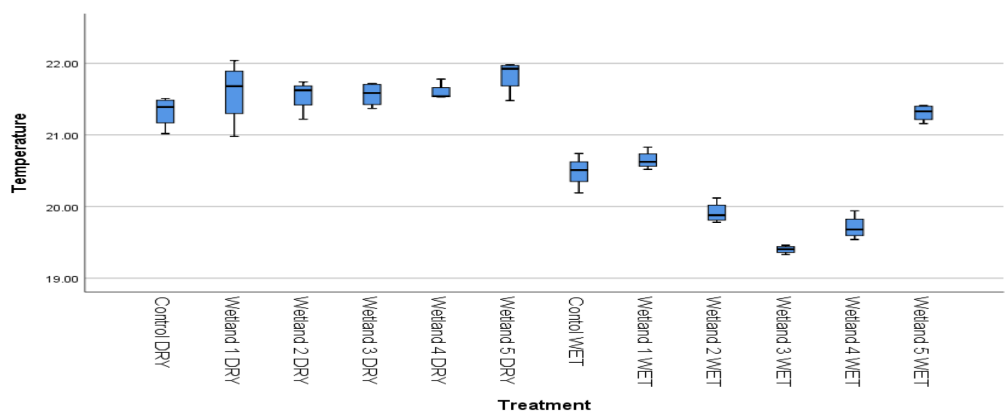

Fig. 3. Variation in temperature down River Sergoit

3.5 Dissolved Oxygen

There was a statistically significant difference in DO between study areas and control samples as determined by one-way ANOVA (F (11, 36) = 64.769, p = 0.000) (Table 7, Fig. 4). A Tukey post hoc test revealed that the DO in the control during the dry and wet seasons was significantly different from wetlands 1, 2, 3, 4, and 5 in both seasons. (Table 7, Fig. 4).

3.6 Water Turbidity

There was a statistically significant difference in turbidity between study areas and control samples as determined by one-way ANOVA (F (11, 36) = 82.340, p = 0.000) (Table 8, Fig. 5). A Tukey post hoc test revealed that the turbidity in wetland 3 and 2 in the dry season were significantly different from wetlands 2, 4, 1, 3 and 5 over the wet season and the control during the wet and dry seasons, and wetlands 4, 5 and 1 during the dry season (Table 8, Fig. 5).

3.7 Water Nitrates

There was a statistically significant difference in nitrates between study areas and control samples as determined by one-way ANOVA (F (11, 36) = 67.598, p = 0.000) (Table 9, Fig. 6). A Tukey post hoc test revealed that the nitrates levels in wetlands 4 and 1 were not significantly different from the control during dry season (Table 9, Fig. 6). There was no statistically significant difference in nitrate level in wetlands 5 during the wet and dry seasons during but there was a significant variation in nitrate levels between the dry and wet season (Table 9, Fig. 6).

3.8 Conductivity

There was a statistically significant difference in conductivity between study areas and control samples as determined by one-way ANOVA (F (11, 36) = 651.859, p = 0.000). A Tukey post hoc test revealed that the conductivity in wetlands 1, 2, 3, 4 and 5 was significantly different from the control during the wet and dry seasons (Table 10, Fig. 7).

3.9 Water Phosphates

There was a statistically significant difference in phosphates between study areas and control samples as determined by one-way ANOVA (F (11, 36) = 15.684, p = 0.000). A Tukey post hoc test revealed that there was significantly different from wetlands between the wet and the dry season (Table 11, Fig. 8). There was significant difference in the control samples between the wet and dry seasons (Table 11, Fig. 8).

Table 7. Variation in levels of DO in samples from different sampling points during dry and wet seasons

DO							
Tukey HSD[a]							
Treatment	**N**	**Subset for alpha = 0.05**					
		1	**2**	**3**	**4**	**5**	**6**
Wetland 5 DRY	4	5.4225[a]					
Wetland 4 DRY	4	6.9350[a]					
Wetland 5 WET	4		9.8725[b]				
Wetland 3 DRY	4		10.4850[b]				
Wetland 4 WET	4		10.9000[b]				
Wetland 3 WET	4			13.6800[c]			
Wetland 2 DRY	4			13.8825[c]			
Wetland 1 DRY	4				15.9350[d]		
Wetland 2 WET	4				16.1250[d]		
Wetland 1 WET	4				17.2850[d]	17.2850[de]	
Control DRY	4					18.5425[e]	18.5425[ef]
Control WET	4						18.8550[f]
Sig.		0.052	0.455	1.000	0.121	0.187	1.000

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 4.000.
Different letters (s) are significantly different at p=0.05, one way ANOVA: Tukey test.

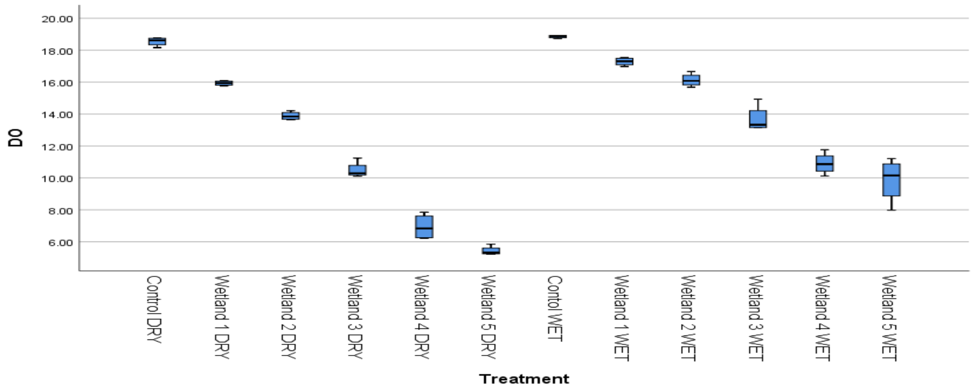

Fig. 4. Variation in dissolved oxygen (DO) down River Sergoit

Table 8. Variation in levels of turbidity in samples from different sampling points during dry and wet seasons

Turbidity							
Tukey HSD[a]							
Treatment	**N**	**Subset for alpha = 0.05**					
		1	**2**	**3**	**4**	**5**	**6**
Wetland 3 DRY	4	12.2125[a]					
Wetland 2 DRY	4	14.8925[a]					
Control DRY	4		21.3325[b]				
Wetland 2 WET	4		22.5125[b]	22.5125[bc]			
Wetland 4 DRY	4		24.4875[b]	24.4875[bc]	24.4875[d]		
Control WET	4		25.2750[b]	25.2750[bc]	25.2750[bcd]	25.2750[e]	
Wetland 4 WET	4		27.1375[b]	27.1375[bc]	27.1375[bcd]	27.1375[bcde]	
Wetland 1 WET	4		27.1850[b]	27.1850[bc]	27.1850[bcd]	27.185[bcde]	
Wetland 3 WET	4			27.4675[c]	27.4675[cd]	27.4675[cde]	
Wetland 5 WET	4				28.6050[d]	28.6050[de]	
Wetland 5 DRY	4					30.8525[e]	
Wetland 1 DRY	4						56.3650[f]
Sig.		0.905	0.055	0.177	0.415	0.081	1.000

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 4.000.
Different letters (s) are significantly different at p=0.05, one way ANOVA: Tukey test

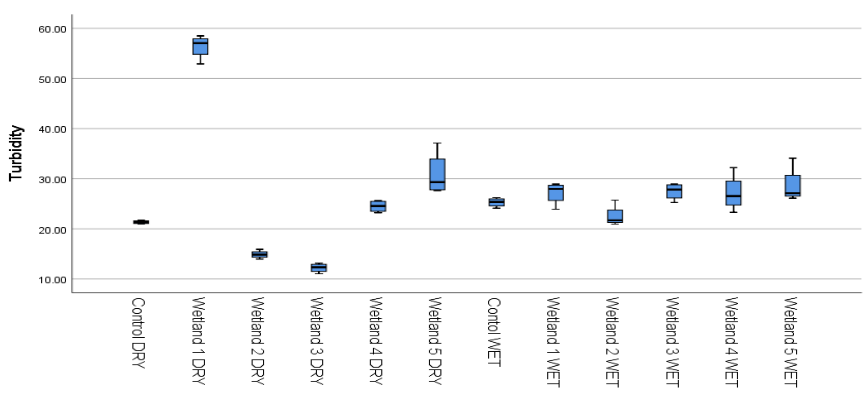

Fig. 5. Variation in turbidity down river Sergoit

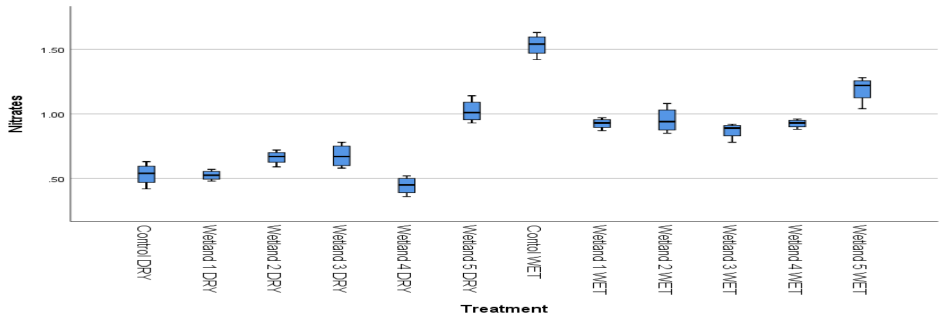

Fig. 6. Variation in nitrates down river Sergoit

Table 9. Variation of levels of nitrate in samples from different sampling points during dry and wet seasons

Nitrates						
Tukey HSD[a]						
Treatment	**N**	**Subset for alpha = 0.05**				
		1	**2**	**3**	**4**	**5**
Wetland 4 DRY	4	0.4450[a]				
Wetland 1 DRY	4	0.5250[a]	0.5250[b]			
Control DRY	4	0.5325[a]	0.5325[b]			
Wetland 2 DRY	4		0.6625[b]			
Wetland 3 DRY	4		0.6750[b]			
Wetland 3 WET	4			0.8700[c]		
Wetland 1 WET	4			0.9250[c]		
Wetland 4 WET	4			0.9250[c]		
Wetland 2 WET	4			0.9525[c]		
Wetland 5 DRY	4			1.0225[c]	1.0225[cd]	
Wetland 5 WET	4				1.1900[d]	
Contol WET	4					1.5325[e]
Sig.		0.886	0.224	0.205	0.116	1.000

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 4.000

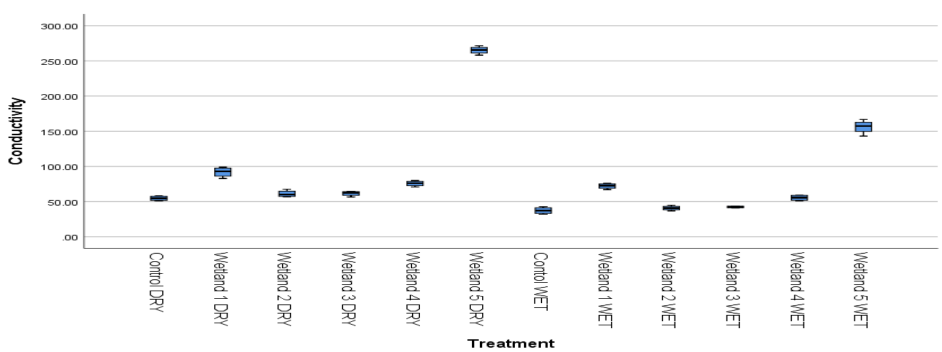

Fig. 7. Variation in conductivity down River Sergoit

3.10 Total Solids

There was a statistically significant difference in total solids between study areas and control samples as determined by one-way ANOVA ($F_{(11, 36)} = 39.020$, $p = 0.000$). A Tukey post hoc test revealed that the level of total solids in control during the wet season was significantly different from the study samples, while the control in the dry season revealed insignificant difference with wetlands 2, 3 and 4 during the dry season, but revealed significant difference with wetlands 1 and 5 during both dry and wet seasons (Table 12, Fig. 9).

4. DISCUSSION OF RESULTS

The World Health Organization (WHO) provides guidelines for drinking water quality (Table 13). Further, Kenya National Water Quality Standards (KNWQS) have been cascaded from international standards (Table 13) for water for domestic use and also for agricultural practices [13].

4.1 Water Temperature

It was established that water temperature was varied between the two seasons, wet and dry, and also among the test samples, but there was insignificant difference as the temperatures were within the KNWQS, which can be attributed to multiple source pollution from adjacent farms and industrial wastes that find their way to contaminate the waters of Marura Wetland. The temperature ranged from a low of 19.22±1.88°C to a high of 21.54±2.33ºC. Water temperature is an important parameter that plays a vital role in regulating nearly all other physical and chemical characteristics of water as well as the biological productivity [14]. Findings from this study revealed that water temperature of the dry season had a mean of 21.56±0.06ºC and the wet season had a mean value of 20.25±0.14ºC (Table 3). Fluctuation in water temperature down the river maybe linked to high air temperature [15,16] and low water level [17] during the dry season. Temperature affects the solubility of many chemical compounds and can therefore influence the effect of pollutants on aquatic life [18]. Increased temperatures elevate the metabolic oxygen demand, which in conjunction with reduced oxygen solubility, impacts many species. The findings of this study are in agreement with those of Jastram et al. [18] who attributed to multiple source pollution from wastes that find their way to contaminate the waters of Wetlands.

4.2 pH

It was established that the pH in water varied the in relation to source of the water as well as the probable sources of pollution. It ranged from 6.32 to 7.32 over the dry season, and 6.96 to 7.62 over the wet season (Table 4). This is an indication of multiple source pollution. Despite the abilities of the plants to remove toxic materials from the waters, there is continuous pollution from the source (Station 1 [control]) to the end (Station [wetland 5]). This pH was within range of KNWQS (Table 13), with exception of wetland 4 over the dry season. Although the tolerance of individual species varies, pH values between 6.5 and 8.5 usually indicate good water quality and this range is typical of most major drainage basins of the world. Water pH can be affected by soil characteristics. Analysis of the pH data generally indicates a broad range of composition indicative of mixed natural and anthropogenic pollutant sources [19]. Pollution can change water pH, which in turn can harm animals and plants living in the water. Additionally, pH indicates whether wetland water is saline or freshwater thus determines the suitability of wetlands for particular plants and animals. For example, macrophytes such as *Cyperus papyrus* thrive well in freshwater environs while *Typha spp* are adapted for saline conditions. In wetlands where they both exist indicates existence of a pH gradient from saline to freshwater conditions or brackish waters. Marura wetland is characterized by *Cyperus papyrus. Typha spp* was established only on few places, probably an indicator to probable different levels of pollution of Marura wetland at different points.

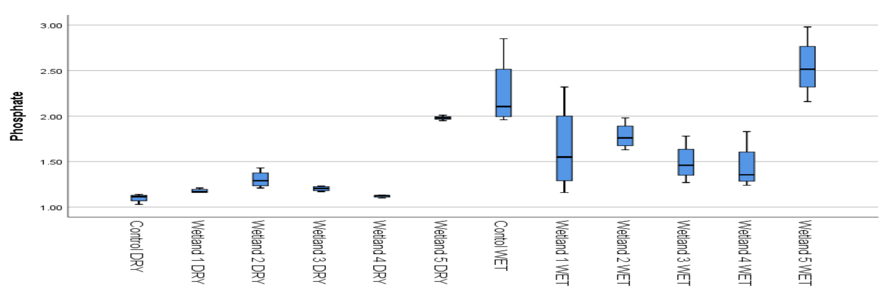

Fig. 8. Variation in phosphates down River Sergoit

Table 10. Variation of conductivity in samples from different sampling points during dry and wet seasons

Conductivity									
Tukey HSD[a]									
Treatment	**N**	**Subset for alpha = 0.05**							
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Control WET	4	37.2400[a]							
Wetland 2 WET	4	40.7725[a]							
Wetland 3 WET	4	42.3550[a]	42.3550[b]						
Control DRY	4		54.6125[b]	54.6125[bc]					
Wetland 4 WET	4			55.4450[c]					
Wetland 2 DRY	4			61.0600[c]	61.0600[cd]				
Wetland 3 DRY	4			61.5350[c]	61.5350[cd]				
Wetland 1 WET	4				72.0550[d]	72.0550[de]			
Wetland 4 DRY	4					75.7350[e]			
Wetland 1 DRY	4						91.8925[f]		
Wetland 5 WET	4							156.1550[g]	
Wetland 5 DRY	4								265.1600[h]
Sig.		.953	.063	.742	.137	.996	1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 4.000.
Different letters (s) are significantly different at p=0.05, one way ANOVA: Tukey test.

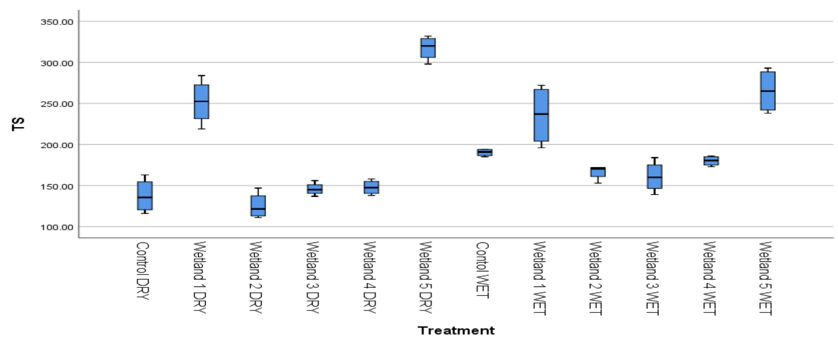

Fig. 9. Variation in TS down River Sergoit

Table 11. Variation of phosphates in samples from different sampling points during dry and wet seasons

Phosphate						
Tukey HSD[a]						
Treatment	N	Subset for alpha = 0.05				
		1	2	3	4	5
Control DRY	4	1.1000[a]				
Wetland 4 DRY	4	1.1200[a]				
Wetland 1 DRY	4	1.1775[a]				
Wetland 3 DRY	4	1.2025[ab]	1.2025[ab]			
Wetland 2 DRY	4	1.3050[ab]	1.3050[ab]			
Wetland 4 WET	4	1.4450[abc]	1.4450[ab]	1.4450[c]		
Wetland 3 WET	4	1.4925[abc]	1.4925[ab]	1.4925[c]		
Wetland 1 WET	4	1.6450[abc]	1.6450[ab]	1.6450[c]		
Wetland 2 WET	4		1.7825[bcd]	1.7825[bcd]	1.7825[bcd]	
Wetland 5 DRY	4			1.9800[c]	1.9800[cd]	1.9800[cde]
Control WET	4				2.2550[d]	2.2550[de]
Wetland 5 WET	4					2.5425[e]
Sig.		0.089	0.055	0.101	0.217	0.070

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 4.000.
Different letters (s) are significantly different at p=0.05, one way ANOVA: Tukey test.

Table 12. Variation of total solids in samples from different sampling points during dry and wet seasons

TS							
Tukey HSD[a]							
Treatment	N	Subset for alpha = 0.05					
		1	2	3	4	5	6
Wetland 2 DRY	4	125.2500[a]					
Control DRY	4	137.5000[a]	137.5000[ab]				
Wetland 3 DRY	4	145.7500[a]	145.7500[ab]	145.7500[abc]			
Wetland 4 DRY	4	147.7500[a]	147.7500[ab]	147.7500[abc]			
Wetland 3 WET	4	160.7500[a]	160.7500[ab]	160.7500[abc]			
Wetland 2 WET	4	166.5000[a]	166.5000[ab]	166.5000[abc]			
Wetland 4 WET	4		180.0000[b]	180.0000[bc]			
Control WET	4			190.2500[c]	190.2500[cd]		
Wetland 1 WET	4				235.5000[d]	235.5000[de]	
Wetland 1 DRY	4					252.0000[e]	
Wetland 5 WET	4					265.2500[e]	
Wetland 5 DRY	4						317.5000[f]
Sig.		0.142	0.117	0.085	0.075	0.571	1.000

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 4.000.
Different letters (s) are significantly different at p=0.05, one way ANOVA: Tukey test.

4.3 DO

The solubility of oxygen and particularly the dynamics of oxygen distribution in wetland waters are basic to the understanding of the distribution, behaviour, and growth of aquatic organisms. DO in a stream may vary from 0 mg/L to 18 mg/L. DO values fluctuated from 1.86±0.98 mg/L (Dry season) (Ref: Table 3) to 14.45±0.70 mg/L (Wet season) (Ref: Table 3). Findings from this study revealed that DO of the dry season with a mean value of 11.88±0.98 mg/L and the wet season with a mean value of 14.45±0.70 mg/L (Table 3). DO was minimum at sampling point 5 and maximum at the source (sampling point 1 [Control]). Decrease in DO value down the river may be attributed to consumption due to decomposition of organic matter, slow movement of water with minimum turbulence and pollution. These findings are in agreement with those of Verma and Thirupathaiah [20,16] who described effects of decomposition of organic matter on levels of DO. These phenomena can also be attributed to high metabolic rate of organisms that inhabit this ecosystem. Increase over the two seasons maybe attributed to turbulence from fast moving waters over the rainy season as compared to the dry season [16].

Table 13. Guidelines set by WHO and KNWQS for drinking water

Parameter	WHO	KNWQS
Temperature	19-30°C	19-30°C
pH	6.5-8.5	6.5-8.5
Total solids	1200 (mg/L)	1200 (mg/L)
DO	0 -18mg/L	0 - 18mg/L
Conductivity	<50 µS/cm	<50 µS/cm
Nitrate-NO_3	10 (mg/L)	10 (mg/L)
Phosphate	<0.05 (mg/L)	<0.05 (mg/L)
Turbidity	<5NTU	<5 NTU

4.4 Nitrate

The nitrate values did not show much fluctuation during the study and ranged from 0.64±0.04 mg/L (Ref: Table 1) in dry season to a high of 1.07±0.05 mg/L (Ref: Table 2). Presence of nitrates in water indicates the final stage of mineralization. The result revealed that there was significant variation in physicochemical parameters and most of the parameters were in the normal range and indicates good quality of water and effects of nutrient extraction by plants. These findings are in agreement with those of Saeed [21] and Vymazal, [22] who described wastewater flow to the next stage of the hybrid system which consist of horizontal subsurface flow system, that promotes reduction of the nitrates by chemo-autotrophic bacteria to gaseous forms of nitrogen (nitric oxide, nitrous oxide and dinitrogen) [21,22] which greatly reduced the effluent TN levels. The findings of this study also agree with those of Zhang et al., [23] who observed that wetland system achieved high TN removal. Findings from this study revealed that nitrates of the dry season had a mean value of 0.64±0.04 mg/L and the wet season had a mean value of 1.07±0.05 mg/L (Table 3). This reveals that the nitrate values increased over the wet season as compared to the dry season. These results also agree with those of Mishra [24]. Nitrate concentration is influenced by dilution with low-nitrate water entering the wetland [24] and this can be related to increase in runoff waters from surrounding farms.

4.5 Phosphate

The phosphate values did not show much fluctuation during the study and ranged from 1.31±0.06 mg/L (dry season) (Ref: Table 1) to 1.86±0.10 mg/L (wet season) (Ref: Table 1). Findings from this study revealed that phosphates of the dry season had a mean value of 1.31±0.06 mg/L and the wet season had a mean value of 1.86±0.10 mg/L (Table 3). The values of phosphate were higher in the wet season as compared to the dry season and were above the recommended standards by the KNWQS of <0.05 (mg/L) (Table 13). This is an indication of probable source of pollution that is releasing phosphates into the River. Numerous studies have demonstrated an association between watershed land use and phosphate loading to surface waters. These findings are in agreement with those of Omernik, Luz E and Allan [25,26,27] describing the relationships between land use and water quality are surprisingly variable at the scale of entire watersheds [25,26,27]. Presence of phosphates in water indicates the possibility of algal blooms which can cause death of aquatic animals. Algae provide essential ecosystem services and, as such, are the key element of the aquatic food web [28]. The result revealed that there was significant variation in phosphates, and can be attributed to excessive nutrients input into wetlands can cause perturbation of the ecosystem. Further, the results reveal that there is pollution from other sources upstream as higher values of phosphates were revealed in the control over the wet season. Phosphate is considered to be the primary driver of eutrophication of aquatic ecosystems, where increased nutrients loads lead to increased primary productivity. These eutrophic states indicate nutrient enrichment as result of human activities such as runoff from agricultural lands and the discharge of municipal and industrial wastes into Marura Wetland.

4.6 Conductivity

The Conductivity values showed significant fluctuation during the study and ranged from 101.6658±15.48315µS/cm (dry season) (Ref:

Table 1) Station 1to 67.3371±8.68615 µS/cm (wet season) (Ref: Table 2). Findings from this study revealed that conductivity of the dry season had a mean value of 101.67±15.48µS/cm and the wet season had a mean value of 67.34±8.69 µS/cm (Table 3). The values of Conductivity were higher in the dry season as compared to the wet season, and were above the recommended standards by the KNWQS of <50 µS/cm (Table 13). Specific conductance is a measure of the ability of water to conduct an electrical current. The usual conductivity range for a contacting sensor is 0.01 to 50,000 uS/cm. It is expressed as micro- or millisiemens per centimeter (uS/cm or mS/cm) of conductance. It is highly dependent and correlated with the amount of dissolved solids (such as salt) in the water [29] and temperature. Temperature influences water density, which leads to stratification. Stratified water can have different conductivity values at different depths. These findings are in agreement with those of LCRA, [30] who described that evaporation can cause salinity concentrations to rise. As the water level lowers, the ions present become concentrated, contributing to higher conductivity levels [30]. Pure water, such as distilled water, will have a very low specific conductance, and sea water will have a high specific conductance. River water often dissolves lots of material and thus often has a higher specific conductance than distilled water. Specific conductance is an important water-quality measurement because it gives a good idea of the amount of dissolved material in the water. High specific conductance may indicate pollution from various sources including effluents from domestic, industrial, and agricultural wastes. Water flow and water level changes can also contribute to conductivity through their impact on salinity.

4.7 Turbidity

This is a measure of the suspended particulate matter in a water body which interferes with the passage of a beam of light through the water. Turbidity values showed significant fluctuation during the study and ranged from 26.6904±3.07095 Nephelometric Turbidity Units (NTU) [Dry season] to 26.3638±0.62665 NTU (wet season) (Ref: Table 1). High turbidity values are seen in wetland 1 during the dry season and wetland 5 during the wet season. This can be attributed to multiple source pollution that waste water is being discharged into waters of Marura Wetland at these points. These findings are in agreement with Kaberi et al. [31] who explored the maximum and minimum aquatic turbidity between different seasons and showed different values of turbidity in different seasons, monsoon and post monsoon. The findings of this study revealed that the wet season decreases the turbidity in waters of this ecosystem (Fig. 5), which can be attributed to dilution factor of rainwaters. Findings from this study revealed that turbidity of the dry season had a mean value of 26.69±3.071 NTU and the wet season had a mean value of 26.36±0.63 NTU (Table 3). Findings showed that turbidity was above the recommended values of <5NTU (Table 13). Materials that contribute to turbidity are silt, clay, organic material, or micro-organisms. High levels of turbidity increase the total available surface area of solids in suspension upon which bacteria can grow. High turbidity reduces light penetration; therefore, it impairs photosynthesis of submerged vegetation and algae. In turn, the reduced plant growth may suppress fish productivity. Turbidity interferes with the disinfection of drinking water and is aesthetically unpleasant.

4.8 Total Dissolved Solids

High concentrations of total dissolved solids may cause adverse taste effects. Total dissolved solids in study area River water samples reveal a fairly lager range of variation from 187.63±15.26 to 199.71±8.78 mg/L, which was within the KNWQS permitted value of not more than 1200 (mg/L). TDS ranges of all the samples were within permissible limit (maximum1200 mg/L), in Kenya. These findings are in agreement with those of Barakati and Abolfazl, [32,33] also in a study on treatment of hospital wastewater by Vetiver and typical reed plants in a horizontal flow wetland who observed that the removal of solids is characteristic of wetland vegetation, and the low values obtained can be attributed to sedimentation of particles and filtration by the vegetation in the wetland. The physical removal of the solids is usually done by media and the roots [34]. Findings from this study revealed that TDS of the dry season had a mean value of 187.63±15.26 mg/L and the wet season had a mean value of 199.71±8.78 mg/L (Table 3). The findings reveal that there was variation between the wet and the dry season, with higher values being obtained in the wet season as compared to the dry season (Fig. 9), and this can be attributed to runoff water from rain and turbulence of waters of the wetland caused by fast moving water over the wet season as compared to the dry season. Wetlands are considered to be the best choice to treat wastewater since they are economical and effective in pollutants removal [35]. The removal of toxic content from waste water in a wetland is done by the vegetation. This findings show that solids in Marura Wetland are not a major concern during the period of study.

5. CONCLUSION AND RECOMMENDATION

The main objective of this study was to monitor the water quality using limnological variables from different sampling points of a swamp during the flood and drought period of the wetland in order to determine levels of pollution. As described by the findings, Marura Wetland is a dwindling habitat at the time of study and requires more attention to avert pollution than is given at the moment. This study concludes that Marura Wetland is a polluted ecosystem as indicated by phosphates, turbidity and conductivity that were above specifications by the KNWQS. The findings of this study provide an important baseline from which to monitor future change in water quality of Marura Wetland. This study recommends that studies should be conducted to establish the actual potential of the site and actual points of source pollution and the types of electrolytes dissolved in the waters of Marura Wetland.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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Peer-review history:
The peer review history for this paper can be accessed here:
http://www.sciencedomain.org/review-history/24364