

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

**Douglas M. Rayori**

*Department of Biological Sciences, Kisii University, Kenya*

*\*Corresponding author: drayori@kisiouniversity.ac.ke*

<https://doi.org/10.62049/jkncu.v5i1.428>

### **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 (YSI) 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.

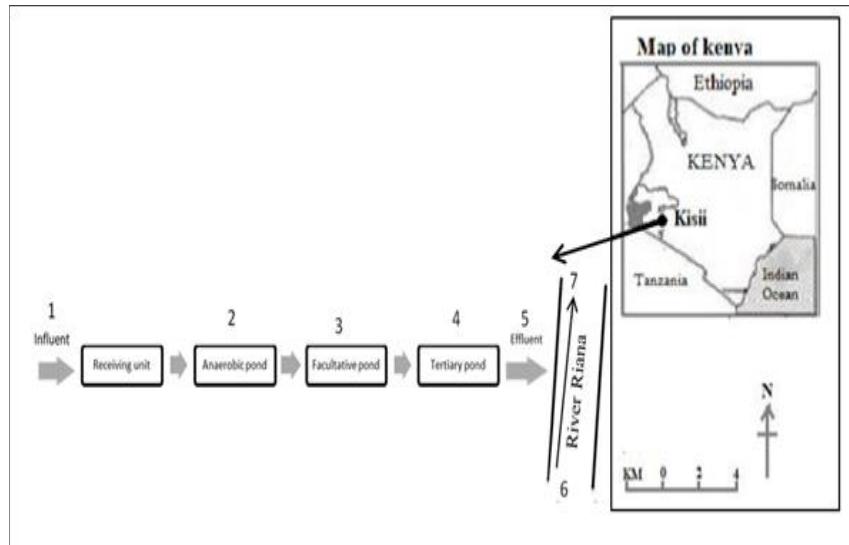
In aquatic habitats, zooplankton float freely, and their distribution is mostly influenced by currents, water mixing, and water quality. As a result, certain species can be found in a variety of environmental conditions, whilst others are restricted by numerous physical and chemical factors, which is 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<sup>3</sup>/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 (Rayorri 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  $\mu\text{m}$  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 ( $\text{IndL}^{-1}$ ) of zooplankton (Omondi et al., 2011).

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

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 (Table 1). The identified species belonged to three broad taxonomic groups namely Rotifera, Cladocera, and Copepoda. 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
<i>Ceriodaphnia cornuta</i>	Copepod nauplius larvae	<i>Asplanchna</i> spp.
<i>Daphnia lumholtzi</i>	Cyclopoida	<i>Brachionus angularis</i>
<i>Diaphanosoma excisum</i>		<i>Brachionus calyciflorus</i>
<i>Moina micrura</i>		<i>Brachionus quadridentatus</i>
		<i>Filinia</i> spp.
		<i>Hexarthra</i> spp.
		<i>Polyarthra</i> spp.
		<i>Trichocerca</i> spp.

### Zooplankton Diversity

The calculated zooplankton diversity indices are summarized in Figure 2. 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).

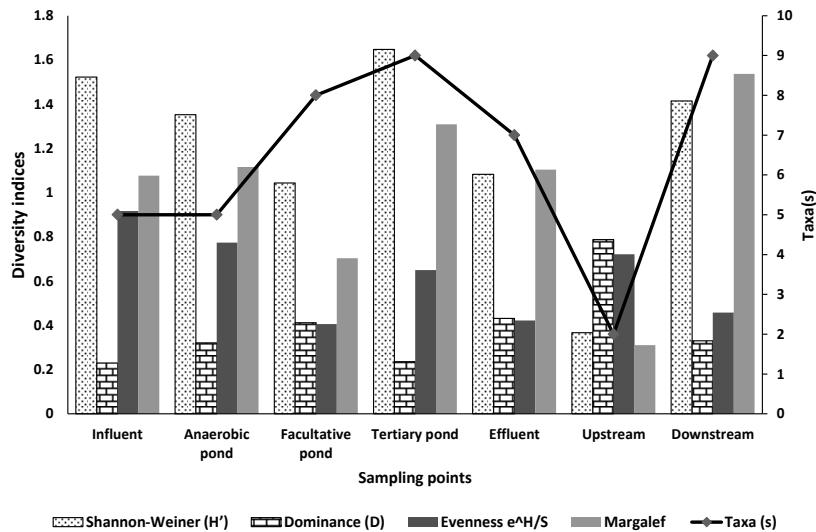


Figure 2: Zooplankton diversity indices recorded in Suneka wastewater treatment plant from August-December 2019

### Monthly Zooplankton Abundance Distribution

The total zooplankton abundance that was recorded in the Suneka wastewater treatment plant was  $5746 \text{ IndL}^{-1}$ , with the month of September recording the highest total zooplankton abundance ( $3109.7 \text{ IndL}^{-1}$ ) that's 54.1 % of the total zooplankton abundance, while the month of August recorded the least total zooplankton abundance ( $130.8 \text{ IndL}^{-1}$ ) accounting for 2.3% of the total zooplankton abundance (Table 2). 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 Table 2. The Cladocera dominated throughout the study period, but the highest total abundance was recorded in the month of September ( $3089.7 \text{ IndL}^{-1}$ ) followed by the month of December ( $2189.2 \text{ IndL}^{-1}$ ). 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  $3.3 \text{ IndL}^{-1}$ . For Copepoda, the highest total taxa abundance was recorded in the month of November ( $66.7 \text{ IndL}^{-1}$ ) followed by December ( $42.5 \text{ IndL}^{-1}$ ), with the least abundance recorded in the month of September ( $2.8 \text{ IndL}^{-1}$ ). 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 ( $82.5 \text{ IndL}^{-1}$ ) followed by November ( $50.0 \text{ IndL}^{-1}$ ) 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<sup>-1</sup>) in the Suneka wastewater treatment plant from August-December, 2019**

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

		<i>Moina micrura</i>	2145.0				
Copepoda	Copepod nauplius larvae	15.0	42.5	82.5			
	Cyclopoida	27.5					
Rotifera	<i>Brachionus angularis</i>	6.7	82.5				
	<i>Filinia</i> sp	55.0					
	<i>Trichocerca</i> 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 Table 3. The facultative pond had the highest zooplankton total abundance of 5038 IndL<sup>-1</sup> followed by effluent sampling point with 228 IndL<sup>-1</sup> while the least total abundance of 25 IndL<sup>-1</sup> 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**

Taxa	Zooplankton abundance (IndL <sup>-1</sup> )						
	Influent	Anaerobic pond	Facultative pond	Tertiary pond	Effluent	Upstream	Downstream
Cladocera							
<i>Ceriodaphnia cornuta</i>		1133		3	1		84
<i>Daphnia lumholtzi</i>				55	26	22	6
<i>Diaphanosoma excisum</i>	10	970	75	137			
<i>Moina micrura</i>		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							
<i>Asphlanchna</i> sp		3		5			5
<i>Brachionus angularis</i>			17				
<i>Brachionus calyciflorus</i>			5				3
<i>Brachionus quadridentatus</i>							4
<i>Fillinia</i> sp				12	56		
<i>Hexarthra</i> sp					6		6
<i>Polyarthra</i> sp							1
<i>Trichocerca</i> 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 ( $2872 \text{ IndL}^{-1}$ ), followed by *Ceriodaphnia cornuta*, which had an abundance of  $1133 \text{ IndL}^{-1}$ . 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  $25 \text{ IndL}^{-1}$ . On the other hand, the effluent sampling point recorded the highest total abundance ( $62 \text{ IndL}^{-1}$ ) of Rotifers. The abundance of *Asplanchna* sp. ranged from 3 to  $5 \text{ IndL}^{-1}$ . With an abundance of  $17 \text{ IndL}^{-1}$ , *Brachionus angularis* was only found in the facultative pond. The abundance of *Trichocerca* sp. ranged from 5 to  $28 \text{ IndL}^{-1}$  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 Table 4 and Table 5. The results show 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 (Table 4). 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 (Table 5). 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. Table 6 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  $\pm$  SE)**

Parameters	Sampling Points							Mean ( $\pm$ SE)
	Influent	Anaerobic pond	Facultative pond	Tertiary pond	Effluent	Upstream	Downstream	
pH	6.5 $\pm$ 0.61 <sup>d,e</sup> (6.29-6.79)	6.0 $\pm$ 0.68 <sup>e</sup> (5.79-6.29)	6.8 $\pm$ 0.75 <sup>c,d</sup> (6.53-7.03)	7.2 $\pm$ 0.62 <sup>a,b,c</sup> (6.95-7.46)	7.1 $\pm$ 0.45 <sup>b,c</sup> (6.89-7.39)	7.7 $\pm$ 0.09 <sup>a</sup> (7.48-7.98)	7.5 $\pm$ 0.18 <sup>a,b</sup> (7.26-7.76)	
Conductivity ( $\mu\text{scm}^{-1}$ )	1404 $\pm$ 325.7 <sup>a</sup> (1356.43-1451.51)	878.9 $\pm$ 79.2 <sup>b</sup> (831.38-926.46)	888.0 $\pm$ 81.7 <sup>b</sup> (840.42-935.49)	926.1 $\pm$ 78.2 <sup>b</sup> (878.60-973.68)	616.1 $\pm$ 37.1 <sup>c</sup> (568.53-663.61)	128.2 $\pm$ 7.9 <sup>d</sup> (80.63-175.71)	240.3 $\pm$ 36.2 <sup>e</sup> (192.73-287.81)	725.9 3 $\pm$ 66.40
Temp. (°C)	22.3 $\pm$ 0.21 <sup>c</sup> (21.58-22.95)	24.0 $\pm$ 0.4 <sup>b</sup> (23.27-24.64)	26.5 $\pm$ 0.84 <sup>a</sup> (25.84-27.21)	26.2 $\pm$ 0.53 <sup>a</sup> (25.55-26.92)	25.9 $\pm$ 0.38 <sup>a</sup> (25.25-26.61)	22.6 $\pm$ 0.28 <sup>b,c</sup> (21.93-23.30)	22.7 $\pm$ 0.25 <sup>b,c</sup> (22.0-23.36)	24.31 $\pm$ 0.25
DO (mgL <sup>-1</sup> )	2.0 $\pm$ 0.73 <sup>e</sup> (1.59-2.42)	0.4 $\pm$ 0.17 <sup>f</sup> (0.003-0.83)	4.5 $\pm$ 1.25 <sup>c</sup> (4.04-4.86)	3.1 $\pm$ 0.58 <sup>d</sup> (2.66-3.48)	5.6 $\pm$ 1.08 <sup>b</sup> (5.16-5.98)	5.6 $\pm$ 1.04 <sup>b</sup> (5.23-6.05)	7.1 $\pm$ 0.21 <sup>a</sup> (6.70-7.52)	4.04 $\pm$ 0.38
TSS (mgL <sup>-1</sup> )	172.6 $\pm$ 39.78 <sup>b</sup> (158.21-186.89)	137.0 $\pm$ 20.51 <sup>c</sup> (122.66-151.34)	205.3 $\pm$ 38.36 <sup>a</sup> (190.97-219.65)	63.0 $\pm$ 6.7 <sup>d</sup> (48.66-77.34)	30.0 $\pm$ 2.36 <sup>e</sup> (15.67-44.36)	137.4 $\pm$ 32.88 <sup>c</sup> (123.07-151.75)	147.5 $\pm$ 33.79 <sup>b,c</sup> (133.16-161.84)	127.5 $\pm$ 12.14
TDS (mgL <sup>-1</sup> )	572.2 $\pm$ 90.97 <sup>a</sup> (549.31-595.01)	318.7 $\pm$ 48.27 <sup>b</sup> (295.80-341.51)	316.4 $\pm$ 20.97 <sup>b</sup> (293.54-339.25)	289.2 $\pm$ 28.13 <sup>b</sup> (266.40-312.10)	293.2 $\pm$ 28.57 <sup>b</sup> (270.37-316.07)	315.8 $\pm$ 45.75 <sup>b</sup> (292.92-338.62)	291.6 $\pm$ 40.22 <sup>b</sup> (268.79-314.50)	342.4 $\pm$ 20.43
NH <sub>4</sub> -N(μgL <sup>-1</sup> )	464.1 $\pm$ 147.93 <sup>d</sup> (366.84-561.43)	674.0 $\pm$ 134.78 <sup>c,d</sup> (576.74-771.33)	1090.0 $\pm$ 194.91 <sup>a</sup> (992.66-1187.25)	987.1 $\pm$ 143.78 <sup>a,b</sup> (889.84-1084.43)	776.1 $\pm$ 109.47 <sup>c</sup> (678.82-873.41)	813.9 $\pm$ 201.67 <sup>b,c</sup> (716.63-911.22)	605.1 $\pm$ 119.87 <sup>c,d</sup> (507.83-702.42)	772.92 $\pm$ 60.18
NO <sub>2</sub> -N (μgL <sup>-1</sup> )	43.3 $\pm$ 9.12 <sup>a</sup> (404.40-46.22)	19.2 $\pm$ 3.78 <sup>e</sup> (16.28-22.09)	19.3 $\pm$ 4.78 <sup>e</sup> (16.43-22.25)	30.5 $\pm$ 6.39 <sup>c,d</sup> (27.60-33.41)	35.5 $\pm$ 7.12 <sup>b,c</sup> (32.55-38.36)	24.6 $\pm$ 4.92 <sup>d,e</sup> (21.64-27.46)	38.4 $\pm$ 0.96 <sup>a,b</sup> (35.52-41.33)	30.11 $\pm$ 2.33
NO <sub>3</sub> -N (μgL <sup>-1</sup> )	67.1 $\pm$ 11.98 <sup>a</sup> (63.13-71.04)	58.1 $\pm$ 10.73 <sup>b</sup> (54.13-62.04)	31.1 $\pm$ 4.3 <sup>c</sup> (27.15-35.06)	44.7 $\pm$ 6.32 <sup>c</sup> (40.76-48.68)	45.7 $\pm$ 7.25 <sup>c</sup> (41.77-49.68)	58.3 $\pm$ 12.17 <sup>b</sup> (54.32-62.23)	62.3 $\pm$ 7.72 <sup>a,b</sup> (58.33-66.24)	52.47 $\pm$ 3.54
TN (μgL <sup>-1</sup> )	800.1 $\pm$ 201.64 <sup>b,c</sup> (654.18-946.05)	409.0 $\pm$ 58.15 <sup>d</sup> (263.07-554.94)	1280.7 $\pm$ 233.55 <sup>a</sup> (1134.77-1426.63)	1231.4 $\pm$ 296.55 <sup>a</sup> (1085.48-1377.34)	1080.5 $\pm$ 248.68 <sup>a,b</sup> (934.52-1226.38)	764.7 $\pm$ 193.43 <sup>c</sup> (618.74-910.61)	856.1 $\pm$ 264.16 <sup>b,c</sup> (710.19-1002.06)	917.5 $\pm$ 87.69

TP ( $\mu\text{gL}^{-1}$ )	1604.2 $\pm$ 213.36 <sup>a,b</sup> (1365.88-1842.57)	1272.3 $\pm$ 250.07 <sup>c,d</sup> (1033.94-1510.63)	1824.9 $\pm$ 406. 49 <sup>a</sup> (1586.56-2063.25)	1542.2 $\pm$ 370.29 <sup>a,b</sup> (1303.88-1780.57)	1443.4 $\pm$ 243.97 <sup>a,b,c</sup> (1205.04-1681.73)	859.7 $\pm$ 210.16 <sup>d</sup> (621.31-1098.00)	1019.5 $\pm$ 159.46 <sup>c,d</sup> (781.19-1257.88)	1367 $\pm$ 8
----------------------------	---	---	---	---	---	---	--	--------------

**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  $\pm$  SE)**

Parameters	Sampling Months			
	August	September	November	December
pH	7.5 $\pm$ 0.15 <sup>b</sup> (7.3-7.68)	7.9 $\pm$ 0.08 <sup>a</sup> (7.76-8.14)	8.1 $\pm$ 0.09 <sup>a</sup> (7.91-8.29)	4.4 $\pm$ 0.46 <sup>c</sup> (4.25-4.62)
Conductivity ( $\mu\text{scm}^{-1}$ )	1125.8 $\pm$ 211.3 <sup>a</sup> (1089.91-1161.78)	774.0 $\pm$ 93.0 <sup>b</sup> (738.10-809.97)	565.3 $\pm$ 64.1 <sup>c</sup> (529.38-601.25)	438.5 $\pm$ 47.4 <sup>d</sup> (402.57-474.44)
Temp. ( $^{\circ}\text{C}$ )	25.2 $\pm$ 0.68 <sup>a</sup> (24.72-25.75)	24.8 $\pm$ 0.49 <sup>a,b</sup> (24.24-25.27)	23.8 $\pm$ 0.45 <sup>b,c</sup> (23.31-24.24)	23.4 $\pm$ 0.26 <sup>c</sup> (22.93-23.96)
DO ( $\text{mgL}^{-1}$ )	6.2 $\pm$ 0.77 <sup>a</sup> (5.88-6.51)	1.2 $\pm$ 0.51 <sup>d</sup> (0.86-1.48)	4.7 $\pm$ 0.73 <sup>b</sup> (4.42-5.04)	4.1 $\pm$ 0.61 <sup>c</sup> (3.74-4.36)
TSS ( $\text{mgL}^{-1}$ )	115.7 $\pm$ 23.03 <sup>b</sup> (104.91-126.59)	61.4 $\pm$ 13.24 <sup>c</sup> (50.55-72.23)	166.5 $\pm$ 26.09 <sup>a</sup> (155.67-177.35)	166.5 $\pm$ 26.09 <sup>a</sup> (155.67-177.35)
TDS ( $\text{mgL}^{-1}$ )	323.68 $\pm$ 8.62 <sup>b</sup> (306.40-340.95)	167.0 $\pm$ 25.14 <sup>c</sup> (149.68-184.23)	439.6 $\pm$ 27.5 <sup>a</sup> (422.30-456.85)	439.6 $\pm$ 27.5 <sup>a</sup> (422.30-456.85)
NH <sub>4</sub> -N ( $\mu\text{gL}^{-1}$ )	750.8 $\pm$ 96.17 <sup>a</sup> (677.22-824.31)	781.5 $\pm$ 133.37 <sup>c</sup> (707.99-855.08)	811.2 $\pm$ 137.34 <sup>b</sup> (737.67-884.77)	748.1 $\pm$ 118.72 <sup>b</sup> (674.60-821.70)
NO <sub>2</sub> -N ( $\mu\text{gL}^{-1}$ )	20.45 $\pm$ 1.10 <sup>c</sup> (18.25-22.65)	47.16 $\pm$ 1.10 <sup>a</sup> (44.96-49.36)	17.50 $\pm$ 1.10 <sup>c</sup> (15.30-19.70)	35.33 $\pm$ 1.10 <sup>b</sup> (33.13-37.53)
NO <sub>3</sub> -N ( $\mu\text{gL}^{-1}$ )	27.19 $\pm$ 1.49 <sup>d</sup> (24.20-30.18)	78.51 $\pm$ 1.49 <sup>a</sup> (75.52-81.50)	43.58 $\pm$ 1.49 <sup>c</sup> (40.60-46.58)	60.58 $\pm$ 1.49 <sup>b</sup> (57.59-63.57)
TN ( $\mu\text{gL}^{-1}$ )	1623.52 $\pm$ 55.07 <sup>a</sup> (1513.21-1733.84)	354.05 $\pm$ 55.07 <sup>c</sup> (243.74-464.37)	459.15 $\pm$ 55.07 <sup>c</sup> (348.83-569.46)	1233.27 $\pm$ 55.07 <sup>b</sup> (1122.95-1343.58)
TP ( $\mu\text{gL}^{-1}$ )	1866.3 $\pm$ 218.51 <sup>a</sup> (1686.10-2046.45)	1407.5 $\pm$ 275.59 <sup>b</sup> (1227.34-1587.69)	883.7 $\pm$ 104.49 <sup>c</sup> (703.49-1063.83)	1309.0 $\pm$ 173.93 <sup>b</sup> (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 <sup>-1</sup> )	Conductivity (µS·cm <sup>-1</sup> )	TSS (mgL <sup>-1</sup> )	TDS (mgL <sup>-1</sup> )	NH <sub>4</sub> -N (µgL <sup>-1</sup> )	NO <sub>2</sub> -N (µgL <sup>-1</sup> )	NO <sub>3</sub> -N (µgL <sup>-1</sup> )	TN (µgL <sup>-1</sup> )	TP (µgL <sup>-1</sup> )
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 ( $5038 \text{ Ind L}^{-1}$ ), 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.

## Acknowledgments

The author is grateful to Gusii Water and Sewerage Company (GWSCO), Kisii County, for providing free access to the Suneka Wastewater Treatment Plant, and the National Commission for Science, Technology, and Innovation (NACOSTI) for granting him permission to conduct this study. Also, the author is deeply grateful for the laboratory facilities provided by the Kenya Marine Fisheries and Research Institute (KMFRI), Kisumu.

## Conflict of Interests

The author declares no conflict of interest.

## Funding

The author received financial support from the African Development Bank (AfDB) through a project research grant that Kisii University hosted for doctoral studies.

## Availability of Data and Materials

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

## References

Ahikari, S., Goswami, A. R., & Mukhopadhyay, S. K. (2017). Diversity of zooplankton in municipal wastewater-contaminated urban pond ecosystems of the lower Gangetic plains. *Turkish Journal of Zoology*, 41, 464–475. <https://doi.org/10.3906/zoo-1601-12>

American Public Health Association. (2014). *Standard methods for the examination of water and wastewater* (22nd ed.). American Public Health Association, American Water Works Association, & Water Environment Federation.

Deksne, R. (2011). Influence of wastewater on zooplankton communities in the Daugava River upstream and downstream of Daugavpils over the last 50 years. *Knowledge and Management of Aquatic Ecosystems*, 402(7), 1–17. <https://doi.org/10.1051/kmae/2011050>

Eyo, V. O., Ekpo, P. B., Andem, A. B., & Okorafor, K. A. (2013). Ecology and diversity of phytoplankton in the Great Kwa River, Cross River State, Nigeria, *1*(2), 1–7.

Hassan, E., Jaafaru, A., Bonjoru, R., Ndeham, V., Jerry, J., Bagauda, D., & Michael, L. (2019). Diversity and abundance of zooplanktons, macroinvertebrates and fish larvae from Lake Ribadu, Adamawa State, Nigeria. *JSM Aquaculture and Research*, *1*(6), 1–7.

Ibrahim, S. (2009). A survey of zooplankton diversity of Challawa River, Kano and evaluation of some of its physico-chemical conditions. *Bayero Journal of Pure and Applied Sciences*, *2*(1), 19–26.

Kabanze, J. M. (2024). Evaluation of species diversity and ecological functions of the anuran species in Kingwal Swamp, a highland wetland of Kenya. *Journal of the Kenya National Commission for UNESCO*, *4*(1), 2958–7999.

Khune, C. J., & Parwate, B. P. (2017). Zooplankton diversity and their seasonal variation in Nav-Talav, Amgaon, Gondia District. *International Journal of Researchers in Biosciences, Agriculture and Technology*, *5*(2), 653–656.

Laffite, A., Kilunga, P. I., Kayembe, J. M., Devarajan, N., Mulaji, C. K., Giuliani, G., & Pote, J. (2016). Hospital effluents are one of several sources of metal, antibiotic resistance genes, and bacterial markers disseminated in Sub-Saharan urban rivers. *Frontiers in Microbiology*, *7*, 1128.

Mukhopadhyay, S. K., Chattopadhyay, B., Goswami, A. R., & Chatterjee, A. (2007). Spatial variations in zooplankton diversity in waters contaminated with composite effluents. *Journal of Limnology*, *66*(2), 97–106.

Nikuze, M. J., Niyomukiza, J., Nshimiyimana, A., & Kwigera, J. (2020). Assessment of the efficiency of the wastewater treatment plant: A case of Gacuriro Vision City. *IOP Conference Series: Earth and Environmental Science*, *448*(12046), 1–10.

Ogbeigbu, A. E. (2005). *Biostatistics: A practical approach to research and data handling* (pp. 153–155). Minex Publishing Company Limited. <https://doi.org/10.35248/2155-9546.20.10.612>

Omondi, R., Yasindi, A. W., & Magana, A. (2011). Spatial and temporal variations of zooplankton in relation to some environmental factors in Lake Baringo, Kenya. *Eger Journal of Science and Technology*, *(1)*, 29–50.

Rayori, D., Getabu, A., Omondi, R., Orina, P., Gisacho, B., & Omondi, A. (2021). Phytoplankton diversity in Gusii wastewater treatment plant in Kisii County, Kenya. *International Journal of Fisheries and Aquatic Studies*, *9*(3), 299–306.

Rayori, D. M. (2023). *Assessment of efficiency of wastewater treatment based on physico-chemical and biological parameters of Kisii Town Wastewater Treatment Plant, Kenya* (Doctoral thesis, Kisii University). <http://localhost:8080/xmlui/handle/123456789/764>

Rayori, D. M., Nyabaro, O., Getabu, A., Omondi, R., & Orina, P. (2024). Evaluation of Suneka Wastewater Treatment Plant based on the efficiency of coliform bacteria removal. *Pan Africa Science Journal*, *4*(03). <https://doi.org/10.47787/pasj.v4i03.77>

Ronoh, A. K. (2017). *Efficacy of sewage treatment plant in Moi University, Uasin Gishu County, Kenya* (Master's thesis, Moi University). <http://ir.mu.ac.ke:8080/xmlui/handle/123456789/845>

UNESCO. (2017). *Wastewater: The untapped resource*. The United Nations World Water Development Report. *Ecohydrology and Hydrobiology*.

Wanjohi, L., Mwasi, S., Mwamburi, L., & Isaboke, J. (2019). Efficiency of University of Eldoret wastewater treatment plant, Kenya. *Africa Environmental Review Journal*, 3(2), 99–109.

Were-Kogogo, P., & Adhiambo, J. (2017). Status of phytoplankton community of Kisumu Bay, Winam Gulf, Lake Victoria, Kenya. *International Journal of Engineering and Sciences*, 6(5), 22–28.

<https://doi.org/10.9790/1813-0605022228>