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STUDIES ON LIMNOLOGICAL CHARACTERISTICS AND PLANKTONIC DIVERSITY IN D.G. KHAN CANAL WATER AT D.G. KHAN (PAKISTAN)

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Abstract

A study was carried out to investigate the seasonal variations in limnological characteristics and planktonic diversity of D.G. Khan Canal water as affected with sewage at D.G. Khan, Pakistan. Water samples were collected on monthly basis and analyzed for estimation of water temperature, light penetration, turbidity, boiling point, surface tension, viscosity, density, specific gravity, pH, EC, dissolved O_2, Free CO_2, alkalinity, carbonates, bicarbonates, sodium, chlorides, acidity, hardness, total solid, total volatile solids, total dissolved solids and total volatile dissolved solids. An attempt was also made to assess the biological parameters including frequency of occurrence, relative abundance and diversity index of plankton life. Density and diversity of plankton was used as a measure of water quality. Phytoplankton were abundant as compared to Zooplankton. 39 Phytoplankton genera were recorded. Among these 08 of Cyanophyta, 12 of Chlorophyta, 11 of Chrysophyta, 4 of Euglenophyta, 2 of each Pyrrhophyta and Cryptophyta. 14 genera of Zooplankton were observed including 9 of Protozoan, 4 of Rotifers and one genus of Cladoceran. Total number of organisms was 616, out of which 523 were Phytoplankton and 93 were Zooplankton. Diversity index of Phytoplankton ranged from 2.53 to 2.99 and diversity index of Zooplankton ranged from 1.08 to 1.68. It may be concluded that the quality of canal water is marginally fit as the diversity index of Phytoplankton and Zooplankton was less than three throughout the study period.

Introduction

Our world especially developing countries are facing the problem of water stress due to rapid growth in population. Food and Agriculture Organization has estimated the world's hunger population 923 million (Anon., 2008). The problem is expected to be further aggravated as there will be an additional 2 billion people by the year 2030 (Gany, 2006). The increased population will increase the demand of food accordingly; enhanced water diversions for irrigation need by 14 -17% (Bos *et al.,* 2005). Major causes of lack of food are water shortages due to limited water availability and inefficient use of available water (Laghari *et al*., 2008).

Most of the cities and great civilizations have developed along the banks of fresh water sources especially canals and rivers for their multi-use. Their untreated sewage discharge not only damage the aquatic life but also hazardous to human health used for drinking and irrigation purpose in the downstream areas (Rather *et al*., 2010). In Pakistan, only a small fraction of urban sewage is treated before discharge in fresh water bodies (Anon., 2007).

Plankton are very sensitive to the environment where they live; so, any change in the environment may leads to the change in the planktonic communities in terms of tolerance, abundance, diversity and dominance in the habitat. Therefore, planktonic population observation can be used as a reliable tool to assess the pollution status of water bodies (Basu *et al.,* 2010; Prabhahar *et al.,* 2011). Planktonic life is an essential part of aquatic ecosystem to maintain a healthy and productive environment (Khangarot & Das, 2009). The physico-chemical properties and nutrient status of aqueous medium have significant role in production of plankton which is critical to maintain aquatic food web foundations (Rahman & Hussain, 2008). Freshwater ecosystems have lost a greater proportion of their species and habitat due to threats from dams, over extraction, pollution, and over fishing (Revenga & Mock, 2000). Biological characteristics are related to density and diversity of organisms (Barnabe, 1990). The high relative abundance of Chlorophyta indicates productive water (Boyd & Tucker, 1998).

D.G. Khan City is located on the western side of Indus River and its area is categorized as Barani in general, because the western side of the city receives hill torrents of Sulaiman Range. The groundwater is saline. The only potable water is from the seepage of Manka and D.G. Khan Canals. The annual design discharge of D.G. Khan Canal is 2.205 MAF and its useable seepage is 0.723 MAF. About 90% of the effluents and municipalities are untreated, which are directly polluting the both water resources and estimated pollution load is 60 Cusecs (Anon., 2006).

Keeping in view the importance of freshwater resources, an attempt has been made to study the limnological characteristics and planktonic diversity in D.G. Khan Canal in comparison to water quality standards.

Materials and Methods

The present study was carried out on mixed water of D.G. Khan Canal at D.G. Khan (*longitude* 70° 29' 7" E and *latitude* 29° 57' 38" N), Pakistan. The study site was suitable for limnological studies because the city sewage is added and properly mixed here, the depth and flow of water was also maximum. Water samples from the surface water column (≤1 m depth) were collected in plastic bottles of 1.5 L capacity on monthly basis for a period of ten months. At the time of sampling, the water temperatures were recorded by using alcoholic thermometer. Light penetration was recorded with the help of Secchi's disc. Boiling point was measured by using mercury thermometer. pH and conductivity were measured by using pH meter (HI-8417) and conductivity meter (AGB-1001, Japan), respectively. Density, specific gravity, viscosity and surface tension were determined by the methods given by Nabi *et al.* (1998) while all other parameters including turbidity, dissolved O_2, Free CO_2, carbonates, bicarbonates, sodium, chlorides, alkalinity, acidity, total hardness, total solids (TS), total volatile solids (TVS), total dissolved solids (TDS) and total volatile dissolved solids (TVDS) were determined by the methods as described by Boyd & Tucker (1998).

The water samples for plankton study were preserved by using 4% formalin solution (Battish, 1992) and examined under a microscope using 10X ocular and 10X and 40X objectives. The identification of phytoplankton and zooplankton were done up to generic level with the help of following literature (Ward & Whipple, 1959; Tonapi, 1980; Battish, 1992). Frequency of occurrence and relative abundance of each genus of Phytoplankton and Zooplankton was calculated for each month. Diversity index of plankton was calculated by using formula as described by Boyd (1981). The data were subjected to analysis of variance to find out statistically significant relationship among different limnological parameters by using MSTATC program (version 2.10).

Results and Discussion

In the present investigation, all the mean data of physico-chemical parameters obtained from the monthly analysis of water samples are summarized in Table 1. During the study period, water temperature ranged from a minimum of 18.3°C (November) to a maximum of 35°C (July). Water temperature was found to increase from March to July and decrease from August to December. Temperature has profound influence, and direct or indirect effect on biodiversity of an ecosystem. Temperature showed an inverse relationship with dissolved oxygen. Basu *et al*., (2010) made similar observation. Light penetration was maximum (38.1 cm) in June and minimum (21.6 cm) in November. There was highly significant ($p<0.001$) positive correlation between temperature and light penetration (Table 4).

Table 1. Limnological characteristics of D.G. Khan Canal water as affected with domestic sewage.

Parameters	Months									
	Mar	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Water temperature (°C)	22.4	31.5	33.3	30.1	35.0	30.5	28.7	26.5	18.3	18.5
Light penetration (cm)	25.9	27.7	32.5	38.1	36.0	31.2	30.2	23.4	21.6	24.1
Boiling point (°C)	97.3	96.0	98.2	99.1	98.2	97.5	97.4	96.7	98.3	96.2
Density (g L^{-1})	0.994	0.990	0.989	0.988	0.995	0.990	0.995	0.997	0.995	0.993
Specific gravity	0.997	0.993	0.993	0.991	0.998	0.993	0.998	1.001	0.998	0.995
Turbidity (mg L^{-1})	0.64	0.76	0.66	0.80	0.40	0.61	0.46	0.33	0.26	0.27
Viscosity (mN S m^{-2})	0.944	0.923	0.899	0.909	0.961	0.995	0.807	0.887	0.918	0.975
Surface tension (dynes cm^{-1})	77.05	78.12	76.45	76.61	73.55	80.16	76.00	74.37	75.69	74.47
pH	7.3	7.6	8.1	8.0	7.7	7.9	7.3	7.1	8.3	7.5
Conductivity (dS m^{-1})	0.37	0.29	0.25	0.23	0.24	0.27	0.32	0.29	0.31	0.42
Dissolved O_2 (mg L^{-1})	6.7	6.5	5.7	4.5	5.2	6.1	6.9	7.7	6.9	6.8
Free CO_2 (mg L^{-1})	9.97	9.22	12.5	12.3	10.5	9.73	7.80	8.57	10.9	9.56
Acidity (mg L^{-1})	32	51	92	83	97	53	42	61	85	101
Hardness (mg L^{-1} as $CaCO_3$)	320	211	200	190	200	203	250	220	260	215
Alkalinity (mg L^{-1})	105	132	177	165	146	108	70	121	174	161
TS (mg L^{-1})	0.61	0.35	0.21	0.57	0.58	0.44	0.48	0.35	0.32	0.20
TVS (mg L^{-1})	0.08	0.05	0.02	0.13	0.13	0.07	0.12	0.07	0.05	0.02
TDS (mg L^{-1})	0.57	0.24	0.25	0.23	0.26	0.22	0.32	0.32	0.25	0.24
TVDS (mg L^{-1})	0.06	0.01	0.06	0.05	0.05	0.01	0.03	0.06	0.05	0.04
SAR	5.85	6.71	7.10	7.42	3.85	4.21	7.36	2.96	3.44	1.36
RSC (meq L^{-1})	Nil	Nil	0.2	Nil	Nil	2.3	Nil	Nil	Nil	Nil

TS: Total Solids, TVS: Total Volatile Solids, TDS: Total Dissolved Solids, TVDS: Total Volatile Dissolved Solids, SAR: Sodium Adsorption Ratio, RSC: Residual Sodium Carbonate

High transparency of freshwater ecosystem coincided with the period of dry season when there is little or no rainfall (Achionye-Nzeh & Isimaikaiye, 2010). The boiling point was maximum (99.1°C) in June and minimum (96°C) in April. The maximum water density (0.997 g L^{-1}) and specific gravity (1.001) was observed in October and minimum (0.988 g $L^{-}1$) and 0.991) in June, respectively. The turbidity was maximum (0.80 mg L^{-1}) in June and minimum (0.26 mg L^{-1}) in November. Turbidity reduces the light penetration and affects the photosynthesis of phytoplankton which ultimately produces less oxygen (Iqbal *et al.,* 2010). The viscosity (0.995 mN S m^{-2}) was observed maximum in August and minimum (0.809 mN S m^{-2}) in September. Viscosity showed significant inverse correlation with temperature and photoperiod while positive correlation with density and turbidity.

The Surface tension ranged from 77.39 to 101.1 dynes cm^{-1} (Table 1). Surface tension ranged from a minimum of 73.55 dynes cm^{-1} (July) to a maximum of 80.16 dynes cm^{-1} (August). The D.G. Khan Canal water showed alkaline condition throughout the study period. The pH value was highest in May (8.1) and lowest in October (7.1). pH showed significant ($p<0.005$) positive correlation with alkalinity (Table 4). pH value of the water changes from basic nature to the acidic due to regular discharge of domestic sewage (Rather *et al.,* 2010). The maximum EC (0.42 dS m^{-1}) was observed in December and minimum (0.23 dS m^{-1}) in June. EC is imperative to find good quality of irrigation water as its high values cause salinization (Ghafoor *et al*., 1993). EC showed highly significant (p<0.001) inverse correlation with water temperature and significant (p<0.005) positive correlation with dissolved O_2 (Table 4). The changes in electrical conductivity are due to fluctuations in dissolved solids (Boyd, 1981). The dissolved O_2 of water varied between 4.5 mg L^{-1} (June) to 7.7 mg L^{-1} (October). High dissolved O_2 is an indication of healthy aquatic ecosystem (Chattopadhyay & Banerjee, 2007). The dissolved O_2 evaluated the degree of freshness of an aquatic ecosystem (Agbaire & Obi, 2009).

Free CO_2 was observed highest (12.5 mg L^{-1}) in May, decreased steadily up to September (7.80 mg L^{-1}) and then increased during rest of period. Free Co_2 showed highly significant (p<0.001) positive correlation with pH and alkalinity, while significant (p<0.005) inverse correlation with dissolved O_2 and hardness (Table 4). The acidity of water ranged from 32 mg L^{-1} (March) to 101 mg L^{-1} (December). The hardness of water fluctuated from 190 mg L^{-1} (June) to 320 mg L^{-1} (March). Total hardness more than 75 mg L^{-1} is undesirable for fish production (Abbasi, 1998). Alkalinity was observed maximum (177 mg L^{-1}) in May and minimum (70 mg L^{-1}) in September. Brown (1993) reported that total hardness acts as limiting factor for alkalinity. Calcareous water with alkalinity more than 50 mg L^{-1} is most productive, zero to 20 mg L^{-1} for low production, 20 to 40 mg L^{-1} for medium production and 40 to 90 mg L^{-1} for higher production. The maximum value (0.61 mg L^{-1}) of TS was observed in March and minimum (0.20 mg L^{-1}) in December. The maximum value of TDS (0.57 mg L^{-1}) and TVDS (0.06 mg L^{-1}) was observed in March and minimum (0.22 mg L^{-1}) and (0.01 mg L^{-1}) in August, respectively. The SAR ranged from 1.36 (December) to 7.42 (June). Irrigation water with high SAR precipitates soil solution calcium and increase solution sodium, resulting in soil dispersion (Pervaiz, 2005). RSC was observed only in May (0.2 meq L^{-1}) and June (2.3 meq L^{-1}).

Phytoplankton were most abundant as compared to Zooplankton during the whole study period. Total number of organisms was observed 616, out of which 523 were Phytoplankton with relative abundance (R.A) 84.9% and 93 were Zooplankton with R.A 15.1%. Total 53 genera were observed in which 39 were of Phytoplankton and 14 of Zooplankton. Phytoplankton belong to Cyanophyta (8 genera), Chlorophyta (12 genera), Chrysophyta (11 genera), Euglenophyta (4 genera), Pyrrhophyta (2 genera) and Cryptophyta (2 genera) while Zooplankton including Protozoan (9 genera), Rotifers (4 genera) and Cladoceran (one genus). Among the Phytoplankton, the members of Cyanophyta, Chlorophyta and Chrysophyta were present throughout the study period. The members of Euglenophyta were present in all months except April. Minimum frequency of occurrence was found in Pyrrhophyta and Cryptophyta. Among the Zooplankton, Protozoan and Rotifers were present in all months while Cladocerans were present in six months (Tables 2 & 3).

In March, *Chlorella* was most abundant genus among Phytoplankton with R.A 17.3% while in Zooplankton, *Difflugia* was most abundant genus with R.A 3.50%. In April, *Cymbella* was most abundant genus among Phytoplankton with R.A 10.6% while in Zooplankton, *Epiphanes* was most abundant genus with R.A 7.57%. In May, *Natrium* and *Treubaria* were most abundant genera among Phytoplankton with R.A 11.8% while in Zooplankton, *Tintinnopsis* was most abundant genus with R.A 7.35%. In June, *Navicula* was most abundant genus among Phytoplankton with R.A 12.3% while in Zooplankton, *Hemiophrys* was most abundant genus with R.A 5.10%. In July, *Chlorella* was most abundant genus among Phytoplankton with R.A 11.1% while in Zooplankton, *Pseudodifflugia* was most abundant genus with R.A 8.45%. In August, *Navicula* and *Tetrastrum* were most abundant genera among Phytoplankton with R.A 9.87% while in Zooplankton, *Daphnia* was most abundant genus with R.A 6.17%. In September, *Closterium* was most abundant genus among Phytoplankton with R.A 11.5% while in Zooplankton, *Paramecium* was most abundant genus with R.A 7.13%. In October, *Melosira* was most abundant genus among Phytoplankton with R.A 12.1% while in Zooplankton, *Colurella* was most abundant genus with R.A 10.3%. In November, *Chodatella* was most abundant genus among Phytoplankton with R.A 11.3% while in Zooplankton, *Centropyxis* was most abundant genus with R.A 5.27%. In December, *Tetrastrum* and *Tabellaria* wer most abundant genera among Phytoplankton with R.A 12.3% while in Zooplankton, *Pseudodifflugia* was most abundant genus with R.A 5.26% (Tables 2 & 3).

Meshram (2003) stated that macrophytes stimulate the growth of Phytoplankton which helps in the recycling of organic matter; this can be positively correlated with high Phytoplankton density. Biodiversity is fluctuated with different factors like water level, temperature and nutrient level. Changes in aquatic environment due to pollution are a cause of growing concern, and require monitoring of the surface water and organisms inhabiting them (Vandysh, 2004).

Schabetsberger *et al*., (2004) concluded that in a freshwater ecosystem, Phytoplankton were dominated by green algae while the Zooplankton were cladocerans. Similarly in present study, the maximum numbers of genera were observed of Chlorophyta in accordance with Ali *et al*., (2010) while studying the algal flora in fresh waters of Swat valley in Pakistan.

Diversity index of Phytoplankton was found to be highest in September (2.99) and lowest in March (2.53), showed an increasing trend up to September and then decreased in rest of months. Diversity index of Zooplankton was observed maximum (1.68) in December and minimum (1.08) in July and October (Table 5). There was highly significant (p<0.001) inverse correlation between relative abundance of phytoplankton and Zooplankton (Table 4). Pathania *et al*., (2010) reported that the diversity index of Phytoplankton and Zooplankton of freshwater pond ranged 1.92 to 2.37 and 0.64 to 0.83, respectively.

Table 2. Relative abundance (%) of Phytoplankton in D.G. Khan Canal water affected with domestic sewage.

Phytoplankton	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Cyanophyta	**1.92**	**6.06**	**11.1**	**16.9**	**7.92**	**7.40**	**6.55**	**1.72**	**14.0**	**5.26**
Anabaenopsis	-	6.06	-	-	-	-	-	-	-	-
Lyngbya	-	-	7.35	-	-	6.17	-	-	-	-
Coelosphaerium	-	-	3.75	-	-	-	-	-	-	-
Gloeocapsa	-	-	-	7.69	-	-	-	-	5.26	-
Dactylococcopsis	-	-	-	9.23	-	-	-	1.72	-	-
Anabaena	1.92	-	-	-	6.34	-	-	-	-	-
Aphanizomenon	-	-	-	-	1.58	-	-	-	-	5.26
Microcystis	-	-	-	-	-	1.23	6.55	-	8.77	-
Chlorophyta	**44.2**	**25.7**	**35.4**	**24.6**	**31.7**	**29.6**	**36.1**	**29.3**	**40.3**	**42.1**
Closterium	11.5	-	-	1.53	-	8.64	11.5	-	-	-
Chlorella	17.3	-	-	-	11.1	4.93	-	-	-	8.77
Oocystis	5.76	7.57	10.3	4.61	-	6.17	-	-	-	-
Gonatozygon	-	7.57	-	-	-	-	-	1.72	-	7.01
Netrium	-	9.09	11.8	-	-	-	-	12.1	8.06	-
Cosmarium	-	-	1.47	-	7.93	-	-	-	4.83	-
Treubaria	-	-	11.8	-	-	-	6.55	-	6.45	-
Asterococcus	9.61	-	-	7.69	-	-	-	-	-	10.5
Chodatella	-	-	-	-	6.34	-	-	5.17	11.3	-
Tetrastrum	-	-	-	10.8	-	9.87	1.63	-	-	12.3
Staurastrum	-	1.51	-	-	6.34	-	8.19	-	-	3.50
Coelastrum	-	-	-	-	-	-	8.19	10.3	9.67	-
Chrysophyta	**40.4**	**31.8**	**22.9**	**33.8**	**20.6**	**33.3**	**24.6**	**34.5**	**16.1**	**26.3**
Navicula	7.69	-	5.88	12.3	-	9.87	9.83	6.89	-	-
Cyclotella	13.5	-	-	-	11.1	-	-	-	-	8.77
Mallomonas	9.61	-	4.41	-	-	-	4.91	-	-	-
Tabellaria	-	9.09	-	9.23	-	8.63	-	-	-	12.3
Cocconeis	-	4.54	3.75	-	-	-	8.19	-	-	-
Melosira	3.84	-	8.82	1.53	-	-	-	12.1	1.61	-
Stephanodiscus	-	-	-	4.61	-	-	-	-	-	5.26
Fragilaria	-	7.57	-	-	-	6.17	-	8.62	4.83	-
Synedra	-	-	-	6.15	-	8.64	-	-	-	-
Nitzschia	5.76	-	-	-	9.52	-	-	-	9.67	-
Cymbella	-	10.6	-	-	-	-	1.63	6.89	-	-
Englenophyta	**7.69**	**-**	**8.82**	**6.15**	**7.92**	**12.9**	**19.7**	**1.71**	**8.06**	**3.00**
Euglenopsis	7.69	-	-	-	1.58	8.64	-	-	-	-
Phacus	-	-	-	6.15	-	-	8.19	-	-	-
Euglena	-	-	-	-	6.34	-	-	1.71	8.06	-
Lepocinclis	-	-	8.82	-	-	4.32	11.5	-	-	3.00
Pyrrhophyta	**-**	**9.09**	**-**	**7.69**	**-**	**4.32**	**3.27**	**-**	**-**	**7.60**
Peridinium	-	9.09	-	-	-	-	3.27	-	-	7.60
Glenodinium	-	-	-	7.69	-	4.32	-	-	-	-
Cryptophyta	**-**	**6.06**	**1.47**	**-**	**6.34**	**-**	**-**	**6.89**	**1.61**	**2.40**
Cryptomonas	-	6.06	1.47	-	-	-	-	-	1.61	-
Nephroselmis	-	-	-	-	6.34		-	6.89	-	2.40

Table 3. Relative abundance (%) of Zooplankton in D.G. Khan Canal water, affected with domestic sewage.

Zooplankton	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Protozoan	**4.74**	**4.54**	**13.2**	**8.60**	**16.4**	**2.23**	**7.13**	**13.2**	**10.5**	**7.01**
Holophrya	1.24	-	-	-	7.93	-	-	-	-	-
Didinium	-	4.54	-	-	-	-	-	-	-	1.75
Tintinnopsis	-	-	7.35	-	-	2.23	-	-	-	-
Hemiophrys	-	-	-	5.10	-	-	-	3.44	-	-
Centropyxis	-	-	-	3.50	-	-	-	-	5.27	-
Pseudodifflugia	-	-	-	-	8.45	-	-	-	-	5.26
Paramecium	-	-	-	-	-	-	7.13	9.80	-	-
Difflugia	3.50	-	-	-	-	-	-	-	1.15	-
Cyphoderia	-	-	5.86	-	-	-	-	-	4.04	-
Rotifers	**1.05**	**9.66**	**2.16**	**2.26**	**9.12**	**4.08**	**2.65**	**10.3**	**4.31**	**2.34**
Asplanchna	-	2.09	-	-	2.78	-	-	-	-	-
Epiphanes	-	7.57	-	1.11	-	-	-	-	-	2.34
Colurella	-	-	-	-	6.34	1.23	2.65	10.3	-	-
Dicranophorus	1.05	-	2.16	1.15	-	2.85	-		4..31	-
Cladocerans	**-**	**7.09**	**4.95**	**-**	**-**	**6.17**	**-**	**2.39**	**5.12**	**3.99**
Daphnia	-	7.09	4.95	-	-	6.17	-	2.39	5.12	3.99

Table 4. Relationship among limnological parameters of D.G. Khan Canal water affected with domestic sewage.

Correlation matrix	WT	LP	Turbidity	pH	EC	DO_2	Free CO_2	Acidity	Hardness	Alkalinity	TS	NPP
LP	**0.795****											
Turbidity	0.563 ^{ns}	0.590 ^{ns}										
pH	0.083 ^{ns}	0.278 ^{ns}	0.167 ^{ns}									
EC	**-0.803****	**-0.708***	-0.447 ^{ns}	-0.450 ^{ns}								
DO_2	-0.577 ^{ns}	**-0.905****	-0.565 ^{ns}	-0.549 ^{ns}	**0.630***							
Free CO_2	0.187 ^{ns}	0.465 ^{ns}	0.369 ^{ns}	**0.779****	-0.466 ^{ns}	**-0.732***						
Acidity	-0.008 ^{ns}	0.199 ^{ns}	-0.345 ^{ns}	0.525 ^{ns}	-0.165 ^{ns}	-0.413 ^{ns}	0.579 ^{ns}					
Hardness	-0.581 ^{ns}	-0.541 ^{ns}	-0.159 ^{ns}	-0.324 ^{ns}	0.583 ^{ns}	0.504 ^{ns}	**-0.291***	-0.576 ^{ns}				
Alkalinity	-0.103 ^{ns}	0.068 ^{ns}	-0.061 ^{ns}	**0.694***	-0.201 ^{ns}	-0.407 ^{ns}	**0.795****	0.846 ^{ns}	-0.405 ^{ns}			
TS	0.280 ^{ns}	0.487 ^{ns}	0.341 ^{ns}	-0.198 ^{ns}	-0.273 ^{ns}	-0.391 ^{ns}	-0.036 ^{ns}	-0.421 ^{ns}	0.288 ^{ns}	-0.448 ^{ns}		
NPP	-0.313 ^{ns}	0.079 ^{ns}	0.327 ^{ns}	-0.105 ^{ns}	0.425 ^{ns}	0.085 ^{ns}	-0.048 ^{ns}	-0.448 ^{ns}	0.477 ^{ns}	-0.393 ^{ns}	0.360 ^{ns}	
NZP	0.313 ^{ns}	-0.079 ^{ns}	-0.327 ^{ns}	0.105 ^{ns}	-0.425 ^{ns}	-0.085 ^{ns}	0.048 ^{ns}	0.448 ^{ns}	-0.477 ^{ns}	0.393 ^{ns}	-0.360 ^{ns}	**-1.000****

ns = non significant ($p \geq 0.05$), * = significant ($p<0.05$), ** = highly significant ($p<0.001$)

WT: Water Temperature, LP: Light Penetration, DO_2: Dissolved Oxygen, TS: Total Solids, NPP: Net Phytoplankton, NZP: Net Zooplankton

Table 5. Diversity indices of Phyto and Zooplankton in D.G. Khan Canal water affected with domestic sewage.

Months	Phytoplankton				Zooplankton			
	S	N	In N	Diversity Index	S	N	In N	Diversity Index
March	11	52	3.95	2.53	3	04	1.39	1.44
April	11	49	3.89	2.57	4	14	2.63	1.14
May	12	59	4.07	2.70	4	09	2.20	1.36
June	13	58	4.06	2.95	4	07	1.94	1.55
July	11	47	3.85	2.59	4	16	2.77	1.08
August	13	67	4.20	2.86	4	14	2.64	1.14
September	13	55	4.01	2.99	3	06	1.79	1.12
October	11	42	3.74	2.67	4	16	2.77	1.08
November	12	41	3.71	2.96	5	21	3.04	1.32
December	12	53	3.97	2.81	4	06	1.79	1.68

S= Number of genera, N= Total number of individuals, In = Natural logarithm

Mason (1998) reported that diversity index is a good pollution indicator in aquatic ecosystem. Diversity index greater than three indicates the clean water; range from one to three is the characteristic of moderately polluted water and values less three characterize the heavily polluted water. Chughtai *et al*., (2011) reported the diversity index of Phytoplankton more than three while of Zooplankton less than three throughout the study period in river Chenab water at Multan and indicated its water quality marginally fit for aquatic life. Similarly, El-Sheekh *et al*., (2010) also studied the water quality of river Nile at different locations and declared as moderately polluted on the basis of biological assessment through diversity and saprobic indices that were less than three throughout the study period.

Conclusions

In an aquatic ecosystem, limnological characteristics can affect both on fauna and flora. The water quality parameters of D.G. Khan were compared with water quality standards. Most of the parameters were found to be in permissible level throughout the study period. However, diversity index of Phytoplankton and Zooplankton was found less than three throughout the study period which indicates the quality of D.G. Khan Canal water as moderately polluted. It is, therefore, necessary to add sewage water after proper treatment to protect this water resource and also the aquatic life.

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