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**RESEARCH ARTICLE**

# EFFECTS OF SELECTED WATER QUALITY PARAMETERS ON PHYTOPLANKTON ABUNDANCE AND DIVERSITY IN RIVER CHEPKOILEL, ELDORET, KENYA

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## *Abstract*

The study on the effects of water quality parameters on phytoplankton abundance and diversity in River Chepkoilel, Eldoret (Kenya) was done between October 2011 and February 2012. Three stations were selected; sampled upstream, midstream and downstream. A total of 31 genera of phytoplankton were identified, the most abundant phytoplankton in the bridge was Anabaena cirnalis (567 cells $mgl^{-1}$), Aphanocapsa rivularis (545 cells $mgl^{-1}$) and Coelomolon vestitoz (242 cells $mgl^{-1}$). The least abundant phytoplankton in the Bridge was Schroidera setigera (3 cells $mgl^{-1}$) and Scenedesmus maximus (6 cells $mgl^{-1}$). Results indicated that many of the phytoplankton in River Chepkoilel are sensitive to physico-chemical fluctuations of water. There was increased diversity at Bridge from the month of October 2011 (H'=2.400) to the month of February 2012 (H'=2.528). This was due to a fairly conducive environment for phytoplankton production. A two way ANOVA test showed that there was a significant difference in pH, DO and conductivity ($p<0.05$) and temperature ($p<0.05$) in all stations.

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## INTRODUCTION

This research is based on a study of effects of water quality parameters on phytoplankton abundance and diversity in River Chepkoilel, Eldoret, Kenya. Phytoplankton productivity and species composition in a water body are mainly influenced by nutrient availability (mainly phosphorus, nitrogen and silica for diatoms), environmental factors such as temperature and light and the morphology of the water body (Kalff, 2002). The phytoplankton diversity, abundance and species composition can be environmental indicators because of their sensitivity to environmental changes (APHA, 1992). But the routine biological monitoring of aquatic ecosystem is based largely on macroinvertebrates or phytoplankton (Weber, 1973; Kelly et al., 1995). According to (Adirondack Ecologists, 2010) abundance, diversity and species composition of phytoplankton can have significant implications with regard to both the water clarity and quality of any given body of water. Data on the phytoplankton and the physico-chemical features of River Chepkoilel is lacking completely. This study was carried out in order to determine some physico-chemical parameters of water as well as the phytoplankton abundance and diversity in this river. Rivers are of immense importance geologically, biologically, historically and culturally. Though, rivers contain only about 0.0001% of the total amount of water in the world at any given time (Vyzmal, 2008).

Rivers are vital as carriers and distributors of water and nutrients to catchment areas all around the earth. They are critical components of the hydrological cycle, acting as drainage channels for surface water. The world's rivers drain nearly 75% of the earth's land surface. They provide habitat, nourishment and means of transport to countless organisms. Their powerful forces create majestic scenery; they provide travel routes for exploration, commerce and recreation. According to (Vyzmal, 2008), rivers can be divided into three primary zones, the crenon is the uppermost zone at the source of the river which is further divided into the eucrenon (spring or boil zone) and

the hypocrenon (brook or headstream zone). These areas are characterized by low temperatures, reduced oxygen content and slow moving water. The rhithron is the upstream portion of the river that follows the crenon; it is characterized by relatively cool temperatures, high oxygen levels, and fast, turbulent flow. The potamon is the remaining downstream stretch of a river and it is characterized by warmer temperatures, lower oxygen levels, slow flow and sand bottoms. In Kenya, streams, rivers and lakes all together form a pattern of drainage systems which is governed by the topography of the land. River Chepkoilel falls under the Lake Victoria South drainage system in the vicinity of Eldoret town. Other rivers around Eldoret town include River Sosian and River Chepkoilel. The river is mainly affected by anthropogenic activities within its catchment, chemical effluents from Equator Flower Farm, appearance of invasive species, sewage discharges and aquaculture discharges from University of Eldoret (Vyzmal, 2008). Deterioration of water quality in River Chepkoilel has not been fully characterized through regular monitoring and therefore this remains a major problem.

## MATERIALS AND METHODS

### Study Area

This study was conducted at River Chepkoilel which flows within the Chepkoilel wetland. The river originates from Chepkoilel near Shamro Primary school and flows along various agricultural farms including the Equator flower farm (Vyzmal, 2008). The river is mainly affected by anthropogenic activities within its catchment, chemicals effluents from Equator Flower Farm, appearance of invasive species, sewage discharges and aquaculture discharges from University of Eldoret (Vymazal, 2008).

### Selection of sampling stations

Three sampling sites were selected in the study. The first site was at the Marura Bridge three kilometers from the river source, the second site was located at Matemo where the river is seen to be receiving lots of inflow from the surrounding agricultural land and the third site was located thirty metres immediately after Chepkoilel treatment discharge.

### Phytoplankton Sampling

Sampling was performed in triplicate at each station on each visit between October 2011 and January 2012. Oblique tows were made using a 25 µ plankton net of 12 cm in diameter. Samples for phytoplankton were preserved using 1 ml Lugol's solution in 35 ml vials. The samples were allowed to settle for 48 hours and concentrated to approximately 35 ml by decanting. In the laboratory phytoplankton was identified using the key contained in the freshwater biology (Needham, 1962) and counted in a Sedgwick Rafter cell (Lund et al., 1958) using an inverted microscope at X400. Counting of the phytoplankton was done in the Sedgwick Rafter cell (50 mm long by 20 mm wide by 1 mm deep with a surface area of $1000mm^2$.

### Water Quality Sampling

Water temperature, pH, conductivity were taken in situ by the use of mercury thermometer, pH meter and the conductivity meter respectively. DO was determined by the Winkler method in the laboratory.

### Phytoplankton abundance

Phytoplankton abundance was given in cells $ml^{-1}$ and was calculated as:

Phytoplankton density $ml^{-1}$ (D) = [(A) (l*w*d)] ..... (Eq.1)

where,

D = phytoplankton density for subsample of $ml^{-1}$ in number;
A = average number of phytoplankton counted in one Sedgwick-Rafter cell;

l = length in mm of the Sedgewick Rafter counting cell (50);
w = width of the Sedgewick Rafter counting cell (20 mm);
d = depth of the Sedgewick Rafter counting cell (1 mm).

The counted number of phytoplankton cells in each 1 ml sub-sample was converted to the original 35 ml sample by the following relationship:

Phytoplankton density in 35 ml (T) = D *$V_1$ ..... (Eq. 1)

where,

D = phytoplankton density for sub-sample in numbers per unit volume ($ml^{-1}$)
$V_1$ = volume of the original sample (35ml).

The 35 ml volume was converted to the total volume filtered during the oblique tows by the following relationship:

Final phytoplankton density = T × (1000/$V_2$) ..... (Eq. 2)

where,

T = phytoplankton density for 35 ml sample
$V_2$ = original volume filtered during the net tows

Sample volume was calculated as follows:

($V_2$) = $\pi r^2$*d ..... (Eq. 3)

Where,

$\pi$ = pi, with a value of 3.142;
r = the radius of the Plankton net mouth (6 cm)
d = distances moved by the net during towing (100 cm)

**Phytoplankton diversity**

Phytoplankton diversity was calculated by Shannon-weaver diversity index, Simpson's diversity index.

i. Shannon-weaver index
Shannon index of diversity was got by
**H'**= $-\sum \mathbf{P_i Ln(P_i)}$ ..... (Eq. 4)
where,
**H'** = the Shannon-Weaver Diversity Index
$\mathbf{P_i}$ = the relative abundance of each group of organisms

ii. Simpson's diversity index was got by
**D**=$\sum \mathbf{(n/N)^2}$ ..... (Eq. 5)
**n=** the total number of organisms of a particular species
N = the total number of organisms of all species

**Statistical analysis**

Shannon (H') and Simpson Diversity (D) were used to determine the phytoplankton diversity between October 2011 and February 2012 (Shannon and Weaver, 1949; Simpson, 1949). Two-way Analysis of Variance (ANOVA) was used to test for equality of variance in physico-chemical parameters using Minitab Release 14.

## RESULTS

**Phytoplankton Composition and Abundance**

A total of 31 genera of phytoplankton were identified from three sampling stations. Among the identified phytoplankton, 13 genera were of class Chlorophyceae, 9 genera were from class of Cyanophyceae, 6 genera from class of Bacillariophyceae, 2 genera of class Euglenophyceae and 1 genus of class Dinophyceae (Table 1).

**Table 1: Phytoplankton identified from the three sampling stations**

| Class | Species | Cell abundance ($mgl^{-1}$) |
|---|---|---|
| Chlorophyceae | Ankistrodesmus falcutus | 19 |
| | Boryococcus braunii | 19 |
| | Closterium navicula | 19 |
| | Coelastrum microphorum | 3 |
| | Coelomoron spp. | 629 |
| | Cosmarium paradoxum | 19 |
| | Crucigenia quadrata | 19 |
| | Crucigenia triangulare | 19 |
| | Monoraphidium spp. | 25 |
| | Oocystis nageli | 3 |
| | Oocystis parva | 19 |
| | Scenedemus curvatus | 19 |
| | Scenedemus longus | 3 |
| | Scenedemus maximus | 6 |
| | Scenedesmus quadricauda | 37 |
| | Schroidera setigera | 3 |
| | Surillella elegans | 3 |
| | Tetraedron-arthromisforme | 3 |
| | Traedron triangulare | 3 |
| Cyanophyceae | Anabaena cirnalis | 567 |
| | Anabaena flos-aquae | 833 |
| | Aphanocapsa rivularis | 545 |
| | Aphanothece spp. | 254 |
| | Chroococcus dispersus | 34 |
| | Chroococcus limneticus | 6 |
| | Chroococcus turgidus | 12 |
| | Coelomoron vestitoz | 242 |
| | Microcystis wasenbergii | 3 |
| | Microcystis aeruginosa | 15930 |
| | Microcystis flos aquae | 5867 |
| | Microcystis virids | 4397 |
| | Planktolyngbya limnetica | 12 |
| | Pseudo anabaena tanganyikae | 3 |
| | Rameria ankensis | 43 |
| Bacillariophyceae | Aulacoseira ambigua | 25 |
| | Aulacoseira nyansensis | 102 |
| | Cymbella cistula | 53 |
| | Diatoma hiemiale | 25 |
| | Navicula granatum | 19 |
| | Navicula spp. | 59 |
| | Nitzschia lucastris | 3 |
| | Nitzschia palea | 22 |
| | Nitzschia sub acicularis | 19 |

| | | |
|---|---|---|
| | Synedra cunningtonii | 59 |
| Euglenophyceae | Euglena acus | 46 |
| | Euglena virids | 3 |
| | Trachelemonous armata | 25 |
| Dinophyceae | Glenodium permadii | 19 |

The most abundant species in the river include Microcystis aeruginosa with 15930 cells $mgl^{-1}$, Coelomoron spp. 629 cells $mgl^{-1}$, Aphanothece spp with 254 cells $mgl^{-1}$, Microcystistis flos-aqua with 5867 cells $mgl^{-1}$, Microcystis virids with 4397 cells $mgl^{-1}$, Aphanocapsa rivularis with 545 cells $mgl^{-1}$, Anabaena cirnalis with 567 cells $mgl^{-1}$ and Coelomoron vestitoz with 242 cells $mgl^{1}$. The least abundant phytoplankton were Euglena virids 3 cell $mgl^{-1}$, Nitzschia lucastris 3 cell $mgl^{-1}$, Microcystis wasenbergii 3 cell $mgl^{-1}$, Pseudo anabaena tanganyikae 3 cell $mgl^{-1}$, Coelastrum microphorum 3 cell $mgl^{-1}$, Tetrahedron arthromisforme 3 cell $mgl^{-1}$ and Traedron triangulare 3 cell $mgl^{-1}$ of total abundance (Table. 1).

The Cyanophyceae were the most abundant class with 94.67% followed by Chlorophyceae with 3.05% and Dinophyceae recorded the least abundance with 0.06% (Fig. 5) and there were also significant variations between stations (Table 2).

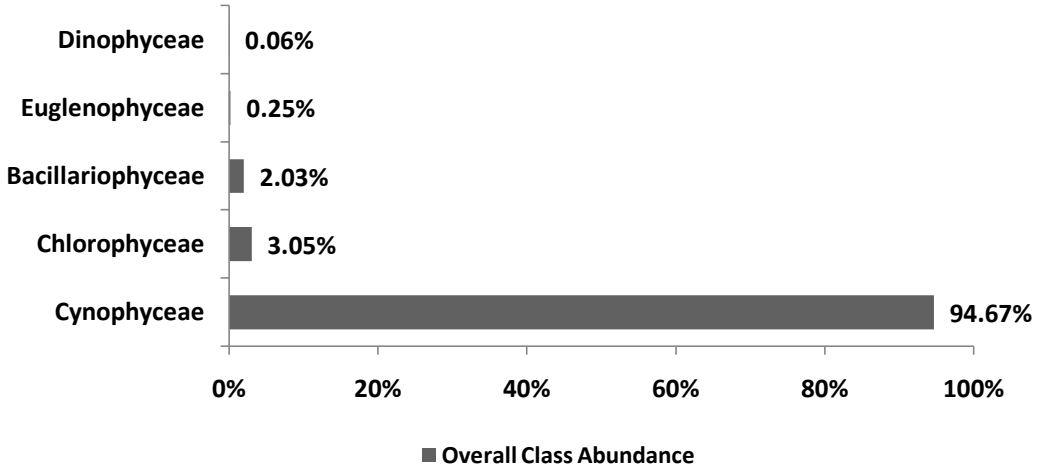


**Figure 1: Overall class abundance of phytoplankton from the sampling stations in percentage**

**Table 2: Class abundance of phytoplankton means and SE in percentage and two way ANOVA P-values between the month of October 2011 and February 2012 per station**

| Class | Bridge | Matemo | Sewage | Status | p.value |
|---|---|---|---|---|---|
| Chlorophyceae | 10.05±3.81 | 4.49±3.44 | 3.26±2.10 | Decreasing | <0.05 |
| Cyanophyceae | 63.37±5.18 | 93.52±4.15 | 95.16±2.66 | Increasing | <0.05 |
| Bacillariophyceae | 20.85±2.34 | 0.84±0.39 | 0.65±0.18 | Decreasing | <0.05 |
| Euglenophyceae | 4.83±0.70 | 1.13±0.83 | 0.77±0.45 | Decreasing | <0.05 |
| Dinophyceae | 0.90±0.14 | 0.02±0.05 | 0.16±0.29 | Not stable | <0.05 |

Both Bacillariophycea and Chlorophyceae decreased downstream whereas the cyanophyceae increased downstream.

**Phytoplankton Diversity**

Matemo had a lower diversity index value as compared to that of the sewage. All the diversity index values indicated a considerable decrease in diversity downstream from the month of November to February. The highest Shannon diversity index (Table 3) was recorded at the Bridge in the month of November (2.573) and the lowest Shannon index was recorded in Matemo in the month of October (1.1700). The highest Simpson's diversity index was recorded at the Bridge in the month of November (0.8981) and the lowest value was recorded at the sewage in the month of December (0.4445).

**Table 3: Diversity indices from the month of October, 2011 to February, 2012 per station.**

| Index | Months | Bridge | Matemo | Sewage |
|---|---|---|---|---|
| Shannon H' | October | 2.400 | 1.1700 | 1.3841 |
| | November | 2.573 | 1.7831 | 1.3463 |
| | December | 2.488 | 1.5044 | 1.2985 |
| | January | 2.563 | 1.6832 | 1.3044 |
| | February | 2.528 | 1.5683 | 1.3592 |
| Simpson's | October | 0.8377 | 0.5539 | 0.6558 |
| | November | 0.8981 | 0.8442 | 0.6379 |
| | December | 0.8684 | 0.7122 | 0.4445 |
| | January | 0.8946 | 0.7969 | 0.6180 |
| | February | 0.8824 | 0.7425 | 0.6440 |

**Physico-chemical Parameters**

The Sewage recorded the highest conductivity of 104.8 µS $cm^{-1}$, with Bridge recording the least conductivity of 39 µS $cm^{-1}$. The Bridge also recorded the highest amount of Dissolved oxygen of 5.9 $mgl^{-1}$ and the Sewage recorded the least amount of Dissolved Oxygen of 2.4 $mgl^{-1}$ (Table 4).

**Table 4: Means and SD for physico-chemical parameters between the month of October 2011 and February 2012**

| Parameter | Bridge | Matemo | Sewage |
|---|---|---|---|
| Temperature (ºC) | 22.0±1.44 | 20.0±1.07 | 18.6±0.48 |
| pH | 7.0±0.25 | 6.2±0.13 | 5.4±0.08 |
| Dissolved Oxygen ($mgl^{-1}$) | 5.9±0.22 | 4.7±0.21 | 2.4±0.17 |
| Conductivity (µS $cm^{-1}$) | 39±2.16 | 54.8±1.96 | 104.8±2.50 |

All the water quality parameters indicated a significant difference between stations (ANOVA, $p<0.05$). The highest temperature was recorded in Bridge 22.0ºC and the lowest temperature was recorded in Sewage (18.6°C). The Sewage recorded the highest conductivity of 104.8 µS $cm^{-1}$ as compared to the other sampling stations (Table 4).

**Table 5: Physico-chemical parameters per sampling stations and respective sampling dates**

| Parameter | Dates | Bridge | Matemo | Sewage | Status |
|---|---|---|---|---|---|
| DO | October | 5.6 $mgl^{-1}$ | 4.5 $mgl^{-1}$ | 2.4 $mgl^{-1}$ | Decreasing |
| | November | 5.9 $mgl^{-1}$ | 4.7 $mgl^{-1}$ | 2.2 $mgl^{-1}$ | Decreasing |
| | December | 6.1 $mgl^{-1}$ | 4.5 $mgl^{-1}$ | 2.6 $mgl^{-1}$ | Decreasing |
| | January | 6.0 $mgl^{-1}$ | 5.0 $mgl^{-1}$ | 2.3 $mgl^{-1}$ | Decreasing |
| | February | 6.1 $mgl^{-1}$ | 4.7 $mgl^{-1}$ | 2.7 $mgl^{-1}$ | Decreasing |
| Temperature | October | 20.5 ºC | 18.9 ºC | 18.0 ºC | Decreasing |
| | November | 23.6 ºC | 19.5 ºC | 18.0 ºC | Decreasing |
| | December | 21.2 ºC | 21.4 ºC | 18.5 ºC | Decreasing |
| | January | 22.9 ºC | 20.0 ºC | 19.0 ºC | Decreasing |
| | February | 20.9 ºC | 21.6 ºC | 19.1 ºC | Decreasing |
| Conductivity | October | 41.0 µS $cm^{-1}$ | 56.0 µS $cm^{-1}$ | 99.0 µS $cm^{-1}$ | Increasing |
| | November | 36.0 µS $cm^{-1}$ | 55.0 µS $cm^{-1}$ | 104.7 µS $cm^{-1}$ | Increasing |
| | December | 40.0 µS $cm^{-1}$ | 62.0 µS $cm^{-1}$ | 102.0 µS $cm^{-1}$ | Increasing |
| | January | 41.0 µS $cm^{-1}$ | 56.3 µS $cm^{-1}$ | 108.0 µS $cm^{-1}$ | Increasing |
| | February | 39.0 µS $cm^{-1}$ | 52.0 µS $cm^{-1}$ | 105.0 µS $cm^{-1}$ | Increasing |
| pH | October | 6.9 | 6.1 | 5.4 | Decreasing |
| | November | 7.0 | 6.3 | 5.5 | Decreasing |
| | December | 7.3 | 6.0 | 5.5 | Decreasing |
| | January | 6.7 | 6.2 | 5.3 | Decreasing |
| | February | 7.1 | 6.5 | 5.4 | Decreasing |

A part from the conductivity results which indicated considerable increased trend downstream from the month of October to February, DO, pH and Temperature all showed a considerable decrease downstream (Table 5).

## DISCUSSION

The identified phytoplankton from the study area can be grouped into Bacillariophyceae, Chlorophyceae, Cyanophyceae, Euglenophyceae and Dinophyceae. The present study revealed that Cyanophyceae was the most abundant group recorded with 94.67% of the total phytoplankton densities and constituted the largest group of phytoplankton in River Chepkoilel. This is an indication of a river which is frequently disturbed by various anthropological activities like agricultural run-off from farms. This was followed by Chlorophyceae with 3.05%, Bacillariophyceae 2.03%, Euglenophyceae 0.25% and Dinophyceae with 0.06% of total abundance respectively.

The higher abundance of the Cyanophyceae could be attributed to conducive environment and tolerance to frequent fluctuation of physicochemical parameters along the river and their higher adaptability to frequent disturbances along the river downstream. The least abundant species along the river include Coelastrum microphorum with 3 cells $mgl^{-1}$, Shroidera setigera 3 cells $mgl^{-1}$, Pseudoanabaena tanganyikae with 3 cells $mgl^{-1}$, Planktolyngbya limnetica with 3 cells $mgl^{-1}$, Nitzschia lucastris with 3 cells $mgl^{-1}$ and Euglena virids with 3 cells $mgl^{-1}$. The least abundance could be attributed to tremendous fluctuation of water quality, low silica in the river, and lack of basal rocks for their attachment.

From the observed diversity indices value from the month of October to February, Bridge showed highest value of (H' = 2.573) compared to Matemo (H' = 1.7831) and Sewage (H' = 1.3841). Recent studies which are also well corresponded with this findings include (Shah et al., 2008) in Bangladesh and (Farahani et al., 2006) in River Jajerood in Iran. The conducive environment in the Bridge could probably have led to the observed highest diversity index (H') of phytoplankton in this station.

The most encountered species of phytoplankton in the three sampling stations was Aulacoseira ambigua, Navicula spp, Botryococcus braunii and Aphanocapsa rivularis. Indicating there adaptability in all the conditions signifying that the river can support different forms of aquatic life though frequently disturbed. The second encountered species in the sampling stations Bridge, Matemo and Sewage were Chroococcus disperses and Chrococcus limnetica and the least encountered species in the three stations was Glenodium pernadii.

Different diversity indices values from the present study clearly demonstrated that the Bridge had higher diversity of phytoplankton compared to the other stations. Abundance was also higher than the other sampling stations. The increased diversity at the Bridge may be attributed to the water runoff that probably brought the phytoplankton from other freshwater sources. Similar finding was observed in studies of (Bailey and James, 2000) and (Nielsen et al., 2003). The Bridge recorded higher values of Shannon diversity throughout the research period with a highest diversity index of (2.573) and lowest diversity index value of (2.400). This could be attributed to optimal physical chemical levels for survival of a most species of phytoplankton. On the other hand the sewage recorded the lowest Shannon diversity indices from the month of November to February with the highest Shannon of (1.3841) and lowest value of (1.2985). This could be attributed to unfavorable conditions for production of phytoplankton. For example, the sewage had the lowest dissolved oxygen 2.4 $mgl^{-1}$ which could be an inhibitor to photosynthesis process of phytoplankton. A test by two way ANOVA showed that there was a significant difference of physico-chemical parameters among the stations. This could be attributed to effluents from the sewage which could probably be contributing to more ions to the river. This interferes with phytoplankton production hence lowering phytoplankton diversity and abundance. The water quality deterioration down the river could be as a result of low phytoplankton diversity and abundance downstream.

## CONCLUSION

Present study revealed that the phytoplankton in River Chepkoilel during the sampling period was not quiet diverse. It also showed that there was spatial and temporal variation in abundance and diversity of phytoplankton. Physico-chemical parameters were significantly different among the sampling stations.

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