

Original Research Article

DWINDLING WETLAND ECOSYSTEMS: A SURVEY OF IMPACTS OF ANTHROPOGENIC ACTIVITY ON MARURA WETLAND, KENYA

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. This study investigated effect of multiple point source pollution on the physicochemical environment of the wetland. Nutrients such as nitrogen and phosphorus were determined. Dissolved oxygen was measured using a dissolved oxygen meter. pH was determined by dipping the pH meter probe in half of 100ml of sample, stirring continued and steady pH reading obtained. Nephelometric method, using a turbidity meter, was used for the measurement of turbidity. There is a statistically significant difference between the control and test sample means of nitrates, phosphates, Dissolved oxygen, pH, BOD5, 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 between study areas and control samples as determined by one-way ANOVA ($F(11, 36) = 651.859, p = 0.000$). This study concludes that there is non-point source pollution as there is variation in water quality all along the river. The study recommends intensified management on close monitoring of effluent discharge into this ecosystem. Catchment areas should also be monitored, as many illegal settlements at the ecotone regions of this ecosystem may be linked to dumping of waste materials and other domestic wastes.

Key words: Socio economic importance, species diversity, Point pollution, Management options.

INTRODUCTION

Marura swamp originates from Sergoit River located in the northern part of Uasin Gishu County Kenya stretching a distance of 74kms wide to Katero. The area, of bushy grassland, is characterized by moderate rainfall (more than 2000mm annually) and episodic rivers. Marura swamp is a riverine wetland dominated by *Cyperus papyrus*. Marura wetland is faced with the problem of land use transformation from large scale ranching to small scale farming. Its presence 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. Although this was the global view of wetlands at that time, the same recommendation is contained in the 1989-93 and 2005-15 Chepkiol development plan. 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 (Mitsch and Gosselink, 2007). 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 (Masese et al., 2009). 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 (Masese et al., 2009).

72

73 **Study area**

74

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 Km² (Jaetzold and Schmidt, 1983). 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 (Kenya Institute of Public Policy Research and Analysis [KIPPRA], 2013). Economic activities include; horticulture, dairy farming, wheat and maize farming, sports and tourism.

82

Statement of the problem

Page 3 of 21

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 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 (Kareri, 1992). However, increased demand for natural resources has resulted in their overexploitation thus affecting their structure, ecology and utilization (Kareri 1992).

METHODOLOGY AND DATA ANALYSIS

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 acted as the control. The sampling points were 15km apart from each other. Using a GPS system the coordinates (Ref: Table 1A) 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 for 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 water samples collected were analyzed for turbidity, pH, dissolved oxygen, Total Dissolved Solids, nitrates, phosphates and electrical conductivity.

Table 1A: 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
	<i>GPS Reading</i>	N00°31'21" E035°21'32"	N00°31'07" E035°21'01"	N00°32'32" E035°20'88"	N00°33'35" E035°19'57"	N00°33'66" E035°19'21"	N00°35'10" E035°20'28"
Altitude	Altitude (m)	2193.04	2179.32	2176.58	2153.11	2150.06	2140.92

Determination of water pH

The pH of the water samples was measured ex-situ using the standard protocols and methods of American Public Health Association [APHA], 1995). This was done in the laboratory by direct reading on a pH meter (Labtech, Model pH-Pro12, Serial. No.-1530, India). The pH meter calibration was done according to the manufacturer's specifications, before recording the measurements. Standard buffer solutions of pH 4 and pH 7 were used for calibration. Fresh buffer solutions of pH 4 and 7 were prepared and then dispensed separately in clean 250 mL glass beakers, and the pH meter electrode immersed in the solution one at a time, to a depth of 2 cm. Calibration was done at both pH 4 and pH 7 by pressing the calibration knob. Another 250 mL beaker was filled with the water from one well. The pH value of the sample was recorded from the digital display after submerging the pH probe in the water sample and holding for 5 minutes to achieve a stabilized reading. After the measurement of each sample, the probe was rinsed with deionized water (American Public Health Association [APHA],

1995), and the procedure was repeated for all the water samples. Three replicate samples were measured and the mean value recorded (APHA, 1995).

Determination of water turbidity

A turbidity meter (LaMotte Turbidimeter, Model 2008, Code 1790; USA) was used to measure turbidity of the water samples. Calibration of the turbidimeter was done using the cuvette with distilled water, where 10 mL of distilled water was pipetted into a cuvette and was used to calibrate the turbidimeter. Each sample was dispensed into a cuvette; 10 mL of sample water was measured by use of a pipette. After achieving stability, the turbidity value of the water samples were recorded by direct readings from the turbidimeter. Three replicate samples were measured and the mean value recorded (APHA, 1995).

Determination of water temperature

Water temperature was determined in the field at the time of collection of the water samples. For each study zone, 50 mL of water sample from a well was poured into a 100 mL glass beaker and the Mercury thermometer was immersed in the sample 5 cm below the surface of the water for at least 3 minutes before recording the reading was recorded. Three replicate samples were measured and the mean value recorded (APHA, 1995).

Determination of total solids

The Total Solids were determined by evaporation technique in which the total solid material was collected and determined gravimetrically (APHA, 1995). Water samples were placed in 500 mL stoppered plastic containers. Each water sample was mixed thoroughly by shaking and stirring in their respective containers. A 50 mL water sub-sample was transferred to a pre-weighed glass evaporating dish. The sample was then let to evaporate to dryness on a steam bath at 110°C for 4 hours and then dried in an air oven at 110°C for 1 hour. Increase in weight over that of the pre-weighed empty dish was recorded as the weight of total solids (APHA, 1995). The dried sample was then left to cool to room temperature in desiccator and weighed to the nearest grams using a three decimal place analytical balance. This was followed by calculations as illustrated below (Equation 3.2).

Calculation for total solids

$$\text{Total solids } \frac{\text{g}}{\text{L}} = \frac{(W_1 - W_2)}{V} \times 1000 \dots \dots \dots \text{(Equation 3.2)}$$

Where:

W1=Mass of dried residue and evaporating dish in grams (after evaporation),

W2=Initial weight of the evaporating dish in grams

V=Volume of water sample taken in milliliters.

Three replicate samples were measured and the mean value recorded (APHA, 1995).

Determination of Nitrate

The amount of nitrate in the water samples was determined with the aid of the Wagtech Nitrate test (Andrew et al., 1995). In this test, nitrate was first reduced to nitrite, and the resulting nitrite was determined by a diazonium reaction to form a reddish dye. By using a zinc-based Nitrate test powder and a Nitrate test tablet, the reduction stage was carried out. 1 mL of wastewater sample was pipetted into a Nitrate test tube. The Nitrate test tube was then filled up to 20 mL with de-ionized water. One Nitricol tablet was added and dissolved in the solution. A blank sample was prepared for zero adjustment of photometer using distilled water. The cuvette was then filled and the absorbance of the solution was measured in the photometer at 540 nm and all samples measured in triplicates. The calibration curve was then prepared by making a standard series with five concentrations in a proper range (0 - 100 mg/L) on nitrate concentrations expected in the samples. The colour intensity was read on a Wagtech

Photometer at wavelength 540 nm. Three replicate samples were measured and mean values recorded (APHA, 1995). The transmission percentage given from the photometer was then extrapolated from the standards curve. The given value was then multiplied by 20 to get the nitrate concentration in the original sample in mg/L.

Determination of Phosphate

Phosphate in wastewater samples was determined by Ammonium molybdate method (Andrew et al., 1995). Erlenmeyer flask (100 ml) was filled with 50 mL of filtered water-samples and 1.5 mL of the mixed reagent (sulfuric acid, Ammonium molybdate solution and potassium antimony tartrate) was added. The solution was then mixed and 0.75 mL of ascorbic acid solution was added and left to react for 5 minutes. A blank sample was prepared using distilled water for zero adjustment of photometer. A cuvette was then filled and absorbance measured in the photometer at a wavelength of 890 nm. All samples were measured in triplicates and the sample reading derived from the standard curves. Three replicate samples were measured and their mean values recorded. The calibration curve was drawn from a series with five concentrations in a range of 0.00 – 0.100 mg/L derived from the phosphate stock solution.

Determination of DO

Readings of the dissolved oxygen (mg/L) in the wastewater samples were taken using a handheld -YSI 550A dissolved oxygen meter. Three replicate samples were measured and their mean values recorded (APHA, 1995). The sensor was cleaned between every measurement using distilled water. Distilled water was used to calibrate the DO meter to a zero reading before samples were measured in situ.

Determination of Conductivity

Conductivity was done *in-situ* using an Extech EC500 portable combination meter, which was calibrated daily. Measurements were made directly in the waters at respective sampling points (Faulkner et al., 1989)

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, one way ANOVA, one-Sample t-Test 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.

RESULTS

Table 1: Mean ($\pm$ SEM) levels of physicochemical characteristics in samples from different sampling points during the dry seasons.

	N Statistic	Minimum Statistic	Maximum Statistic	Mean Statistic	Std. Error	Std. Deviation Statistic	Variance Statistic
Nitrate	24	0.36	1.14	0.6438	± 0.04135	0.20257	0.041

Phosphate	24	1.03	2.01	1.3142	±0.06417	0.31435	0.099
DO	24	5.21	18.77	11.8671	±0.98473	4.82418	23.273
Temperature	24	20.98	22.04	21.5775	±0.05550	0.27191	0.074
Turbidity	24	11.04	58.49	26.6904	±3.07095	15.04452	226.337
Conductivity	24	51.04	271.44	101.6658	±15.48315	75.85165	5753.474
TS	24	111.00	332.00	187.6250	±15.25874	74.75224	5587.897

Table 2: Mean (±SEM) levels of physicochemical characteristics in samples from different sampling points during the wet season.

	N Statistic	Minimum Statistic	Maximum Statistic	Mean Statistic	Std. Error	Std. Deviation Statistic	Variance Statistic
Nitrates	24	.78	1.63	1.0658	±0.05041	.24695	.061
Phosphate	24	1.16	2.98	1.8604	±0.10354	.50722	.257
DO	24	7.98	18.93	14.4529	±0.69638	3.41157	11.639
Temperature	24	19.33	21.41	20.2450	±0.13626	.66753	.446
Turbidity	24	20.94	34.08	26.3638	±0.62665	3.06993	9.424
Conductivity	24	31.99	166.73	67.3371	±8.68615	42.55326	1810.780
TS	24	139.00	293.00	199.7083	±8.78373	43.03131	1851.694

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 KNWQS limits of 6.5-8.5 over the dry season (Table 3, Figure 2). In all the sampling points, pH showed an increasing trend from the dry to wet season.

Table 3: 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

254

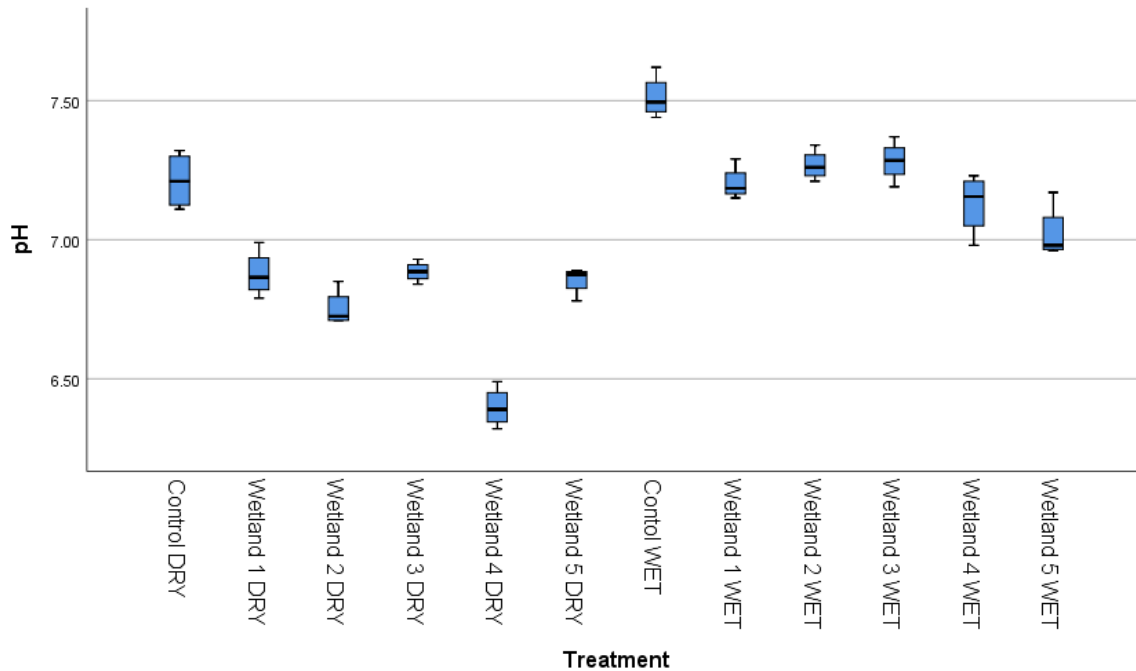


Figure 2: Variation in pH down River Sergoit

One way ANOVA

Table 4 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, BOD₅, 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 statistically significant difference among the different parameters in study area and control.

Table 4: ONE-WAY ANOVA showing significance differences among the study areas

		ANOVA				
		Sum of Squares	df	Mean Square	F	Sig.
Temperature	Within Groups	.213	36	.006		
	Total	4.125	47			
	Between Groups	31.656	11	2.878	64.769	.000
	Within Groups	1.600	36	.044		
DO	Total	33.256	47			
	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			

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 2,3,1,4 and 5 (Dry season) were not significantly different. was significantly different from wetlands 1, 2, 3, 5 and the control (Table 5, 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 2, 5, 1 and 3 during the dry season but there was a significant difference between the dry and wet season (Table 5, Figure 3).

Table 5: 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.		.054	.993	.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.

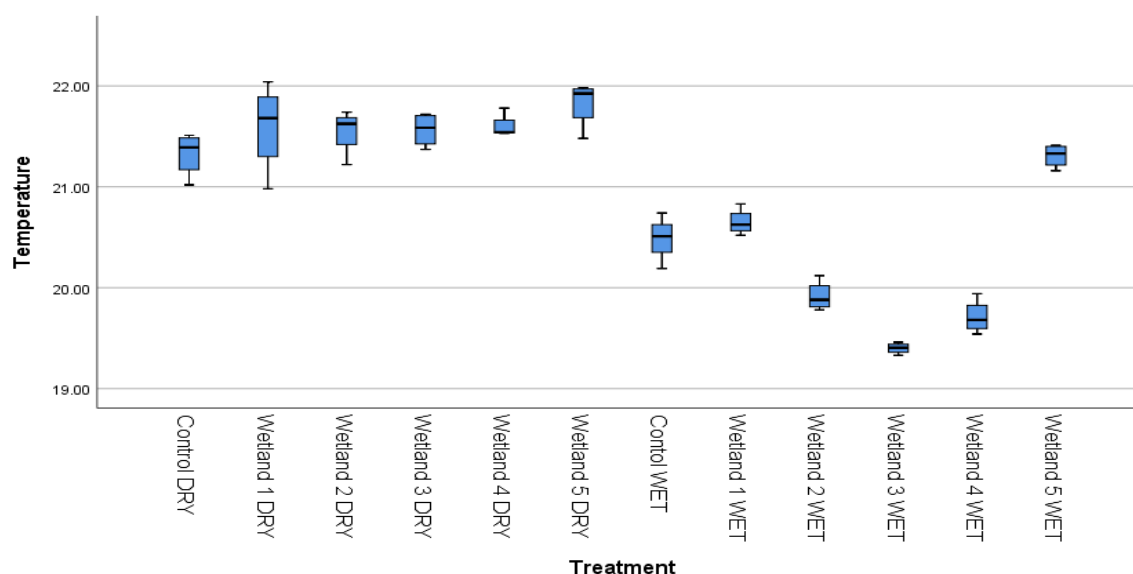


Figure 3: Variation in temperature down River Sergoit

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 6, Figure 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 6, Figure 4).

Table 6: Variation in levels of DO in samples from different sampling points during dry and wet seasons.

		DO					
Tukey HSD ^a		Subset for alpha = 0.05					
Treatment	N	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.		.052	.455	1.000	.121	.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.

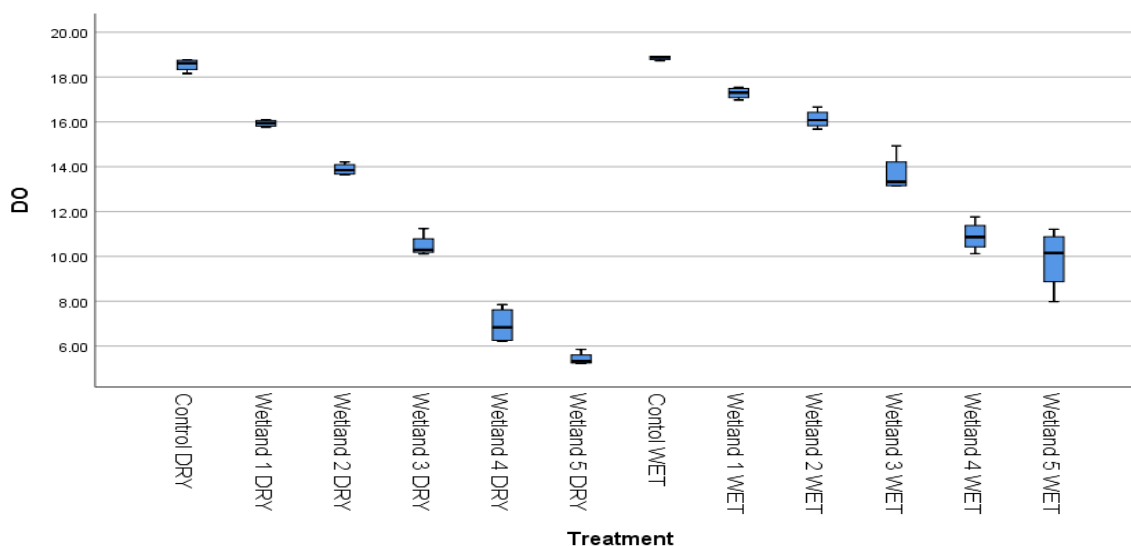


Figure 4: Variation in dissolved oxygen (DO) down River Sergoit

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 7, Figure 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 7, Figure 5).

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

		Turbidity					
Tukey HSD ^a		Subset for alpha = 0.05					
Treatment	N	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 ^{bcd}	
Wetland 1 WET	4		27.1850 ^b	27.1850 ^{bc}	27.1850 ^{bcd}	27.1850 ^{bcd}	
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.		.905	.055	.177	.415	.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.

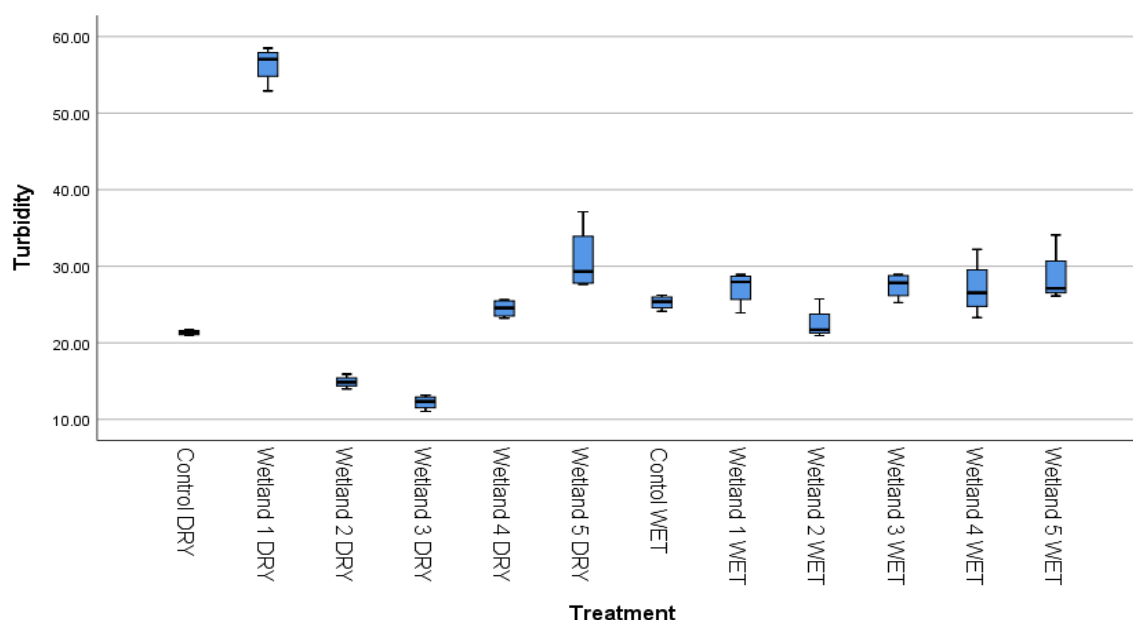


Figure 5: Variation in turbidity down River Sergoit

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 8, Figure 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 8, Figure 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 8, Figure 6).

Table 8: 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.		.886	.224	.205	.116	1.000

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 4.000.

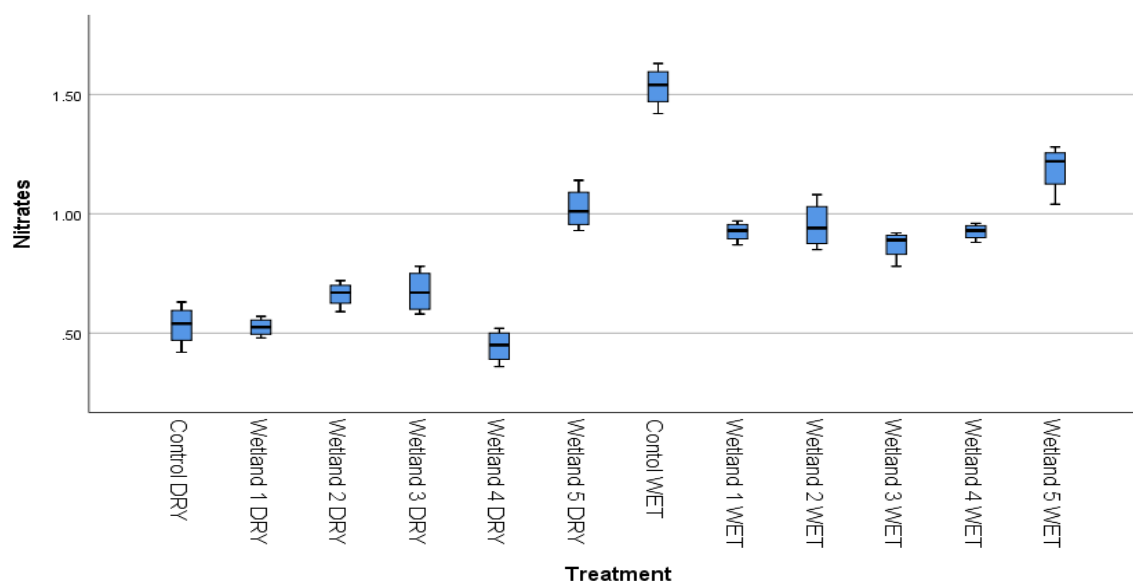


Figure 6: Variation in nitrates down River Sergoit

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 9, Figure 7).

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

		Conductivity							
Tukey HSD ^a		Subset for alpha = 0.05							
Treatment	N	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.

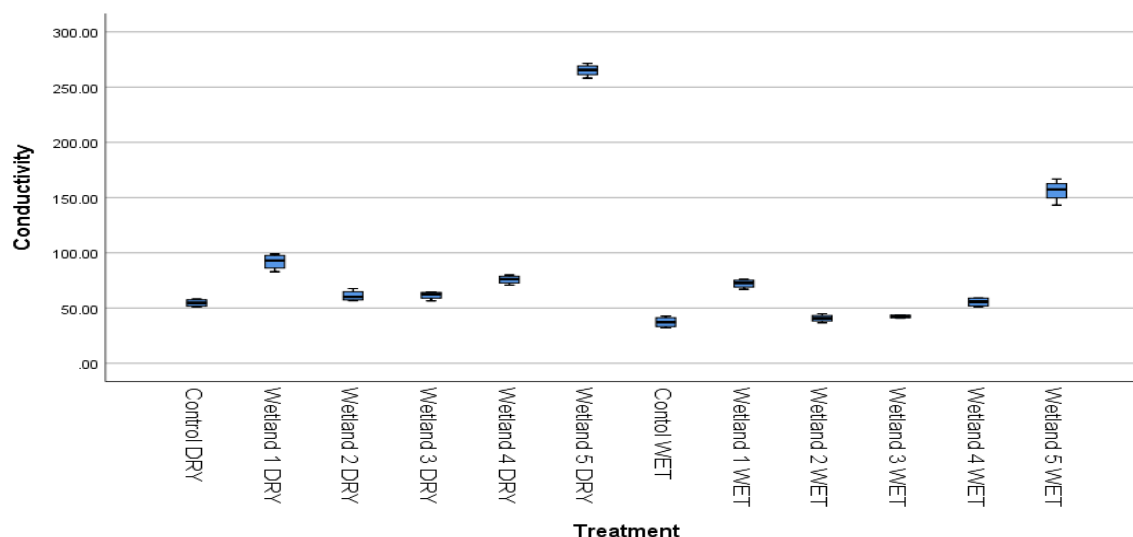


Figure 7: Variation in conductivity down River Sergoit

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 10, Figure 8). There was significant difference in the control samples between the wet and dry seasons (Table 10, Figure 8).

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

		Phosphate				
Tukey HSD ^a		Subset for alpha = 0.05				
Treatment	N	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.		.089	.055	.101	.217	.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.

366

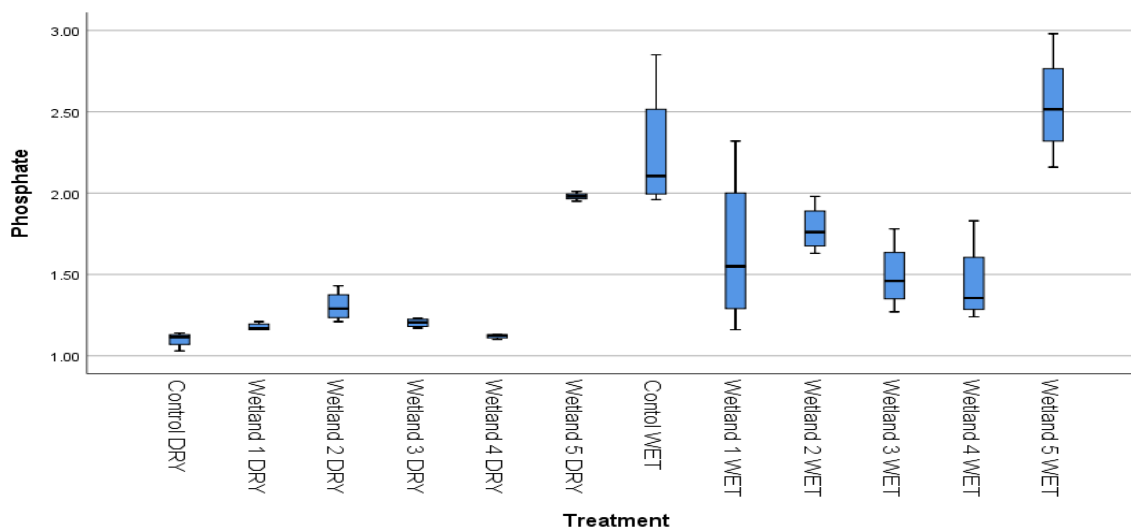


Figure 8: Variation in phosphates down River Sergoit

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 11, Figure 9).

Table 11: 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.		.142	.117	.085	.075	.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.

382

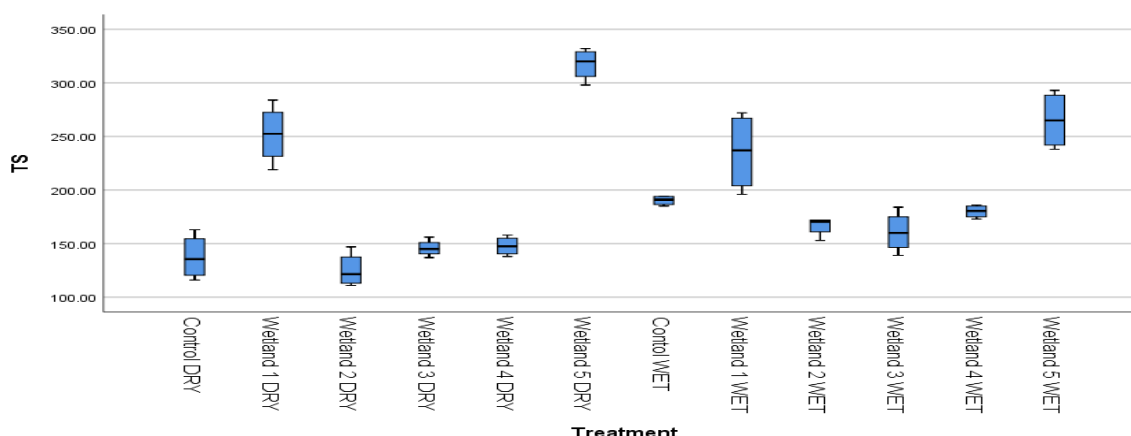


Figure 9: Variation in TS down River Sergoit

DISCUSSION OF RESULTS

The World Health Organization (WHO) provides guidelines for drinking water quality (Table 12). Further, Kenya has set quality standards (Table 12) for water for domestic use and also for agricultural practices (Moraa, et al., 2012).

Table 12: 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
BOD (5 days at 20°C) max	0.8 - 5mg/l	0.8 - 5mg/l
Total solids	1200 (mg/L)	1200 (mg/L)
Nitrate-NO ₃	10 (mg/L)	10 (mg/L)
Phosphorous	<0.05 (mg/L)	<0.05 (mg/L)
Turbidity	<5NTU	<5 NTU

Water temperature

It was established that water temperature was corresponding the air temperature and it ranged from a low of $19.22 \pm 1.88^{\circ}\text{C}$ to a high of $21.54 \pm 2.33^{\circ}\text{C}$. 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 (Wetzel, 2001). Fluctuation in water temperature down the river maybe linked to high air temperature (Manjare et al. 2010 and Thirupathiah et al., 2012) and low water level (Shinde et al., 2011). Temperature affects the solubility of many chemical compounds and can therefore influence the effect of pollutants on aquatic life. Increased temperatures elevate the metabolic oxygen demand, which in conjunction with reduced oxygen solubility, impacts many species. However, this was not consistent in the findings of this study, as other properties also affect solubility of gasses in water, especially altitude and solvents in water. This can therefore be attributed to multiple source pollution from adjacent farms and industrial wastes that find their way to contaminate the waters of Marura Wetland.

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 and phytoremediation. It ranged from 6.32 to 7.32 over the dry season, and 6.96 to 7.62 over the wet season (Table 3). This is an indication of multiple source pollution. Despite the phytoremedial potential, there is continuous pollution from the source (Station 1 [control]) to the end (Station [wetland] 5). This pH was within range of recommended standard, 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. 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* prefer saline conditions. In wetlands where they both exist indicates existence of a pH gradient from saline to freshwater conditions. Marura wetland is characterized by *Cyperus papyrus*. *Typha spp* was established only on few places, probably linked to sources of pollution of Marura wetland. The pH of wetlands is correlated with the calcium content of water (pH 7 = 20 mg Ca/L). Wetland waters usually have a pH of around 6-8 (Kadlec and Knight, 1996). The biota of wetlands especially can be impaired by sudden changes in pH. When acid waters (waters with low pH values) come into contact with certain chemicals and metals, this often makes them more poisonous than normal. As an example: fish that usually can withstand pH values as low as 4.8 will die at pH 5.5 if the water they're swimming in contains as little as 0.9 mg/L of iron. Mix acid water with small amounts of aluminum, lead, or mercury, and you will have a similar problem - one that far exceeds the usual dangers of these substances. Heavy metals can accumulate on the gills of fish or cause deformities in young fish, reducing their chance of survival.

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 values fluctuated from $1.8671 \pm 0.98473 \text{ mg/l}$ (Dry season) (Ref: Table 1) to $14.4529 \pm 0.69638 \text{ mg/l}$ (Wet season) (Ref: Table 2). 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, 2009 and Thirupathiah et al., 2012, 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.

Nitrate

The nitrate values did not show much fluctuation during the study and ranged from $0.6438 \pm 0.04135 \text{ mg/l}$ (Ref: Table 1) in dry season to a high of $1.0658 \pm 0.05041 \text{ mg/l}$ (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 phytoremediation. These findings are in agreement with those of Saeed and Sun, 2012 and Vymazal, 2006, 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) (Saeed and Sun, 2012; Vymazal, 2006,) which greatly reduced the effluent TN levels. These findings also agree with those of Zhang et al. (2015) who observed that hybrid system achieved high TN removal. These results also agree with those of Mishra and Patro, 2015. Nitrate concentration is influenced by dilution with low-nitrate water entering the (Mishra and Patro, 2015).

Phosphate

The phosphate values did not show much fluctuation during the study and ranged from 1.3142 ± 0.06417 mg/l (dry season) (Ref: Table 1) to 1.8604 ± 0.10354 mg/l (wet season) (Ref: Table 1). The values of phosphate were higher in the wet season as compared to the dry season. 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 phosphorus (P) loading to surface waters. These findings are in agreement with those of Omernik 1977; Luz E and others 2004; Allan 2004, describing the relationships between land use and water quality are surprisingly variable at the scale of entire watersheds (Omernik 1977; Luz E and others 2004; Allan 2004). Presence of phosphates in water indicates the possibility of algal blooms which can cause death of aquatic animals. The result revealed that there was significant variation in phosphorus. Excessive nutrients input into wetlands can cause perturbation of the ecosystem. Phosphorous 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 wastes into wetlands.

Conductivity

The Conductivity values showed much fluctuation during the study and ranged from 101.6658 ± 15.48315 μ S/cm (dry season) (Ref: Table 1) Station 1 to 67.3371 ± 8.68615 μ S/cm (wet season) (Ref: Table 2). Conductivity was higher in the dry season as compared to the wet season. 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 μ S/cm. It is expressed as micro- or millisiemens per centimeter (μ S/cm or mS/cm) of conductance. It is highly dependent and correlated with the amount of dissolved solids (such as salt) in the water (EPA, 2012), 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, 2014, 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 (LCRA, 2014). 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.

Turbidity

Turbidity values showed much fluctuation during the study and ranged from 26.6904 ± 3.07095 NTU (Dry season) Nephelometric Turbidity Units (NTU) to

26.3638±0.62665NTU (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 this ecosystem. These findings are in agreement with Kaberi et al., in 2012, who explored the maximum aquatic turbidity was observed in monsoon in the month of October, followed by postmonsoon in the month of November, and premonsoon in the month of March, which showed different values of 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. 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.

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 larger range of variation from 187.6250±15.25874 to 199.7083±8.78373 mg/L. TDS ranges of all the samples are within permissible limit (maximum 1200 mg/L), in Kenya. These findings are in agreement with those of Barakati et al. (2011); Abolfazl et al. (2014) 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 this can be attributed for the reason of low values that are within specifications of the Kenyan Government. The physical removal of the solids is usually done by media and the roots (Dhanya and Jaya, 2013).

CONCLUSION AND RECOMMENDATION

Marura wetland is a habitat is a dwindling ecosystem and requires more attention than is given at the moment. More studies should be conducted to establish the actual potential of the site and actual points of source pollution. This study recommends that further studies should be conducted to examine what limits the distribution of different species of plants and animals at Marura wetlands, examining the role of both physical and biological factors and the dwindling size of the wetland. In addition to examining spatial differences among sites with different management practices, long-term monitoring should be conducted to track changes in the location of the ecotone over time. Ecotones should be managed in accordance to outlined Kenyan laws of human habitation.

REFERENCES

- Abolfazl R. S., & Fateme D, (2014). Treatment of hospital wastewater by vetiver and typical reed plants at wetland method. Indian Journal of Fundamental and Applied Life Sciences ISSN: 2231– 6345 (Online) An Open Access, Online International Journal Available at www.cibtech.org/sp.ed/jls/2014/03/jls.htm 2014 Vol. 4 (S3), pp. 890-897/Sani and Dareini
- Allan, J.D., (2004). Influence of land use and landscape setting on the ecological status of rivers. *Limnetica* 23, 187–196.

- 562 American Public Health Association (APHA), (1995). Standard Method for Examination of
563 Water and Waste Water. 19th Edition, Published by E and F N Poan, Washington
564 D.C.: 2-56.
565
- 566 Andrew, D.E., Lenore, S.C., & Arnold, E.G. (1995). Standard Methods for the Examination
567 of Water and Wastewater. 19th Edition.
568
- 569 Barakati, F., Alidade, Ho., Najafpoor, Al., & Hasani, Am. (2011). Use the vetiver instead
570 reed in wetland system in municipal wastewater treatment. Proceeding of the 14th
571 National Conference on Environmental Health yazd.
572
- 573 Dhanya G & Jaya DS (2013). Pollutant Removal in Wastewater by Vetiver Grass in
574 Constructed. Wetland System. IJERT-International Journal of Engineering Research
575 and Technology 2(12) 1361-68.
576
- 577 EPA. (2012). 5.9 Conductivity. In Water: Monitoring and Assessment. Retrieved from
578 <http://water.epa.gov/type/rsll/monitoring/vms59.cfm>
579
- 580 Faulkner, S. P., Patrick Jr., W. H., & Gambrell, R. P.: Field techniques for measuring wetland
581 15 soil parameters, Soil Sci. Soc. Am. J., 53, 883–890, 1989.
582
- 583 Jaetzold, R. & Schmidt, H. (1983). Farm Management Handbook of Kenya. Vol. II/B.
584 Central Kenya. Nairobi. Republic of Kenya: Ministry of Agriculture.
585
- 586 Luz E. de-Bashan, & Yoav Bashan, (2004). Recent advances in removing phosphorus from
587 wastewater and its future use as fertilizer (1997–2003). Water Research 38 (2004)
588 4222–4246., www.elsevier.com/locate/watres
589
- 590 Kaberi Chaudhuri, Suman Manna, Kakoli Sen Sarma, Pankaj Naskar, Somenath
591 Bhattacharyya & Maitree Bhattacharyya, (2012). Physicochemical and biological
592 factors controlling water column metabolism in Sundarbans estuary, India Chaudhuri
593 et al. Aquatic Biosystems 2012, 8:26;
594 <http://www.aquaticbiosystems.org/content/8/1/26>
595
- 596 Kadlec, R. H. & Kinght, R.L., Treatment Wetlands, Boca Raton, FL, CRC Press, (1996).
597
- 598 Kareri, R. W., (1992). The sociological and economic values of Kenya's wetlands. In Crafter,
599 S. A., S. G. Njuguna & G. W. Howard (eds), Wetlands of Kenya, Proceedings of the
600 Kenya Wetlands Working Group Seminar on Wetlands of Kenya, National Museums
601 of Kenya, Nairobi, Kenya 3–5 July 1991. Vii + 183 pp.
602
- 603 Kenya Institute for Public Policy Research and Analysis (KIPPRA) (2013). Creating an
604 enabling environment for stimulating investment for competitive and sustainable
605 counties. Kenya Economic Report. Retrieved from <http://www.kippira.org>
606
- 607 LCRA (2014) Water quality indicators. In: Colorado river watch network. Retrieved from
608 [http://www.lcra.org/water/quality/colorado-river-watch-network/Pages/water-quality-](http://www.lcra.org/water/quality/colorado-river-watch-network/Pages/water-quality-indicators.aspx)
609 [indicators.aspx](http://www.lcra.org/water/quality/colorado-river-watch-network/Pages/water-quality-indicators.aspx)
610

- Manjare, S.A., Vhanalakar, S.A. & Muley, D.V. (2010). Analysis of water quality using physico-chemical parameters Tamdalge tank in Kolhapur district, Maharashtra. *International Journal of Advanced Biotechnology and Research*, 1(2): 115-119.
- Masese F. O., Muchiri M. & Raburu P. O. (2009). Macroinvertebrate assemblages as biological indicators of water quality in the Moiben River, Kenya. *African journal of aquatic sciences*. 193 2009, 34 (1): (15-26) doi: 10.2989/AJAS.2009.34.1.2.727
- Mishra Sujata & Patro Lingaraj (2015). Evaluation of Physico-Chemical property- Carbon dioxide, Dissolved Oxygen & Total dissolved Solid content of water of Chilika Lagoon, *Journal of Global Biosciences*, 4. (2). 1543- 1550 (2015).ISSN 2320-1355
- Mitsch M. J. & Gosselink J. G. (2007). *Wetlands* 4th Edition. (Hardcover) (2007).
- Moraa, H., Otieno, A., & Salim, A. (2012). Water governance in Kenya: Ensuring accessibility, service delivery and citizen participation. Retrieved from: www.ihub.co.ke/ihubresearch/.../2012/july/1343052795_537.
- Omernik JM. (1977). Non-point source stream nutrient level relationships: a nationwide study. Corvallis, Oregon, USA: U.S. Environmental Protection Agency.
- Saeed, T. & Sun, G. (2012). A Review on Nitrogen and Organics Removal Mechanisms in Subsurface Flow Constructed Wetlands: Dependency on Environmental Parameters, Operating Conditions and Supporting Media. *Journal of Environmental Management*, 112, 429-448. <http://dx.doi.org/10.1016/j.jenvman.2012.08.011>
- Shinde S. S., Kamtikar V. N., Muley S.P. & Nimbalkar R. K. (2011). Studies on physico-chemical parameters of water and zooplanktons diversity in Kham river, Aurangabad District (MS, India). *Bioscience Discovery*, 02 (2): 207-213.
- Thirupathaiah, M., Sravanthy, C. & Sammaiah C. (2012). Diversity of zooplankton in Lower Manair reservoir, Karimnagar, A.P., India. *International Research Journal of Biological Sciences*, 1(7): 27-32.
- Verma, P. (2009). Ecology and economic valuation of Lake Surinsar, Ph.D. Thesis, University of Jammu, Jammu.
- Vymazal, J. (2006). Removal of nutrients in various types of constructed wetlands. *Science of the Total Environment*, 380 (1–3), 48–65.
- Wetzel R. G. (2001). *Limnology*, 5th ed. Academic Press, California.
- Zhang, D. Q., Jinadasa, K. B. S. N., Gersberg, R. M., Liu, Y., Ng, W. J., & Tan, S. K. (2014). Application of constructed wetlands for wastewater treatment in developing countries—a review of recent developments (2000–2013). *Journal of environmental management* 141, 116 131. <https://doi.org/10.1016/j.jenvman.2014.03.015>