Zooplankton Community Structure in a Wastewater Treatment Plant. A Case of Suneka Wastewater Treatment Plant, Kenya

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Abstract

Water quality determines aquatic organisms' community structure. As a result, selected planktons have been used as bioindicators of water quality. In the current study, we determined zooplankton community structure and diversity in Suneka wastewater treatment plant in addition to selected physical and chemical parameters of the wastewater. The zooplankton samples were collected in triplicate once every month from August to December, 2019 from seven sampling points at sub-surface level. Temperature, pH, electrical conductivity (EC), and dissolved oxygen (DO) were measured in situ using calibrated portable professional series (YS1) multiparameter meter model 35C at each sampling point. Nutrient analysis, wastewater samples were collected in triplicate using acid-washed bottles from the different sampling points and analyzed ex-situ using the spectrophotometric method for the determination of water and wastewater according to APHA, 2014. The results revealed the presence of 13 zooplankton species belong to three taxa: Cladocera, Rotifera, and Copepoda. In terms of abundance, Cladocera was the most dominant group, while Copepoda and Rotifera maintained lower and more stable populations across the sampling stations. Moreover, the study revealed there was spatial and temporal variation in zooplankton in terms of diversity and distribution. The variations in zooplankton diversity can be attributed to changes in physical and chemical parameters in addition to primary productivity in the respective sampling stations. The study findings form baseline information on the zooplankton assemblage for the Suneka wastewater treatment plant for future studies.

Keywords: Suneka Wastewater Treatment Plant, Zooplankton Community Structure, Physical, And Chemical Parameters

Introduction

Water quality determines aquatic organisms' community assemblage and diversity (Hassan et al., 2019; Kabanze, 2024; Omondi et al., 2011). Wastewater is highly polluted and has been characterized with low biodiversity. Zooplankton are heterotrophic aquatic organisms that feed on bacteria, phytoplankton, and other zooplankton organisms. In turn, they are fed on by most aquatic animals including larval stages of fish. Thus, they play an integral role in aquatic ecosystems food web. They facilitate the transfer of primary productivity to fish and other higher aquatic species, as well as the regulation of microbial and algal productivity through grazing.

In aquatic habitats, zooplankton float freely, and their distribution is mostly influenced by currents, water mixing, and water quality. As a result, certain species can be found in a variety of environmental conditions, whilst others are restricted by numerous physical and chemical factors, which is why some are used as bio-indicators of water quality (Hassan et al., 2019). Because the majority of the species have short generation cycles, the community frequently reacts rapidly to a wide range of environmental changes, including nutrient loading, pollutants, fish concentrations, and sediment inputs. Environmental changes in water quality have different effects on different groups of zooplankton. Wastewater quality has an impact on the plankton, specifically phytoplankton and zooplankton species structure and distribution (Deksne, 2011; Ibrahim, 2009; Khune & Parwate, 2017; Omondi et al., 2011; Rayori et al., 2021). Research has shown that the discharge of treated wastewater into rivers causes a decrease in zooplankton species diversity and abundance (Rayori, 2023), while in another study on a lentic ecosystem, the discharge of municipal wastewater resulted in richness in zooplankton diversity because of nutrient enrichment (Adhikari, et al., 2017).

In order to advance our understanding of zooplankton in tropical wastewater lagoons, the current study was conducted to evaluate the zooplankton diversity, as well as their spatial and temporal distribution and abundance, in the Suneka wastewater treatment plant. Additionally, it can serve as the foundation for figuring out the treatment plant's productivity. Furthermore, by using this baseline data, we will be able to create suggestions for the monitoring program that will be used to assess the effectiveness of the remedial measures and, in the end, enable comparison with the structure of the zooplankton community in the future.

Materials and Methods

Study Area

The study was carried out in the Suneka wastewater treatment plant. The plant is located at Suneka Division at latitude 00 39' 30'' S and Longitude 340 42' 30'' E, in Kisii County, Kenya. The plant design has a capacity of treating 8,000m^3/day of sewage wastewater received from Kisii town and its surrounding areas. In the treatment plant, the received sewage wastewater passes through a series of ponds that's anaerobic, facultative, and tertiary ponds for pollutant removal before the effluent is discharged into Riana River (Figure 1).

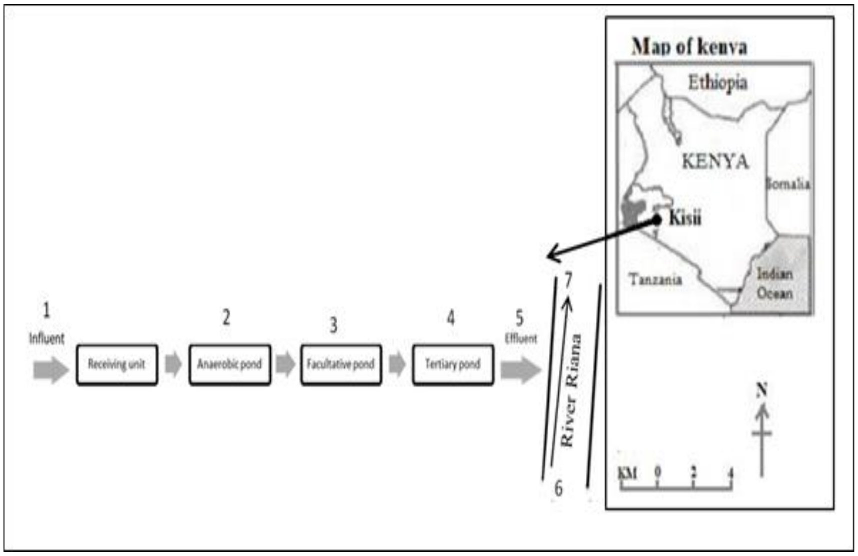

Figure 1: A sketch showing the wastewater treatment stages and sampling points in Suneka wastewater treatment plant (Rayori et al., 2021).

Zooplankton Samples Collection, Identification and Enumeration

Zooplankton samples were collected in triplicate once every month from August to December, 2019 during the morning hours (between 8.00 am and 10.00 am) from seven sampling points at sub-surface level. The sampling points were: Influent, anaerobic, facultative, and tertiary ponds, effluent, and two sampling points along river Riana, that's upstream and downstream at the effluent discharge point into the river (Figure 1). The zooplankton samples were obtained by filtering 20 liters of wastewater through a 1.0-meter-long zooplankton net with 60 µm mesh size. The filtrate was then transferred into clearly labeled pre-cleaned 100 ml plastic bottles and 4% formalin was added to preserve the samples. The preserved samples were then transported to the laboratory for analysis.

In the laboratory, a dissecting microscope (X50) was used for identification of the zooplankton up to species level. A light compound microscope (Model: Olympus, Japan) with a magnification of 100–400X was used for the detailed identification of zooplankton. Using standard identification keys, zooplankton taxa were identified. The following formula was used to calculate the number of individuals per litre (IndL^{-1}) of zooplankton (Omondi et al., 2011).

$$D = {}^{N}\!/_{V} \ldots\ldots\ldots\ldots\ldots.\ Equation\ 1$$

Where N = number of organisms in sample calculated by the formula:

$$N = \frac{(Number\ in\ wastewater\ subsample) \times (Volume\ of\ sample)}{Volume\ of\ subsample} \text{……..Equation ……..2}$$

Where V = Volume of wastewater filtered

Zooplankton Diversity Indices

Shannon-Wiener (H'), Margalef's Index (d), and species evenness were among the diversity indices that were computed using the formulas developed by Ogbeigbu (2005) and Eyo et al., (2013). The diversity indices were determined using PAST software, and Microsoft Excel version 2010 was used to calculate the Person correlation coefficient (r) values (significant at $P < 0.05$) between the zooplankton abundance and certain physicochemical parameters of the several sampling points.

Physical-Chemical Parameters

Wastewater temperature, pH, electrical conductivity (EC), and dissolved oxygen (DO) were measured *in situ* using calibrated portable professional series (YS1) multiparameter meter model 35C at each sampling point. For nutrient analysis, wastewater samples were collected in triplicate using acid-washed bottles from the different sampling points and analyzed *ex-situ* using the spectrophotometric method for the determination of water and wastewater according to APHA, 2014. The nutrients which were analyzed included nitrates (NO_3-N), nitrites (NO_2-N), total phosphorous (TP), total nitrogen (TN), and ammonium (NH_4-N). The data obtained was organized using Microsoft Excel version 2010. Spatial and temporal variations in the physical and chemical parameters between sampling points, and among months were determined by Two-way Analysis of Variance (ANOVA) at a pre-determined alpha value of 0.05.

Results

Zooplankton Composition

A total of thirteen zooplankton species were identified in the Suneka wastewater treatment plant including the two sampling points along Riana River during the entire study period (**Error! Reference source not found.**). The identified species belonged to three broad taxonomic groups namely Rotifera, Cladocera, and Copepopeda. The highest number of species, 8 (61.5%) belonged to Rotifera, followed by Cladocera with 4 species (30.8%). The Copepoda were identified as mature cyclopoida and nauplii (immature) stage as a result, the family was only represented by one species (7.7%).

Table 1: Zooplankton Taxa Recorded in Suneka Wastewater Treatment Plant From August-December 2019

Cladocera	Copepoda	Rotifera
Ceriodaphnia cornuta	Copepod nauplius larvae	*Asplanchna* spp.
Daphnia lumholtzi	Cyclopoida	*Brachionus angularis*
Diaphanosoma excisum		*Brachionus calyciflorus*
Moina micrura		*Brachionus quadridentatus*
		Filinia spp.
		Hexarthra spp.
		Polyarthra spp.
		Trichocerca spp.

Zooplankton Diversity

The calculated zooplankton diversity indices are summarized in **Error! Reference source not found.**. The total number of zooplankton species observed at various sampling points varied from 2 to 9. The tertiary pond had the largest total number of zooplankton species, with 9 followed by facultative pond, with 8, while the upstream sampling point had the lowest number, with 2. The indices of Margalef's diversity (d), species evenness (E), and Shannon-Wiener (H) were determined. At the tertiary sampling station, the Shannon-Wiener (H') diversity index was 1.648, while at the upstream, it was 0.3669. The dominant index (D) had the least value of 0.2302 at the influence, and the maximum value above 0.788 at the upstream sampling point. In terms of species richness (d), the downstream station was richer (with a value of 1.537) while the upstream had the least value (0.3107).

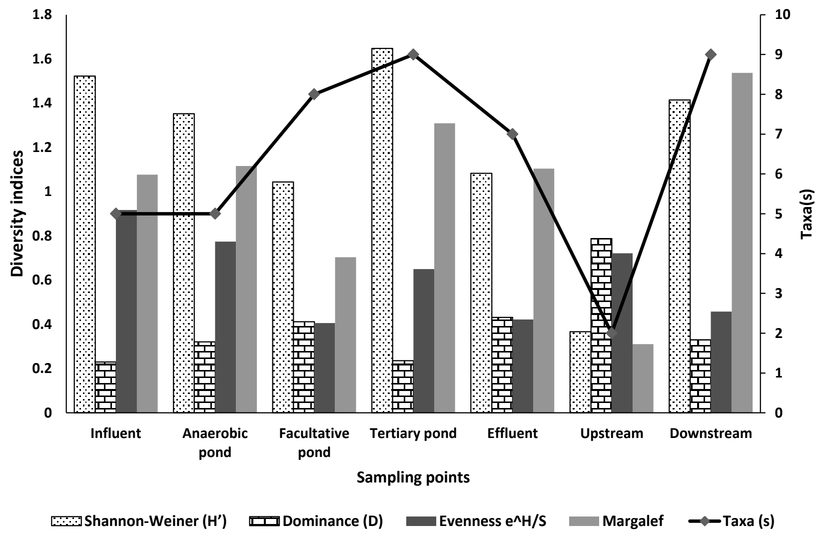

Figure 2: Zooplankton diversity indices recorded in Suneka wastewater treatment plant from August-December 2019

Monthly Zooplankton Abundance Distribution

The total zooplankton abundance that was recorded in the Suneka wastewater treatment plant was 5746 $IndL^{-1}$, with the month of September recording the highest total zooplankton abundance (3109.7 $IndL^{-1}$) that's 54.1 % of the total zooplankton abundance, while the month of August recorded the least total zooplankton abundance (130.8 $IndL^{-1}$) accounting for 2.3% of the total zooplankton abundance (**Error! Reference source not found.**). In terms of number of species, the month of November the highest number of zooplankton species of 11, while the other months recorded each with 7 zooplankton species.

The monthly distribution for the total zooplankton abundance per taxa and species is summarized in **Error! Reference source not found.**. The Cladocera dominated throughout the study period, but the highest total abundance was recorded in the month of September (3089.7 $IndL^{-1}$) followed by the month of December (2189.2 $IndL^{-1}$). Among the Cladocera, *Ceriodaphnia cornuta* and *Diaphanosoma excisum* dominated in the month of September while *Moina micrura* was dominant in the month of September and December. *Daphnia lumholtzi* recorded the least total abundance of 3.3 $IndL^{-1}$. For Copepoda, the highest total taxa abundance was recorded in the month of November (66.7 $IndL^{-1}$) followed by December (42.5 $IndL^{-1}$), with the least abundance recorded in the month of September (2.8 $IndL^{-1}$). The mature stages of the Copepods that's the Cyclopoida dominated during the entire study period. For Rotifers, the highest total taxa abundance was recorded during the month of December (82.5 $IndL^{-1}$) followed by November (50.0 $IndL^{-1}$) with *Trichocerca* sp. accounting for the largest percentage of the total abundance in each of the mon

Table 2: Monthly distribution of total zooplankton abundance (IndL-1) in the Suneka wastewater treatment plant from August-December, 2019

Month	Taxa	Species	Total zooplankton abundance (IndL^{-1})		
August	Cladocera	*Diaphanosoma excisum*	21.7	100.8	130.8
		Moina micrura	79.2		
	Copepoda	Cyclopoida	15.0	15.0	
	Rotifera	*Asplanchna* sp	7.5	15.0	
		Brachionus calyciflorus	2.5		
		Brachionus quadridentatus	4.2		
		Polyarthra sp	0.8		
September	Cladocera	*Ceriodaphnia cornuta*	1218.1	3089.7	3109.7
		Diaphanosoma excisum	971.1		
		Moina micrura	900.6		
	Copepoda	Copepod nauplius larvae	1.7	2.8	
		Cyclopoida	1.1		
	Rotifera	*Filinia* sp	5.6	17.2	
		Hexarthra sp	11.7		
November	Cladocera	*Daphnia lumholtzi*	3.3	73.3	190.0
		Diaphanosoma excisum	51.7		
		Moina micrura	18.3		
	Copepoda	*Calanoida*	11.7	66.7	
		Copepod nauplius larvae	10.0		
		Cyclopoida	45.0		
	Rotifera	*Asplanchna* sp	5.0	50.0	
		Brachionus angularis	10.0		
		Brachionus calyciflorus	5.0		
		Filinia sp	6.7		
		Trichocerca sp	23.3		
December	Cladocera	*Diaphanosoma excisum*	44.2	2189.2	2314.2

		Moina micrura	2145.0		
	Copepoda	Copepod nauplius larvae	15.0	42.5	
		Cyclopoida	27.5		
	Rotifera	*Brachionus angularis*	6.7	82.5	
		Filinia sp	55.0		
		Trichocerca sp	20.8		

Spatial Distribution of Zooplankton

The total zooplankton abundance distributions across all the sampling points were determined and the findings are summarized in **Error! Reference source not found.**. The facultative pond had the highest zooplankton total abundance of 5038 $IndL^{-1}$ followed by effluent sampling point with 228 $IndL^{-1}$ while the least total abundance of 25 $IndL^{-1}$ zooplankton were recorded in the anaerobic pond and upstream sampling points.

Table 3: Spatial distribution of zooplankton taxonomic groups and their abundance in the Suneka wastewater treatment plant

	Zooplankton abundance ($IndL^{-1}$)						
Taxa	**Influent**	**Anaerobic pond**	**Facultative pond**	**Tertiary pond**	**Effluent**	**Upstream**	**Downstream**
Cladocera							
Ceriodaphnia cornuta			1133		1		84
Daphnia lumholtzi				3			
Diaphanosoma excisum	10		970	55	26	22	6
Moina micrura			2872	75	137		60
Total	10		4974	133	164	22	150
Copepoda							
Nauplii				22	2	3	
Cyclopoida	11	18	13	33	1		13
Total	11	18	13	55	3	3	13

Rotifera							
Asphlanchna sp		3		5			5
Brachionus angularis			17				
Brachionus calyciflorus			5				3
Brachionus quadridentatus							4
Fillinia sp				12	56		
Hexarthra sp					6		6
Polyarthra sp							1
Trichocerca sp	11	5	28				
Total	11	8	50	17	62		18
Zooplankton total abundance	32	25	5038	205	228	25	181

The facultative pond had the highest total abundance of Cladocera species, whereas the anaerobic pond none was recorded. In the facultative pond station, *Moina micrura* was the most dominant and reached its highest abundance (2872 $IndL^{-1}$), followed by *Ceriodaphnia cornuta*, which had an abundance of 1133 $IndL^{-1}$. Copepoda were recorded in all sampling points unlike the Cladocera. The highest total abundance was recorded in the tertiary pond. However, the immature stages were only recorded in the tertiary pond, effluent and upstream sampling points while the mature stages were recorded in all sampling points except the upstream point. For Rotifers, the least total zooplankton abundance was recorded in the anaerobic pond and upstream sampling points each with 25 $IndL^{-1}$. On the other hand, the effluent sampling point recorded the highest total abundance (62 $IndL^{-1}$) of Rotifers. The abundance of *Asplanchna* sp. ranged from 3 to 5 $IndL^{-1}$. With an abundance of 17 $IndL^{-1}$, *Brachionus angularis* was only found in the facultative pond. The abundance of *Trichocerca* sp. ranged from 5 to 28 $IndL^{-1}$ and was recorded at three sampling points that's the influent, anaerobic pond, and facultative pond.

Spatial, Monthly, and Trends in Physical, and Chemical Parameters

The spatial, monthly, and trends in the physical, and chemical parameters across all the sampling points in the Suneka wastewater treatment plant including the two sampling points along Riana river findings are summarized in **Error! Reference source not found.** and **Error! Reference source not found.**. The results sh ow that all the parameters analyzed varied both spatially and monthly (Two way ANOVA: $p < 0.05$). In terms of trends spatially, there was a decrease in the means of conductivity, TSS, TDS, and nitrate concentrations between the influent through the wastewater stabilization ponds to the effluent sampling points, an indication of wastewater polishing. Similarly, there was an increase in the means for dissolved oxygen concentration between the influent through the wastewater stabilizing ponds to the effluent similar to pH, and temperature, an indication improvement on the wastewater quality. However, for TN mean concentrations fluctuated with an increasing trend while TP mean concentrations exhibited a declining trend between the influent and the effluent sampling points. For ammonium-nitrogen concentration, there was no trend neither decreasing nor increasing between the influent and effluent sampling points as the wastewater went through the wastewater treatment plant during polishing (**Error! Reference source not found.**). During the entire study period, it is only the mean concentrations for conductivity and temperature which had a decreasing trend between the month of August and December while the rest of the parameters studied fluctuated with no clear decreasing or increasing trends. For pH, it showed an increasing trend between the months of August-November and then showed a sharp decline in December (**Error! Reference source not f ound.**). For pH, the lowest values recorded in the month of December can be associated with elevated levels of inorganic and organic concentrations in the ponds due to water evaporation during the drier seasons attributed to short rains.

Correlation Between Physical and Chemical Parameters and Zooplankton Abundance and Distribution in the Initial Suneka Wastewater Treatment Plant

The correlation analysis demonstrated the relationship between physical and chemical parameters and zooplankton abundance. **Error! Reference source not found.** shows the obtained correlation matrices at 5% level of significance and only those variables with Pearson coefficients equal or higher than 0.50 ($r = 0.50$) were significant. Among the 12 variables analyzed, only some of them showed significant correlation relationship with zooplankton abundance. Cladocera had a strong positive correlation with temperature ($r = 0.5396$), ammonium-nitrogen ($r = 0.6564$), TN ($r = 0.5503$) and TP ($r = 0.5989$) but with a very strong negative correlation to nitrate-nitrogen ($r = -0.7684$). For Rotifera, there was a strong positive correlation to TN ($r = 0.6455$) and TP ($r = 0.5564$); with a very strong positive correlation with temperature ($r = 0.7230$) and very strong negative correlation to nitrate-nitrogen ($r = -0.7129$)

Table 4: Spatial variations in physical and chemical parameters in the Suneka wastewater treatment plant (Mean ± SE)

Parameters	Sampling Points							Mean (±SE)
	Influent	Anaerobic pond	Facultative pond	Tertiary pond	Effluent	Upstream	Downstream	
pH	6.5 ± 0.61[d,e] (6.29-6.79)	6.0 ± 0.68[e] (5.79-6.29)	6.8 ± 0.75[c,d] (6.53-7.03)	7.2 ± 0.62[a,b,c] (6.95-7.46)	7.1 ± 0.45[b,c] (6.89-7.39)	7.7 ± 0.09[a] (7.48-7.98)	7.5 ± 0.18[a,b] (7.26-7.76)	
Conductivity (μscm^{-1})	1404 ± 325.7[a] (1356.43-1451.51)	878.9 ± 79.2[b] (831.38-926.46)	888.0 ± 81.7[b] (840.42-935.49)	926.1 ± 78.2[b] (878.60-973.68)	616.1 ± 37.1[c] (568.53-663.61)	128.2 ± 7.9[d] (80.63-175.71)	240.3 ± 36.2[e] (192.73-287.81)	725.93 ± 66.40
Temp. (°C)	22.3 ± 0.21[c] (21.58-22.95)	24.0 ± 0.4[b] (23.27-24.64)	26.5 ± 0.84[a] (25.84-27.21)	26.2 ± 0.53[a] (25.55-26.92)	25.9 ± 0.38[a] (25.25-26.61)	22.6 ± 0.28[b,c] (21.93-23.30)	22.7 ± 0.25[b,c] (22.0-23.36)	24.31 ± 0.25
DO (mgL^{-1})	2.0 ± 0.73[e] (1.59-2.42)	0.4 ± 0.17[f] (0.003-0.83)	4.5 ± 1.25[c] (4.04-4.86)	3.1 ± 0.58[d] (2.66-3.48)	5.6 ± 1.08[b] (5.16-5.98)	5.6 ± 1.04[b] (5.23-6.05)	7.1 ± 0.21[a] (6.70-7.52)	4.04 ± 0.38
TSS (mgL^{-1})	172.6 ± 39.78[b] (158.21-186.89)	137.0 ± 20.51[c] (122.66-151.34)	205.3 ± 38.36[a] (190.97-219.65)	63.0 ± 6.7[d] (48.66-77.34)	30.0 ± 2.36[e] (15.67-44.36)	137.4 ± 32.88[c] (123.07-151.75)	147.5 ± 33.79[b,c] (133.16-161.84)	127.5 ± 12.14
TDS (mgL^{-1})	572.2 ± 90.97[a] (549.31-595.01)	318.7 ± 48.27[b] (295.80-341.51)	316.4 ± 20.97[b] (293.54-339.25)	289.2 ± 28.13[b] (266.40-312.10)	293.2 ± 28.57[b] (270.37-316.07)	315.8 ± 45.75[b] (292.92-338.62)	291.6 ± 40.22[b] (268.79-314.50)	342.4 ± 20.43
NH_4-N(μgL^{-1})	464.1 ± 147.93[d] (366.84-561.43)	674.0 ± 134.78[c,d] (576.74-771.33)	1090.0 ± 194.91[a] (992.66-1187.25)	987.1 ± 143.78[a,b] (889.84-1084.43)	776.1 ± 109.47[c] (678.82-873.41)	813.9 ± 201.67[b,c] (716.63-911.22)	605.1 ± 119.87[c,d] (507.83-702.42)	772.92 ± 60.18
NO_2-N (μgL^{-1})	43.3 ± 9.12[a] (404.40-46.22)	19.2 ± 3.78[e] (16.28-22.09)	19.3 ± 4.78[e] (16.43-22.25)	30.5 ± 6.39[c,d] (27.60-33.41)	35.5 ± 7.12[b,c] (32.55-38.36)	24.6 ± 4.92[d,e] (21.64-27.46)	38.4 ± 0.96[a,b] (35.52-41.33)	30.11 ± 2.33
NO_3-N (μgL^{-1})	67.1 ± 11.98[a] (63.13-71.04)	58.1 ± 10.73[b] (54.13-62.04)	31.1 ± 4.3[c] (27.15-35.06)	44.7 ± 6.32[c] (40.76-48.68)	45.7 ± 7.25[c] (41.77-49.68)	58.3 ± 12.17[b] (54.32-62.23)	62.3 ± 7.72[a,b] (58.33-66.24)	52.47 ± 3.54
TN (μgL^{-1})	800.1 ± 201.64[b,c] (654.18-946.05)	409.0 ± 58.15[d] (263.07-554.94)	1280.7 ± 233.55[a] (1134.77-1426.63)	1231.4 ± 296.55[a] (1085.48-1377.34)	1080.5 ± 248.68[a,b] (934.52-1226.38)	764.7 ± 193.43[c] (618.74-910.61)	856.1 ± 264.16[b,c] (710.19-1002.06)	917.5 ± 87.69

TP (µgL^{-1})	1604.2 ± 213.36^{a,b} (1365.88-1842.57)	1272.3 ± 250.07^{c,d} (1033.94-1510.63)	1824.9 ± 406.49^{a} (1586.56-2063.25)	1542.2 ± 370.29^{a,b} (1303.88-1780.57)	1443.4 ± 243.97^{a,b,c} (1205.04-1681.73)	859.7 ± 210.16^{d} (621.31-1098.00)	1019.5 ± 159.46^{c,d} (781.19-1257.88)	1367 ± 106.78

NOTE: *Values in a row with different superscript letters (i.e a,b,c) are significantly different at p < 0.05 level (Tukey test is applied). Values in brackets are ranges.*

Table 5: Monthly variations in physical and chemical parameters in the Suneka wastewater treatment plant (Mean ± SE)

Parameters	**Sampling Months**			
	August	**September**	**November**	**December**
pH	7.5 ± 0.15^{b} (7.3-7.68)	7.9 ± 0.08^{a} (7.76-8.14)	8.1 ± 0.09^{a} (7.91-8.29)	4.4 ± 0.46^{c} (4.25-4.62)
Conductivity (µscm-1)	1125.8 ± 211.3^{a} (1089.91-1161.78)	774.0 ± 93.0^{b} (738.10-809.97)	565.3 ± 64.1^{c} (529.38-601.25)	438.5 ± 47.4^{d} (402.57-474.44)
Temp. ($^{\circ}$C)	25.2 ± 0.68^{a} (24.72-25.75)	24.8 ± 0.49^{a,b} (24.24-25.27)	23.8 ± 0.45^{b,c} (23.31-24.24)	23.4 ± 0.26^{c} (22.93-23.96)
DO (mgL^{-1})	6.2 ± 0.77^{a} (5.88-6.51)	1.2 ± 0.51^{d} (0.86-1.48)	4.7 ± 0.73^{b} (4.42-5.04)	4.1 ± 0.61^{c} (3.74-4.36)
TSS (mgL^{-1})	115.7 ± 23.03^{b} (104.91-126.59)	61.4 ± 13.24^{c} (50.55-72.23)	166.5 ± 26.09^{a} (155.67-177.35)	166.5 ± 26.09^{a} (155.67-177.35)
TDS (mgL^{-1})	323.68 ± 8.62^{b} (306.40-340.95)	167.0 ± 25.14^{c} (149.68-184.23)	439.6 ± 27.5^{a} (422.30-456.85)	439.6 ± 27.5^{a} (422.30-456.85)
NH_4-N (µgL^{-1})	750.8 ± 96.17^{a} (677.22-824.31)	781.5 ± 133.37^{c} (707.99-855.08)	811.2 ± 137.34^{b} (737.67-884.77)	748.1 ± 118.72^{b} (674.60-821.70)
NO_2-N (µgL^{-1})	20.45 ± 1.10^{c} (18.25-22.65)	47.16 ± 1.10^{a} (44.96-49.36)	17.50 ± 1.10^{c} (15.30-19.70)	35.33 ± 1.10^{b} (33.13-37.53)
NO_3-N (µgL^{-1})	27.19 ± 1.49^{d} (24.20-30.18)	78.51 ± 1.49^{a} (75.52-81.50)	43.58 ± 1.49^{c} (40.60-46.58)	60.58 ± 1.49^{b} (57.59-63.57)
TN (µgL^{-1})	1623.52 ± 55.07^{a} (1513.21-1733.84)	354.05 ± 55.07^{c} (243.74-464.37)	459.15 ± 55.07^{c} (348.83-569.46)	1233.27 ± 55.07^{b} (1122.95-1343.58)
TP (µgL^{-1})	1866.3 ± 218.51^{a} (1686.10-2046.45)	1407.5 ± 275.59^{b} (1227.34-1587.69)	883.7 ± 104.49^{c} (703.49-1063.83)	1309.0 ± 173.93^{b} (1128.79-1489.13)

NOTE: *Values in a row with different superscript letters (i.e a,b,c) are significantly different at p < 0.05 level (Tukey test is applied). Values in brackets are ranges.*

Table 6: Pearson Correlation Coefficient (r) matrix of zooplankton abundance and physical and chemical parameters for the Suneka wastewater treatment plant at 95 % confidence interval

	PH	Temp (°C)	DO (mgL^{-1})	Conductivity (μScm^{-1})	TSS (mgL^{-1})	TDS (mgL^{-1})	NH_4-N (μgL^{-1})	NO_2-N (μgL^{-1})	NO_3-N (μgL^{-1})	TN (μgL^{-1})	TP (μgL^{-1})
Cladocera	-0.1408	0.5396	0.1024	0.1510	0.5399	-0.1328	0.6564	-0.4883	-0.7684	0.5503	0.5989
Copepoda	-0.1051	0.3933	-0.3973	0.3625	-0.2790	-0.1366	0.3420	-0.0528	-0.2062	0.2974	0.3085
Rotifera	-0.0068	0.7230	0.3261	0.0715	-0.2704	-0.2715	0.4166	0.0067	-0.7129	0.6455	0.5564

Discussion

Wastewater is rich with pollutants namely biological, inorganic, organic, and emerging pollutants like pesticides, pharmaceuticals, and microplastics among others (Laffite et al., 2016; Unesco, 2017, Rayori, 2023, Rayori, 2024). In the current study, the results show that the sewage wastewater treatment plant is rich with nutrients resulting from high organic load it receives from the town and the catchment areas resulting from increasing human population and activities within the town and its catchment area. The results also show that the pollutants were attenuated as the wastewater passed through the treatment plant stabilization ponds an indication improvement in wastewater quality. Similar observations have been made in other similar studies which include the studies in the University of Eldoret (Wanjohi 2019, Moi university (Ronoh, 2017), and in the Gacuriro Vision City, Rwanda (Nikuze et al., 2020) wastewater treatment plants. Moreover, the pollutants removals were differential in all of these studies just like in the current study (Rayori, 2023; Wanjohi et al., 2019). The differential pollutant removal have been attributed to poor management of the wastewater treatment facilities resulting in their frequent breakdown, lack of qualified personnel, and increased volume of sewage wastewater beyond their capacity designs due to increased population in the catchment areas among other factors (Kilingo, Bernard, & Hong-bin, 2021). As a result, these wastewater treatment facilities have been associated with discharge of untreated or partially treated effluents to the environment including rivers resulting to ecosystem pollution ultimately leading to loss of biodiversity, and outbreak of diseases (Nikuze et al*.,* 2020; Rayori, 2023; Ronoh, 2017; Were-Kogogo, & Adhiambo, 2017; Wanjohi 2019).

Zooplankton are relatively small in size, thus they are free floating in aquatic ecosystems. Moreover, they play a key role in the aquatic ecosystem food webs. Their community structure and assemblage solely depends on the environmental conditions, rendering them suitable as water quality bio-indicators (Adhikari, Goswami & Mukhopadhyay, 2017; Deksne, 2011; Khune & Parwate, 2017). From the results obtained, they show that the zooplankton abundance, composition, and diversity were variable across all the sampling sites within the wastewater treatment functional ponds including the two sampling points in River Riana. The Facultative pond recorded the highest abundance (5038 Ind L^{-1}), suggesting it supports favorable conditions for zooplankton growth. The Cladocera showed high variability and dominated in the anaerobic pond, while the Copepoda abundance was relatively low across all the sampling sites with consistency. On the other hand, Rotifera had moderate abundance but picked in the effluent sampling station. These variations in zooplankton composition in the respective sampling sites can be attributed to changes in the physical, chemical and biological properties in the functional ponds within the wastewater treatment plant and in the river. The high organic load rich with nutrients received into the wastewater treatment plant might have enhanced primary productivity which supported high zooplankton production. The findings corroborate other similar studies which have shown that plankton (phytoplankton and zooplankton) assemblages are influenced by changes in water quality (Adhikari, Goswami & Mukhopadhyay, 2017; Deksne, 2011; Khune & Parwate, 2017; Mukhopadhyay et. al., 2007; Rayori, 2023).

Conclusion

The present study on zooplankton assemblage for the Suneka wastewater treatment plant revealed the presence of 13 species which were from three taxa: Cladocera, Rotifera, and Copepoda. In terms of abundance, Cladocera was the most dominant group, while Copepoda and Rotifera maintained lower and more stable populations across the sampling stations. Moreover, the study revealed there was spatial variation in zooplankton in terms of diversity and distribution. The facultative and anaerobic ponds supported the highest zooplankton abundance. The variations in zooplankton diversity can be associated with physical and chemical parameters in addition to primary productivity in the respective sampling stations. This study finding forms baseline information on the zooplankton assemblage for the Suneka wastewater treatment plant for future studies. The suneka wastewater treatment plant should be renovated on its wastewater treatment capacity to mitigate the increased volume of wastewater it receives with the intent of enhancing its efficacy in wastewater polishing preventing environmental pollution and degradation of aquatic ecosystems resulting from discharge of partially or untreated effluent rich with pollutants.

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Conflict of Interests

The author declares no conflict of interest.

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Availability of Data and Materials

The necessary data is available upon request from the corresponding author.

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