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Effect of Organic Effluents on Water Quality and Benthic Macroinvertebrate Community Structure in Njoro River, Kenya

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Abstract

Njoro River, which is the primary freshwater source for the urban and rural-based residents within its basin, has been subjected to increasing anthropogenic pressure that threatens its ecological and socio-economic values. An empirical study was conducted in the mid reaches of this river to determine the effect of organic effluents on water quality and benthic macroinvertebrate community structure. Organic pollutants input into the river can lead to immense ecosystem impairment. The effect of organic effluents on water quality was assessed in this study using a combination of physico-chemical parameters and benthic macroinvertebrate community structure. Four sampling sites were chosen corresponding to both diffuse and point source pollution of organic effluents. Dissolved oxygen, conductivity, turbidity and pH were determined *in situ*. Water samples were collected using 500 ml acid washed bottles before laboratory analysis for Biological Oxygen Demand, nitrogen, phosphates and Total Suspended Solids. Benthic macroinvertebrates were sampled using a kick net (mesh size 250 µm with an effective area 0.2025 m^2) during each sampling session and identified using aquatic invertebrates identification keys. Results indicate that effects of organic effluents were more pronounced at downstream sites compared to the upstream ones. One-Way ANOVA indicated a significant difference in dissolved oxygen, conductivity, Biological Oxygen Demand, turbidity, ammonium, nitrates and total phosphorus levels among the sampling sites. Benthic macroinvertebrates species diversity was high in upstream sites with order Ephemeroptera being the most dominant taxa (51.26%) whereas order diptera dominated the downstream sites (42.38%). Among the genus of order diptera identified downstream, genus *Polypedilum* was dominant. The results from this study form baseline information in biomonitoring the Njoro River which can be adopted at a wider scope to the existing management strategies and policies towards pollution control and abatement in aquatic systems.

Keywords: Physico-chemical parameters; Diversity; *Polypedilum sp*

Introduction

Freshwater ecosystems play a major role in sustaining the lives and livelihoods of human beings. They as well provide habitat to about 6% of the world's total known species, 40% of the global fish species and 25% of all vertebrate species. Therefore, they are speculated to be the most threatened ecosystems in the world [1]. With rapid increase in human population compounded by high industrialization and urbanization rate, larger quantities of organic waste have increasingly been generated [2]. These organic wastes are frequently disposed into rivers and streams from different riverine settlements particularly from semi-informal agricultural and semi-industrial community setups according to Fischman [3].

Water quality deterioration is the primary outcome of organic wastes disposal which, in turn seriously threatens the freshwater biodiversity influencing their ecological balance, normal functioning and population dynamics [4]. Macroinvertebrates, being the main faunal component in stream and river ecosystems, are the primary victims of poor water quality which is indicated by their composition, diversity and abundance [5]. It is indisputable that macroinvertebrates can therefore serve as good biological indicators of water quality. This is because they are abundant and ubiquitous in nature, thereby offering a wide spectrum of observable responses to environmental changes [6].

Benthic macroinvertebrates were used in this study to determine the effect of organic effluents on their community structure and diversity. In tropical streams, information on the effect of organic (industrial and domestic) effluents on benthic macroinvertebrates is scanty. Njoro River therefore offered an excellent opportunity for study as it serves as a receptor for both industrial and domestic effluents from Njoro canning and Egerton university and its surroundings respectively. Discharge of these organic effluents within and along the Njoro River proved it to be a perturbed system. The data and information gained in this study is targeting to enhance the existing monitoring and implementation strategies and policies of the Njoro River towards pollution control and abatement.

Materials and Methods

Study area

The Njoro River spans a distance of about 60 km from its source at the native forests of the Eastern Mau Escarpment (2700-3000 m above the sea level) to the mouth at Lake Nakuru (1759 m above the sea level). The river's long-term mean annual rainfall varies from 1200 mm in the upper reaches to 800 mm at Lake Nakuru which has a tri-modal pattern with peaks in April (biggest), August (second) and November (smallest). The hot-dry season runs from January to March as descried by Shivoga et al. [7]. Studies by Mokaya et al. [8] reports that the river acts as drainage for both natural and anthropogenic pollutant inputs.

These pollutant inputs result from agricultural activities, sewage treatment plants and wastes from the riparian communities which have minimal sanitation services.

Sampling design

The four sampling sites in this study were selected longitudinally on the basis of their difference in the types of sustained anthropogenic disturbances, ease of accessibility and presence of microhabitats (pool, riffle and run) along the Njoro River. Little Shuru (00° 22' 23.9''S, 035° 55' 02.4''E) and Mugo (00° 22' 32.0''S, 035° 56' 13.1''E) were classified as the upstream sampling sites as they received diffuse organic pollutants, thus used to determine the effects of non-point source pollution. The two sites downstream of the river; Upper canning (00° 22' 08.5''S, 035° 56' 31.4''E) and Lower canning (00° 21' 54.7''S, 035° 56' 24.7''E) were selected to determine the effects of point source organic pollutants (industrial and domestic effluents) (Figure 1).

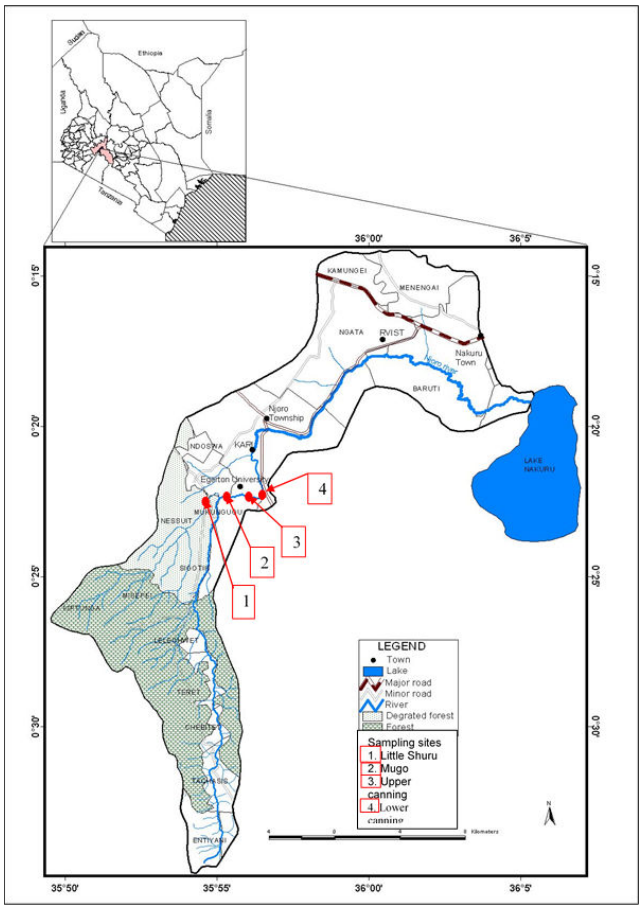

Figure 1: Determine the effects of point source organic pollutants.

Sample collection and analysis

Water samples were collected monthly from November 2016 to February 2017. Physico-chemical parameters; dissolved oxygen (DO), pH, water temperature, turbidity and electrical conductivity (EC) were measured *in-situ* at each study site three times a month for the four months. EC, pH and temperature were measured using HACH HQ 40d meter while HACH HQ 11d was used to measure the turbidity. DO concentrations were measured using HACH HQ 30d meter during each sampling session. Triplicate water samples were collected at each site using acid washed 500 ml plastic sampling bottles for nutrients (SRP, TP, NO_3-N, NO_2-N, NH_4-N) and TSS analysis. The water samples were transported in a cool box and filtered using 0.45 µm Whatman GF/C filters on arrival in the laboratory. The filtered samples were refrigerated at 4°C for soluble nutrients (SRP, NO_3-N, NO_2-N and NH_4-N) analysis. For BOD_5 analysis, triplicate water samples were collected at each site using 500 ml acid washed BOD glass bottles for incubation set up in the laboratory.

The analysis of Soluble Reactive Phosphorus (SRP) was carried out in triplicates using the Ascorbic Acid method as described in APHA [9]. On the other hand, Total Phosphorus (TP) was determined through persulphate digestion of unfiltered water samples. This reduced the forms of phosphorus present into SRP which was then analyzed using the Ascorbic Acid method. Nitrate-Nitrogen (NO_3-N) was determined using sodium-salicylate method while Nitrite-Nitrogen (NO_2-N) was carried out through the reaction between sulfanilamide and N-Naphthyl-(1) ethylendiamin-dihydrochloride. NH_4-N was determined through reaction of sodium-salicylate solution with hypochloride solution. The absorbances for different nutrient analysis were read using a GENESYS 10 UV scanning spectrophotometer. The final concentrations of NH_4-N, NO_3-N and NO_2-N were calculated from their respective equations generated from standard calibration curves.

Total Suspended Solids (TSS) was determined by filtering a known volume of water samples using pre-weighed 0.45 µm Whatman GF/C filters. The filter papers were then dried to a constant weight at 95°C for 3 hours and cooled in a desiccator. Equation 1 was used to calculate TSS volume as described in APHA [9].

$$TSS\ (mg/L) = ((Wc - Wf) \times 10^6) / V \quad \text{Equation 1}$$

Where, TSS=Total suspended solids (mg l^{-1}), W_f=Weight of dried filter paper in grams, W_c=Constant weight of filter paper + residue in grams, V=Volume of water filtered (ml).

The amount of organic matter in water was measured as Biological Oxygen Demand (BOD_5). Water samples were filled in six (6) 500 ml BOD bottles. Initial DO was determined in one of the bottles immediately after water sample collection. The other water samples were incubated for five days in a water bath thermostatically controlled at 21°C and placed in the dark. Light was excluded by wrapping water bottles with aluminum foil to prevent the possibility of photosynthetic production of oxygen. The initial and final DO were determined using the Iodometric titration procedure (Winkler method). One (1) ml of Manganese II chloride (Reagent 1) was added to the water samples followed by immediate addition of 1 ml sodium iodide-sodium hydroxide solution (Reagent 2) to fix the samples. Further, 1 ml 0.5 M H_2SO_4 (Reagent 3) was added to the water samples and mixed well until the manganic oxide precipitate dissolved. Titration was done using 50 ml of the water sample against 0.01 M sodium thiosulfate with starch solution as the indicator. Equation 2 was used to calculate oxygen concentration (ml O_2 L^{-1}).

$$O_2(ml/l) = \frac{((R - R_{blank}) \times V_{I03} \times N_{I03} \times E)}{(R_{std} - R_{blank}) \times (V_{bottele} - V_{rgts})} - DO_{rgts}$$

Equation 2

Where,

R=Volume of thiosulfate used to titrate the sample (ml),

R_{std}=Volume of thiosulfate used to titrate the Potassium Iodate (KIO_3) standard (ml),

R_{blank}=Volume of thiosulfate used to titrate the blank as measured above (ml),

N_{IO3}=Normality of standard Potassium Iodate (KIO3) (equiv./l),

V_{IO3}=Volume of KIO_3 standard (ml),

V_{bottle}=Volume of sample bottle (ml),

DO_{rgts}=Oxygen added in reagents,

V_{rgts}=Volume of reagents,

BOD_5 was calculated through the determination of the difference between initial and final DO using Equation 3 as per APHA [5].

BOD_5 (mg/L)=D_1 - D_2 Equation 3

Where,

D_1=initial dissolved-oxygen (DO) concentration (in mg/L) in the water sample,

D_2=final DO (in mg/L) in the water sample after 5 days incubation.

Benthic macroinvertebrate samples were collected from riffle, pool and run habitats in triplicates, using the multi-habitat sampling (MHS) approach, at the four sites during low flow conditions according to Moog [10]. All samples were collected quantitatively using a kick-net sampler with an effective sampling area of 0.2025 m^2 and mesh size 100 µm. The kick-net sampler was placed at the sampling points facing upstream and sediments upstream of the sampler disturbed for one (1) minute. The samples obtained were emptied into pre-labelled polythene bags, fixed with 4% formalin and taken to the laboratory for sorting and analysis to determine the community structure, composition and abundance. In the laboratory, the samples were washed under tap water through a series of mesh sieves (1 mm, 500 µm and 100 µm) to remove debris, stones and wash away formalin. The sorting of benthic macroinvertebrates was undertaken using forceps and identified to the family level following methods described by Gerber and Gabriel [11].

Species richness was calculated using Margalef's index (Equation 4) as described by Chakravorty et al. [12]. Species diversity was obtained from Shannon-Wiener Index (Equation 5). Species evenness and species similarity were calculated using Shannon's Equitability index (Equation 6 and 7) and Sorensen's coefficient of community similarity respectively (Equation 8).

Margalef's index=S-1/ ln (n) Equation 4

Where,

S=number of taxa,

n=number of individuals.

$$H' = \sum P_i \ln P_i \; where \; P_i = \frac{n_i}{N}$$ Equation 5

Where,

H´=Shannon-Weinner diversity index,

Pi=relative abundance of each species,

ni=number of individuals in each species,

N=total number of all individuals.

E_H=H´/ $_{Hmax}$ Equation 6

Where,

H´=Shannon-Weinner diversity index.

H_{max}=H´/*ln* S……...……Equation 7

Where,

S=total number of species in the community,

CC=2c/ (S_1+ S_2+ S_3+ S_4) Equation 8

Where,

c=number of species common to both communities,

S_1=number of species of community 1,

S_2=number of species in community 2,

S_3=number of species in community 3,

S_4=number of species in community 4.

Descriptive statistics presented as means and their standard deviations were used to summarize the data characteristics. One-way Analysis of Variance (ANOVA) and Tukey's *post hoc* test were used to test for significant differences in physico-chemical parameters and benthic macroinvertebrates abundance among study sites. All statistical procedures were performed using SPSS and PAST statistical software. The data was log (x+1) transformed to meet the normality test. All significant tests were performed at α=0.05 level.

Results

Physico-chemical water quality parameters

Mean values for physico-chemical variables obtained in Njoro River are presented in Table 1. DO concentrations differed significantly among the sites (one-way ANOVA, $F_{(3,116)}$=4.811 p<0.01) with a gradual decline from Little Shuru to Lower Canning. The highest mean DO concentrations were recorded at Little Shuru with Lower Canning recording the lowest concentrations (Tukey HSD, p<0.01). Contrary to DO, Lower Canning showed the highest mean BOD_5 values among the study sites (Turkey HSD, p<0.01) with Little Shuru having the lowest. Thus, BOD_5 values among sites was statistically significant (one-way ANOVA, $F_{(3,116)}$=3.60, p<0.05). Conductivity values among sites was statistically highly significant (one-way ANOVA, $F_{(3,116)}$=6.12, p=0.01). Lower canning recorded highest mean conductivity (Turkey HSD, p<0.01), while the lowest was recorded at upstream Little Shuru site. A significant difference was observed in turbidity values among the sites (one-way ANOVA, $F_{(3,116)}$=5.03, p<0.01). Lower canning had the highest turbidity mean values among the study sites, with Little Shuru and Mugo recording the lowest values (Turkey HSD, p<0.01). The TSS mean values ranged between 21.72 ± 4.67 to 29.92 ± 6.65 mg/L with Lower Canning recording the highest mean value. However, no significant difference was observed in the TSS values among the four study sites (one-way ANOVA, $F_{(3,116)}$=0.46 p>0.05). Water temperature values showed a highly significant difference among the study sites (one-way ANOVA, $F_{(3,116)}$=9.67 p<0.001). The highest mean water temperature was recorded at the Lower canning (Turkey HSD, p<0.01) with Little Shuru recording the lowest values. The pH values among the study sites ranged between 8.0 and 8.10 with no significant difference observed among the study sites (one-way

ANOVA, $F_{(3,116)}$=0.97, p>0.05). The highest nutrient concentrations were obtained at Lower Canning, with Little Shuru having the lowest (Table 1), with significant spatial variations being observed (P<0.05). The Ammonium (NH_4^+-N) and Nitrates (NO_3-N) concentrations were statistically significant among study sites (one-way ANOVA, $F_{(3116)}$=3.57, p<0.05 and $F_{(3\ 116)}$=9.60, p<0.001 respectively). No significant difference in the NO_2--N values among the four study sites (one-way ANOVA, $F_{(3,116)}$=1.37, p>0.05). The total phosphorus (TP) and soluble reactive phosphorus (SRP) concentrations were significantly different among sampling sites (one-way ANOVA, $F_{(3116)}$=11.40, p<0.001 and $F_{(3116)}$=4.33, p<0.01 respectively with Lower canning having the highest TP and SRP values. (Turkey HSD, p<0.001 and Turkey HSD, p<0.001 respectively).

Parameter	Organic effluents non-impacted sites		Organic effluents impacted sites		
	Little Shuru	Mugo	Upper Canning	Lower Canning	P-value
DO (mg/L)	8.29 ± 0.88	8.16 ± 0.90	7.99 ± 0.08	7.87 ± 0.08	0.003
BOD5 (mg/L)	1.74 ± 0.08	2.05 ± 0.89	2.14 ± 0.90	2.48 ± 1.07	0.016
EC (µS/ cm)	125.73 ± 4.81	135.24 ± 5.031	145.29 ± 5.83	159.14 ± 7.14	0.001
Turbidity (NTU)	30.11 ± 2.11	31.69 ± 2.187	34.75 ± 2.07	48.18 ± 6.35	0.003
TSS (mg/L)	21.72 ± 24.26	25.67 ± 22.93	25.78 ± 18.73	29.92 ± 34.53	0.720
Temperature (°C)	15.33 ± 0.37	16.65 ± 0.41	17.83 ± 0.52	18.81 ± 0.60	>0.001
pH	8.09 ± 0.12	8.31 ± 0.14	8.25 ± 0.05	8.10 ± 0.11	0.410
$NH4^+$-N (µg/L)	5.46 ± 0.86	7.86 ± 2.31	12.78 ± 2.43	17.98 ± 4.76	0.033
$NO3^-$-N (mg/L)	17.66 ± 2.12	25.13 ± 2.84	29.77 ± 3.22	42.78 ± 4.83	>0.001
NO_2^--N (µg/L)	12.47 ± 2.24	13.67 ± 1.27	15.10 ± 2.28	19.91 ± 4.39	0.256
SRP (µg/L)	54.26 ± 6.21	77.36 ± 10.66	136.55 ± 21.99	216.12 ± 30.11	0.006
TP (µg/L)	53.48 ± 6.40	87.8 ± 12.72	334.77 ± 71.60	397.82 ± 72.10	>0.001

Table 1: Physico-chemical variables measured in the Njoro River study sites based on absence and presence of organic effluents discharge between November 2016 and February 2017. Bolded figures are means ± SE, n=27.

Benthic macroinvertebrate species diversity and abundance

Benthic macroinvertebrate collected from different sites along River Njoro comprised of 10 orders and 18 families.

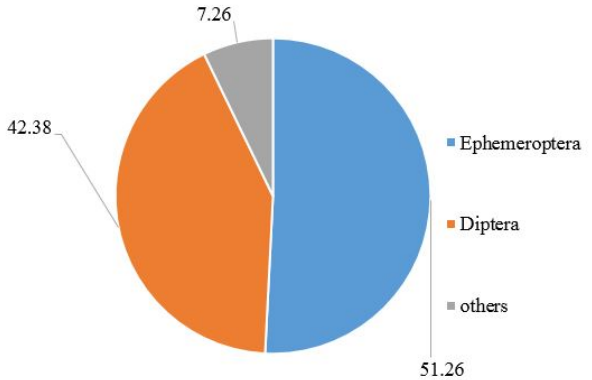

Figure 2: Percent composition of the dominant benthic macroinvertebrate taxa in Njoro.

Order Ephemeroptera and Diptera formed the dominant taxa, contributing 51.26% and 42.38% respectively of the total benthic macroinvertebrates obtained (Figure 2).

Macroinvertebrate densities collected from Little Shuru and Mugo study sites ranged between 429.8-458.1 individuals m^{-2} whereas those from Upper and Lower Canning ranged between 469-663.2 individuals m^{-2} (Table 2). No significant difference was observed in abundance of benthic macroinvertebrates among the sites (one-way ANOVA, $F_{(1,69)}$=0.206 p>0.05). Order Heptageniidae was most abundant at Little Shuru while Order Chironomidae dominated Mugo, Upper and Lower Canning as depicted in Table 3.

Taxonomic groups							
Organic Effluents	Site	a	b	c	d	e	f
Absent	Litle Shuru	96.25	111.95	16.05	28.74	137.88	38.91
	Mugo	141.63	74.37	31.01	82.07	69.88	59.11
Present	Upper Canning	185.04	107.16	23.26	72.69	44.59	36.25

	Lower Canning	336.2	151.51	12.59	42.72	90.72	29.48

Table 2: Densities (m^{-2}) of the major macroinvertebrate taxonomic groups in the selected study sites in Njoro. a- Chironomidae, b- Baetidae, c- Simuliidae, d- Caenidae, e- Heptageniidae, f- others.

Site	a	b	c	d	e	f	Total (%)
Litle shuru	22.39	26.04	3.73	6.69	32.08	9.05	100
Mugo	30.92	16.24	6.77	17.92	15.25	12.9	100
TOTAL	53.31	42.28	10.5	24.61	47.33	21.95	
Upper canning	39.45	22.85	4.96	15.5	9.5	7.73	100
Lower canning	50.69	22.84	1.9	6.44	13.68	4.44	100
TOTAL	90.14	45.69	6.86	21.94	23.18	12.17	

Table 3: Relative abundance of the major macroinvertebrate groups that dominated the study sites along the Njoro River. a- Chironomidae, b- Baetidae, c- Simuliidae, d- Caenidae, e- Heptageniidae, f- others.

Illustrations in Table 4 indicates that Little Shuru had the highest diversity index and mean species richness among the four sites. Although high abundance was recorded at Lower canning, the diversity and species richness were low at this site. The diversity of benthic macroinvertebrate did not differ significantly among the study sites. (t=1.36, df=18, p=>0.05). Shannon's Equitability index showed that Little Shuru had the lowest benthic macroinvertebrates distribution as compared to the other sites. Similarities between benthic macroinvertebrate communities from different sampling sites were recorded at 0.39.

Sampling site	Margalef richness index	Shannon index (H')	Equitability index (E)	Sorensen's coefficient
Little Shuru	1.97	1.98	0.67	0.39
Mugo	1.75	1.72	0.61	
Upper canning	1.54	1.73	0.64	
Lower canning	1.47	1.43	0.53	

Table 4: Species richness, diversity, evenness and similarity indices of benthic macroinvertebrates in Njoro River.

Discussion

Physico-chemical variables along the Njoro River

All the four investigated sites of the Njoro River showed water quality deterioration. Results indicate significant difference in DO concentration among these sites. This infers increased biodegradation of organic waste coupled with reduced water velocity, hence lack of turbulent water movements due to the river damming at Upper and Lower canning. These findings showed similarity to studies conducted by Raburu and Okeyo-Owuor [13] in Nyando River where dissolved oxygen was lower in stations located downstream of organic effluent discharge points. This is confirmed by high BOD concentrations recorded at Upper and Lower Canning probably as a result of accumulation of organic materials due to continuous influx and deposition of wastewater into the river. Consequently, resulting to reduction of oxygen content as explained above. This observation is in agreement with the findings by Mokaya et al. [8] who reported values between 12-125 mg/L in areas of wastewater influent in the Njoro River. Emere and Nasiru [14] classified rivers and streams based on BOD levels as unpolluted (BOD<1.0 mg/L), moderately polluted (BOD<2-9 mg/L) and heavily polluted (BOD>10 mg/L). Based on the above classification, all the study sites along the Njoro River could be placed under moderately polluted according to this study.

The significantly higher conductivity at the Lower Canning compared to the other sites, can be attributed to combined effect of organic wastes discharged probably from neighboring Egerton University and Njoro Canning, also indicated by low DO and high BOD, TSS and turbidity. Emere and Nasiru [14] reported that accumulation of suspended solid in aquatic systems reduce water transparency, effectively impacting on primary productivity, thus affecting benthic macroinvertebrates. Anyona et al. [15] further illustrates that high concentration of suspended solids cause damage to exposed respiratory organs of benthic macroinvertebrates resulting to their dislodgment. Suspended solids can equally destroy critical habitats by settling at the substrate of the water body, forming a blanket over critical spawning and breeding ground. The resulting outcome is disruption of species cycle hence, low diversity and composition.

The high nutrient concentrations observed at Upper and Lower canning could be attributed to decomposition and degradation of organic matter discharged into the river. The high concentration of NO_3--N recorded at all sampling points along the river is attributed to destruction of the riparian vegetation by man and livestock thus high run-off from the agricultural fields and other human activities in the catchment. Thus, discharge of untreated organic effluents combined with nitrogen transformation and transportation have resulted to elevated NO_3--N concentrations at Lower Canning. The relatively high DO levels along the sampling sites explain the low NO_2--N concentrations recorded. Emere and Nasiru [14] reported that for nitrate reduction to take place, the DO concentrations should be maintained below 0.5 mg/L. All sampling sites had concentrations above this threshold value which may have contributed to equally high levels of NO_3--N.

High SRP and TP concentrations recorded at Lower Canning almost 4 and 7-fold respectively compared to the other three sites could be attributed to discharge of phosphate-containing-detergent effluents into the river as a result of clothes and vehicles washing. Equally, the use of mineral fertilizers and manure used in agriculture and diffuse sewage effluents from the adjacent settlements (i.e, Njokerio) with minimal sanitation facilities, effluents from Egerton and Njoro canning could have led to the elevated levels of phosphates at this site [16].

The general inference that could be drawn from the nutrient results was that the whole river area under study was polluted according to WHO [17] standards (Table 5). Nutrient enrichment in this river is thus attributed to be one of the main causes of stream impairment imposing severe threats to ecosystem structure and function. Consequently, as Adeogun and Fafioye [18] reported, nutrients' direct impacts as increase of autotrophic production and change of species assemblages as well as accelerating litter breakdown rates by bacteria and fungi. (Alkharkhi et al. [19] reported that, nutrient concentrations

increase destabilization of the primary producer assemblage and water chemistry and consequently a shift in macroinvertebrate communities from sensitive species to more tolerant, often non-native species. Therefore, causing alteration in the food web resulting to changes in ecosystem function. Additionally, Davinson et al. [20] explained that high nutrient levels can have adverse effects by making drinking water toxic especially when nitrate concentration are high (>10 mg/L).

Parameter	WHO Limit (2004)
pH	6.5-8.5
T (°C)	15
EC (µS/cm)	750
NH_4^+(mg/L)	0.2
NO_3^-(mg/L)	10

Table 5: Summarized World Health Organization water quality standard values.

Benthic macroinvertebrates composition, abundance and diversity along the Njoro River

Ten benthic macroinvertebrate orders comprising of eighteen families were encountered along Njoro River. In comparison with previous studies in the Kenyan lotic systems, the ten orders recorded were relatively low for the Njoro River [6,21,22]. The composition and species diversity results obtained in this study were in agreement with studies reported in almost similar tropical streams in parts of Africa. For instance, in Southern urban stream in Zimbabwe [23] and Zaria river in Nigeria [24].

The Order Ephemeroptera dominated Little Shuru while family Chironomidae, which is pollution tolerant taxa, dominated the order Diptera density at Mugo, Upper and Lower Canning. The low abundance of family Chironomidae at the Little Shuru indicates clearly the effect of increased pollutants production and discharge on water quality at the downstream sites. The dominance of pollution tolerant taxa (Chironomidae) over the sensitive and non-tolerant taxa at these downstream stations could be a pointer to poor water quality particularly at Upper and lower Canning. This is similar to findings by Masese et al. [6] who established that pollution and excessive nutrient enrichment from anthropogenic sources can affect benthic macroinvertebrates' habitats hence, change in their community structure and composition. Anyona et al. [15] also reported that continuous exposure of benthic macroinvertebrate to pollution, changes their species composition in response to the magnitude, duration and frequency of the pollutants and level of human disturbance.

Family Chironomidae exemplify the characteristics of tolerant species to extreme environmental changes [25]. They have the ability to reproduce quickly and in large numbers and are highly diverse [26]. They compete with other benthic organisms for food and are capable of thriving in low resource, otherwise undesirable locations [27-30]. Its prominence in this study is similar to many tropical assemblages reported by other researchers like Fritz and Dodds [31] and Johnson et al. [32] in other aquatic systems. *Polypedilum sp.* showed its peak at the Lower Canning which exhibited low DO indicating high organic matter discharge from the surroundings probably from Egerton University, Njoro canning as well as input from domestic animals during watering. The results clearly indicate deterioration of water quality at this part of the river. However, prominence of Polypedilum sp. has been reported by Emere and Narisu [14] to dominate benthic macroinvertebrate communities in an urbanized Kaduna stream in Nigeria since they don't show habitat restriction.

This study exhibited a low Shannon–Weiner diversity index values of 1.43-1.98 indicating an overall low diversity of benthic macroinvertebrates along the Njoro River. In comparison to results obtained by Kibichii et al. [33] in studies carried out in the same system, there is a clear shift of benthic macroinvertebrates abundance from pollution sensitive taxa to pollution tolerant taxa. This indicates that organic pollution resulting to excessive nutrient enrichment from anthropogenic sources can affect benthic macroinvertebrates' trophic relationships as well as their habitats and thus change their composition and diversity. Adakole and Annune [24] established that changes in physico-chemical parameters disrupts macroinvertebrates' life and reproductive cycles, impact on food chain and migration patterns as well as stressing them physiologically. Magurran [25] also reported that continuous exposure of benthic macroinvertebrate to pollution, changes their species composition in response to the magnitude, duration and frequency of the pollutants and level of anthropogenic disturbance. However, two families are worth noting, Potamonautidae and Pyralidae which are pollution sensitive species, appeared only in upstream sites (Little Shuru) giving a clear indication of the impact of increased anthropogenic activities within the basin on water quality of the Njoro River.

Conclusion

It is evident that the Njoro River is highly impacted by increased anthropogenic activities leading to organic effluent discharge. Discharged organic wastes has contributed to water quality deterioration. Evidence is shown by change in physico-chemical water quality parameters which resulted to changes in macroinvrtebrtes species diversity and composition. Consequently, triggering dominance of pollution tolerant *Polypedilum sp.* along the lower study sites. These results clearly show the impact of increased anthropogenic activities within the Njoro River basin particularly on water quality. The results obtained in this study demonstrates that, a compromised aquatic ecosystem will not only change the aquatic fauna's community structure but also inhibit important ecological processes including the natural self-purification capability. There is therefore an urgent need to protect the Njoro River water resource through maintenance of ecological integrity by controlling anthropogenic activities, protection of the river channel and its basin coupled with increased public education and awareness in regard to environmental integrity. Therefore, a management strategy and implementation of policies towards pollution control and abatement in Njoro River should become a priority for all stake holders.

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References

1. Dudgeon D (2010) Prospects for sustaining freshwater biodiversity in the 21st century: linking ecosystem structure and function. Curr Opin Environ Sustain 2: 422-430.
2. Karr JR, Chu EW (2000) Introduction: Sustaining Living Rivers. Assessing the Ecological Integrity of Running Waters 149: 1-14.
3. Fischman RL (2004) The meanings of biological integrity, diversity, and environmental health. Natural Resources Journal 44: 989-1026.
4. Kithiia SM (2012) Effects of Sediments Loads on Water Quality within the Nairobi River Basins, Kenya. International Journal of Environmental Protection 2: 16-20.
5. Adeogun AO, Fafioye OO (2011) Impact of Effluents on Water Quality and Benthic Macroinvertebrate Fauna of Awba Stream and Reservoir. Journal of Applied Science and Environmental Management 15: 105-113.
6. Masese FO, Raburu PO, Muchiri M (2009) A preliminary benthic macroinvertebrate index of biotic integrity (B-IBI) for monitoring the Moiben River, Lake Victoria Basin, Kenya. African Journal of Aquatic Science 34: 1-14.
7. Shivoga WA, Muchiri M, Kibichi S, Odanga J, Miller SN, et al. (2007) Influences of land use/cover on water quality in the upper and middle reaches of River Njoro, Kenya. Lakes and Reservoirs: Research and Management 12: 97-105.
8. Mokaya SK, Sophia K, Jude MMM, Leichtfried M (2004) Influence of anthropogenic activities on water quality of a tropical stream ecosystem. African Journal of Ecology 42: 281-288.
9. APHA (2005) Standard method for the examination of water and waste water (21st Edn). Washington DC: America Water Works Association and Water Control Federation.
10. Moog O (2005) Manual on pro-rata multi-habitat sampling of benthic invertebrates from wade-able rivers in the HKH-Region. Deliverable 8, Part 1 for ASSESS-HKH, European Commission.
11. Gerber A, Gabriel MJM (2002) Aquatic Invertebrates of South African Rivers: Field Guide. Institute for Water Quality Studies.
12. Chakravorty PP, Sinha M, Kumar S (2014) Impact of industrial effluent on water quality and benthic macro invertebrate diversity in fresh water ponds in Midnapore district of west Bengal, India. Journal of Entomology and Zoology Studies 2: 93-101.
13. Raburu PO, Okeyo-Owuor JB (2005) Impact of agro-industrial activities on the water quality of River Nyando, Lake Victoria Basin, Kenya 2: 307-314.
14. Emere MC, Nasiru NC (2007) Macroinvertebrates as indicators of the water quality of urbanized stream Kaduna Nigeria. Journal of Fisheries International 2: 152-157.
15. Anyona DN, Abuom PO, Dida GO, Gelder FB, Jackson O, et al. (2014) Effect of Anthropogenic Activities on Physico- chemical Parameters and Benthic Macroinvertebrates of Mara River Tributaries, Kenya 2: 98-109.
16. Yillia PT, Kreuzinger N, Mathooko JM (2007) In-Stream Activities Influence Microbial Water Quality Of A Shallow Mountain Stream In Rural Kenya. Hydrobiologia 458: 131-139.
17. World Health Organization (WHO) (2004) Guidelines for drinking-water quality (3rd edn).
18. Adeogun AO,Fafioye OO (2011) Impact of Effluents on Water Quality and Benthic Macroinvertebrate Fauna of Awba Stream and Reservoir. Journal of Applied Science and Environmental Management 15: 105-113.
19. Alkarkhi AFM, Ahmad A, Easa AM (2008) Assessment of surface water quality of selected estuaries of Malaysia: multivariate statistical techniques. The Environmentalist 29: 255-262.
20. Davison A, Howard G, Stevens M, Callan P, Fewtrell L, et al. (2005) Water Safety Plans 38: 296-298.
21. Mathooko JM (2001) Disturbance of a Kenyan Rift Valley stream by the daily activities of local people and their livestock. Hydrobiologia 458: 131-139.
22. Mbaka JG, M'Erimba CM, Mathooko JM (2015) Impacts of Benthic Coarse Particulate Organic Matter variations on Macroinvertebrate Density and Diversity in the Njoro River, A Kenyan Highland Stream. Journal of East African Natural History 103: 39-48.
23. Ogbeibu AE, Oribhabor BJ (2002) Ecological impact of river impoundment using benthic macroinvertebrates as indicators. Water Research 36: 2427-2436.
24. Adakole JA, Annue PA (2003) Benthic Macroinverteberates as indicators of Environmental quality of an urban stream, Zaria, Northern Nigeria. Journal of Aquatic Sciences 18: 85-92.
25. Demoor FC (1992) Factors influencing the establishment of aquatic insect invaders. Transactions of the Royal Society of South Africa 48: 141-158.
26. Armitage PD, Cranston PS, Pinder LC (1995) The Chironomidae: biology and ecology of non-biting midges. Chapman and Hall, London.
27. Brodin Y, Andersson MH (2009) The marine splash midge Telmatogon japonicas (Diptera; Chironomidae) — extreme and alien? Biological Invasions 11: 1311-1317.
28. Hughes KA, Worland MR (2010) Spatial distribution, habitat preference and colonization status of two alien terrestrial invertebrate species in Antarctica. Antarctic Science 22: 221-231.
29. Evenhuis NL, Eldredge LG (2013) The nuisance marine midge, Kiefferulus longilobus, is established in Hawaii (Diptera: Chironomidae). Occasional Papers 114: 59-60.
30. Gruszka PJ, Rokicka-Praxmajer J, Cupak J, Wolska M, Radziejewska T, et al. (2013) Unintended "biological cargo" of ships entering the River Odra estuary: assemblages of organisms in ballast tanks. Zeszyty Naukowe 33: 22-29.
31. Fritz KM, Dodds WK (2004) Resistance and resilience of macroinvertebrate assemblages to drying and flood in a tallgrass prairie stream system. Hydrobiologia 527: 99–112.
32. Johnson RK, Hering D, Furse MT, Verdonschot PF (2006) Indicators of ecological change: Comparison of the early response of four organism groups to stress gradients. Hydrobiologia 566: 139-152.
33. Kibichii S, Shivoga WA, Muchiri M, Miller SN (2007) Macroinvertebrate assemblages along a land-use gradient in the upper River Njoro watershed of Lake Nakuru drainage basin, Kenya 12: 107-117.