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A SURVEY OF ZOOPLANKTON DIVERSITY OF CHALLAWA RIVER, KANO AND EVALUATION OF SOME OF ITS PHYSICO-CHEMICAL CONDITIONS

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ABSTRACT
Between July 2006 and December 2007 changes in some physico-chemical and biological conditions of Challawa River were assessed by collecting water samples from it, except for temperature, pH and Secchi disc transparency that were measured in situ, at four selected sites on fortnight basis between 8:00 – 10:00a.m.. The results revealed that the minimum and maximum temperature, pH, electrical conductivity, secchi disc transparency, dissolved oxygen, biochemical oxygen demand and zooplankton densities were 15.5-31.5^{o}C, 3.67-8.69, 44.0-4865.0µScm^{-1}, 0.04-0.149M, 0.20-9.15mg/L, 1.30-19.80mg/L and 0.00-45.30Org/L respectively. Significant differences occurred between the wet and dry season values of temperature, pH, and Secchi disc transparency (P<0.01) but at P>0.01 for electrical conductivity. However, no significant difference was found between the seasons in terms of dissolved oxygen, biochemical oxygen demand and zooplankton distribution (P>0.05). Zooplankton density was found to correlate positively with pH, secchi disc transparency and dissolved oxygen among others. Eighteen (18) zooplankton species were identified and include protozoa, 5 (22.78%); insecta 2(11.11%); copepoda, 5(27.78%); cladocera, 1(5.55%); and rotifera, 5(27.78%). The first two sites before the above that were off stream had higher zooplankton diversity and appeared to be unpolluted. Although the river generally had low zooplankton diversity, perhaps due to low transparency among other factors that limit phytoplankton growth, the discharge of untreated effluent into the river could be said to cause pollution in a localized state at the effluent inflow site. It was recommended that appropriate authorities should ensure that neighboring industries comply with emission standards set out by government with the view to minimizing the negative effects of their actions on both humans and aquatic biodiversity of the river. Similarly, it was recommended that there should be continual monitoring of the biological and physico-chemical status of the river, which appears to be neglected by the concerned authorities at present so that appropriate actions can take place before the situation go out of hand.

Key words: Physico-chemical, zooplankton, season, Challawa River, Kano

INTRODUCTION

In an aquatic ecosystem, interaction occurs between living and non-living components. Environmental factors comprising physical and chemical components have been reported in several studies to have a great influence on the well-being of aquatic species, plankton inclusive (Ovie, 1997; Kawo, 2005; Okogwu and Ugwunba, 2006). In an aquatic ecosystem, zooplankton form the microscopic animals (Redmond, 2008) that play an important role in an aquatic food chain as they are largely consumed by fishes and other higher organisms in food chain. Zooplankton density has also been reported to vary depending on the availability of nutrients and the stability of the water (Redmond, 2008). Equally, results of several studies have shown that physical and chemical condition of aquatic ecosystems determine the occurrence, diversity and density of both flora and fauna in any given habitat, which may change with season of the year (Aoyagui and Bonecker, 2004; Ayodele and Adeniyi, 2006). In view of the foregoing, this study was conducted in Challawa River, Kano in order to assess some of its physico-chemical conditions as they affect the dynamics of its zooplanktonic organisms presently lacking or scanty and hence serving as a means of providing a baseline data in the field of plankton dynamics in the river.

MATERIALS AND METHODS

Study Site

Challawa River is located within latitude 11^{o}55'N and longitude 8^{o}22'E and ranked as second largest river in Kano State after Kano River. It made a confluence with Kano River at Tamburawa village, some 20km from Kano closed settled zone and flows to the northeast joining Hadejia River. Geomorphologic characteristics and the climate of the area were well described by Olofin (1980; 1987). For decades; this river basin sustains local communities along its course particularly for agricultural activities. Similarly, the Kano State main waterworks treatment plant (Challawa Waterworks) is situated on this river, thus, providing source of water for agricultural, industrial and domestic purposes in Kano metropolis.

Sampling Sites

Four (4) sampling sites were selected for the purpose of this study based on differences in their anthropological conditions as follows:

Site A: This site (N 11°52.689', E 008°28.001') is on the watercourse of the Challawa River and extends some 120 meters west to the edge of the new bridge leading to Garu village. At this site, human activities such as fishing, washing, sand collection and other domestic activities are taking place regularly.

Site B: This site (N 11°52.718', E 008°28.183') is near the river intake point (the point at which the Kano State Waterworks draws its raw river water to the treatment plant for purification purposes.

Site C: This is the site (N 11°52.745', E 008°28.473') where raw industrial effluent, primarily from food, textile and tannery industries is discharged in to the river.

Site D: This is at Tamburawa, near the bridge (N 11°50.503', E 008°30.979') where Challawa River forms a confluence with Kano River along Kano-Zaria Road. At this site, agricultural activities, fishing and other activities are taking place. This site is close to the new Tamburawa Water Treatment Plant under construction by Kano State Government for overcoming some of the water crisis in the state (Africa, 2007).

Determination of Physico-chemical Parameters

Six (6) physico-chemical parameters were determined from the river between 8:00 a.m. and 10:00 a.m. at the above sites. The physico-chemical parameters were temperature, pH, electrical conductivity, secchi disc transparency, dissolved oxygen and biochemical oxygen demand.

A digital pH-Temperature meter (PTI–58 Model) was used in recording pH and temperature readings of the water at each of the sampling site (Sutherland, 1997). Similarly, a standard secchi disc was used for the determination of Secchi Disc Transparency (SDT) of the river water (Brown, 1987). Electrical conductivity of the water samples was determined with digital conductivity meter (Jenway 4010) as described by Sutherland (1997). Dissolved oxygen (DO) was measured through Winkler method as described by Best and Ross (1977) and Sutherland (1997) while Bennett and Humphries (1974) and Bryan (1976) technique were followed for BOD_5 determination of the water samples.

Zooplankton Sampling: The zooplanktons were sampled with the aid of plankton net (made of bolting cloth with a fine mesh aperture, 20-60µm, with a small bottle container of 30 cm^3 capacity attached to its narrow end). The water sample collected at each site was always carefully emptied into a dark sample bottle of about 100cm^3 capacity and always rinsed with distilled water in-between samples to avoid contamination.

Centrifugation and Preservation of Zooplankton: The collected samples were further centrifuged in the laboratory at 1500 rpm using centrifuge machine (Centromix), Huddersfield, England). A portion of each of the samples above was examined fresh with the aid of a light microscope while the remaining was preserved with 4% formalin (Supplied by Sallymore (Nig.) Limited) for detailed microscopic analysis (Jeje and Fernando, 1986).

Identification and Counting of the Zooplankton: The zooplankton samples collected from the river were observed and identified with the aid of light microscope (Olympus, Japan) and identification guides by Edmondson (1959), Pennak (1978), Jeje and Fernando (1986) and Patterson and Hedley (1992). Glycerine (Supplied by Sallymore (Nig.) Limited) and strong sugar solution were used as mountants for fast-swimming organisms in order to slow down their movement and therefore make the identification and counting easier.

Plankton abundance was estimated with the aid of Olympus compound microscope as described by Nlewadim and Adeyemo (1998) using the following relationship: -

$$A = \frac{YZ}{ax}$$; Where,

A = Average zooplankton per litre, Y = Average plankton per sample, Z = Concentrate volume (ml), a = original volume of sample per litre, x = Volume of sample or counting chamber examined (ml).

Statistical Analysis

The physico-chemical and biological data generated were analysed statistically (SAS, 1985) using analysis of variance (ANOVA) for significant differences or otherwise between the wet season (May - October) and the dry season (November - April). Pearson Correlation analysis was also carried out to determine the relationship between the above parameters in the ecosystem (SAS, 1985).

RESULTS AND DISCUSSION

The effects of temperature and pH on zooplankton dynamics in Challawa River during the study period are presented in Table 1. All the mean monthly temperature values at the sites were within the FEPA (1991) emission standard of 30°C for discharge of industrial effluent into rivers except in July 2006 when 31.5°C was recorded at site C which was an industrial effluent receiving site. This could be due to higher temperature of the effluent discharged from the neighbouring industries. Sharp drops in the temperature recorded during transition from wet to the dry season could be attributed to the effect of harmattan (Ezra, 2000). In addition, the relatively higher temperatures recorded during the warmer months could be due to increased solar radiation during the period (Ezra, 1999). Similarly, the mean pH recorded at all the sites were within the acceptable limit of 6.5 – 8.5 recommended for inland and drinking water quality (Antoine and Al-Sa'adi, 1982; WHO, 1996) except at site C in November 2006 (8.69) and site D in August 2006 (3.67), which could also be attributed to unusual effluent discharges into the river system from the surrounding industries. Moreover, despite the effluent discharges in addition to agricultural run offs (with varying pH conditions) into the river, the relatively stable pH recorded during this research seems to corroborate with the reports of Toman (1996) and Ibrahim (2003) that rivers can self purify themselves of pollution.

Variations in zooplankton density with changes in Electrical Conductivity (EC) and Secchi Disc Transparency (SDT) in Challawa River during this study are presented in Table 2. The means of electrical conductivity from the river decreased in the order: site C > site D > site B > site A with means being 79.0μScm^{-1}, 82.6μScm^{-1}, 1441.7μScm^{-1} and 131.2μScm^{-1} at site A-D respectively. The above observation also indicated the highest conductivity at site C can directly be associated with the inflow of industrial effluent, and the conductivity at site B being higher than that at site A could probably be attributed to seepage from site C and other activities associated with the site or as a result of local variations. Similarly, as the water displayed a conductivity >1,200 μScm^{-1} at site C, it can be regarded as being at a level above what is supposed to be obtained in freshwaters (http://www.lavaris-lake.de/en/content/view/30/41/) thus, indicating a clear presence of pollution in a localised form. Moreover, the SDT appeared to be extremely low, which might be largely responsible for the very low zooplankton densities recorded during the study period as Dejen *et al*. (2004) had earlier reported that silt held in suspension in turbid water interferes with filter feeding mechanisms of crustaceans and this affects their reproduction success. Similarly, Hart (1986) reported that SDT values above 0.30 - 0.35M appeared to be necessary for the development of sufficient and suitable zooplankton to benefit fishery and none of the SDT values recorded during this study was up to the above minimum of 0.30M. Thus, even the highest value was only 0.149M recorded from site D in November 2007 during the dry season (Table 2).

Dissolved Oxygen (DO) and Biochemical Oxygen Demand (BOD_5) values recorded from the river as they affect zooplankton dynamics are shown in Table 3. This table indicated that DO at site A, B and D was not a bio-limiting factor in the river as their means were all above the minimum of 5.00mg/L required for the survival of aquatic organisms and drinking water quality (FEPA, 1991). However, the least mean DO of 2.15 mg/L on the other hand recorded from site C could be one of the reasons why least zooplankton recovery of 4 species only (Table 4) occurred at that site. Similarly, the re-emergence of 8 zooplankton species at site D down stream tends to further support the ability of the river to undergo self purification down stream (Toman, 1996; Ibrahim, 2003). The high mean DO values recorded in the dry season could partly be due to effect of harmattan wind that facilitates mixing of the surface water with atmospheric oxygen in the river. Indeed, the results of this study showed that BOD_5 at the sampling sites was generally low throughout the study period with the lowest and highest value from sites A, B and D of 1.30 mg/L and 4.60 mg/L recorded from site A and site D in September and December respectively (Table 3) but at site C it was only in December 2006 the BOD_5 was found to be very low (3.50 mg/L) perhaps as a result of low production rate of the industries in the area due to *Eid-Al-Kabir* ('Sallah') and Christmas holidays that were observed in the same period. The above finding corroborated with the work of Bashir *et al*. (2002) that recorded low phytoplankton and zooplankton populations from some industrial effluent polluted streams in Kano. Hence, the mean BOD_5 at site C was found to be 13.49 mg/L, which was above the FEPA (1991) standard of 10.00 mg/L.

Double maxima occurred in terms of the total monthly density of the zooplanktons recovered from site A, which were 33.88 Org/L and 35.91 Org/L in April and August 2007 respectively as presented in Table 4. The above observations corroborate with the reports of Ovie (1997), and Okogwu and Ugwumba (2006) that plankton maxima may occur at any time of the year in the tropics, depending on the conditions of the ecosystem. Indeed, even under favourable environmental conditions, zooplanktons such as *Cladocera* may be monocyclic or dicyclic, with one or two population maxima during the year (Pennak, 1978). Cladocerans such as *Daphnia pulex* are also reported to be rare in rapid streams and grossly polluted waters (Pennak, 1978) thus, absent at site C (Table 4), which was most unstable and polluted. Additionally, some species, particularly rotifers have been found to unaccountably disappear for one or more years although they are cosmopolitan in distribution (Pennak, 1978). Similarly, copepods are reported to be either absent or present in small numbers in streams and therefore rivers by extension (Pennak, 1978). Consequently, zooplanktons were found to be very low in density in the Challawa River due to the above reasons coupled with their inability to maintain footing and therefore develop a stable community in a lotic environment, which is fundamental for reproduction success as earlier reported by Dejen *et al*. (2004). The extremely low zooplankton densities of 0.00 – 64.48 Org/L at the sampling sites recorded during the study period agreed with the finding of Howick and Wilhm (1984) that reported zooplankton densities of between 0.00 - 61.3 Org/L in Lake Carl Blackwell. Analysis of variance (ANOVA) of the results of this study using SAS (1985) showed that significant differences occurred in the temperature, pH and SDT values recorded in the wet and the dry seasons at $P < 0.01$ and at $P>0.01$ for EC but no significant differences existed between the seasons for DO, BOD_5 and zooplankton densities at $P > 0.05$. Similarly, the Pearson Correlation analysis revealed that positive correlation occurred between EC versus temperature and pH; SDT versus pH; DO versus SDT; BOD_5 versus temperature, pH and EC; and zooplankton versus pH, SDT and DO.

Table 1: Mean Monthly Values of Temperature, pH and Zooplankton Density from Challawa River (July 2006-December 2007)

	Temperature (^0C)				pH				Zooplankton Density (Org/L)			
Month	**Site A**	**Site B**	**Site C**	**Site D**	**Site A**	**Site B**	**Site C**	**Site D**	**Site A**	**Site B**	**Site C**	**Site D**
July 2006	27.5	27.5	31.5	30.0	6.58	6.55	6.80	6.73	18.80	9.58	0.00	3.51
August	27.0	27.5	29.5	29.0	7.36	7.19	7.19	3.67	1.17	0.00	0.00	9.58
September	27.5	26.7	27.5	28.4	7.48	7.82	7.14	7.47	2.78	1.39	0.00	6.34
October	27.0	27.5	29.0	28.5	7.87	7.60	7.66	7.55	10.23	0.00	3.17	7.60
November	20.5	21.5	22.0	23.6	7.88	7.75	8.69	8.23	9.53	0.00	0.00	13.02
December	18.5	19.0	19.0	20.5	7.70	7.82	6.87	7.61	6.63	0.00	0.00	0.00
Jan. 2007	17.5	18.0	22.0	18.5	7.26	7.45	7.87	7.49	7.15	8.87	0.00	2.51
February	20.5	20.5	22.0	22.0	7.31	7.44	7.04	7.53	1.21	2.81	0.00	0.00
March	23.0	23.0	24.5	24.0	8.06	7.92	7.63	7.67	10.23	11.25	0.00	6.84
April	26.0	26.0	27.5	27.0	7.76	8.17	8.38	8.34	33.88	13.92	0.00	0.00
May	27.5	28.0	28.5	29.0	6.94	7.22	7.56	7.85	4.96	5.65	4.34	0.00
June	26.0	26.0	27.0	28.0	6.78	6.61	6.91	6.83	2.28	5.71	1.39	2.76
July	24.0	24.0	25.0	25.8	7.45	6.95	7.04	7.08	13.77	7.95	4.94	2.38
August	22.5	22.5	23.0	22.5	7.73	8.06	7.47	7.69	35.91	45.30	11.93	16.45
September	23.7	23.7	24.3	24.3	7.21	7.53	7.89	7.41	13.97	8.25	5.30	3.26
October	21.5	21.5	22.0	22.5	7.44	7.41	6.93	7.04	9.33	3.18	0.00	2.30
November	19.0	19.0	19.5	20.3	7.42	7.73	7.63	7.55	1.81	5.84	0.00	2.82
December	15.5	15.5	15.5	16.8	6.97	7.57	7.54	7.62	0.00	19.62	24.53	0.00
Mean	**23.0**	**23.2**	**24.4**	**24.5**	**7.40**	**7.49**	**7.46**	**7.30**	**10.26**	**8.30**	**3.09**	**4.41**

Table 2: Mean Monthly Values of Electrical Conductivity, Secchi Disc Transparency and Zooplankton Density from Challawa River (July 2006-December 2007)

	Electrical Conductivity(μScm^{-1})				Secchi Disc Transparency (M)				Zooplankton Density (Org/L)			
Month	**Site A**	**Site B**	**Site C**	**Site D**	**Site A**	**Site B**	**Site C**	**Site D**	**Site A**	**Site B**	**Site C**	**Site D**
July 2006	89.0	67.5	2210.0	87.0	0.065	0.068	0.050	0.063	18.80	9.58	0.00	3.51
August	75.5	84.1	2615.0	94.5	0.069	0.042	0.052	0.062	1.17	0.00	0.00	9.58
September	67.5	76.5	3120.0	83.6	0.072	0.073	0.058	0.066	2.78	1.39	0.00	6.34
October	74.5	74.0	4865.0	103.0	0.076	0.079	0.055	0.067	10.23	0.00	3.17	7.60
November	78.5	66.0	788.5	88.5	0.092	0.097	0.060	0.083	9.53	0.00	0.00	13.02
December	132.5	72.0	1223.5	72.5	0.098	0.098	0.062	0.094	6.63	0.00	0.00	0.00
Jan. 2007	77.5	76.5	1470.5	94.2	0.099	0.106	0.048	0.090	7.15	8.87	0.00	2.51
February	84.0	80.0	1006.0	94.5	0.108	0.097	0.058	0.094	1.21	2.81	0.00	0.00
March	90.5	273.5	354.5	131.0	0.097	0.096	0.057	0.089	10.23	11.25	0.00	6.84
April	80.0	81.0	694.5	230.0	0.096	0.098	0.060	0.082	33.88	13.92	0.00	0.00
May	92.0	86.5	2981.0	223.0	0.091	0.090	0.056	0.094	4.96	5.65	4.34	0.00
June	78.0	75.0	194.0	137.0	0.052	0.056	0.040	0.044	2.28	5.71	1.39	2.76
July	88.5	75.0	575.0	472.0	0.068	0.085	0.080	0.095	13.77	7.95	4.94	2.38
August	73.5	66.5	642.5	98.0	0.068	0.088	0.070	0.103	35.91	45.30	11.93	16.45
September	74.3	78.3	2764.0	120.7	0.110	0.100	0.088	0.103	13.97	8.25	5.30	3.26
October	55.5	49.0	216.0	58.5	0.115	0.104	0.089	0.109	9.33	3.18	0.00	2.30
November	65.0	60.5	140.0	97.0	0.120	0.128	0.128	0.149	1.81	5.84	0.00	2.82
December	46.5	44.0	90.0	77.3	0.123	0.125	0.140	0.133	0.00	19.62	24.53	0.00
Mean	**79.0**	**82.6**	**1441.7**	**131.2**	**0.090**	**0.090**	**0.069**	**0.090**	**10.26**	**8.30**	**3.09**	**4.41**

Table 3: Mean Monthly Values of in Dissolved Oxygen, Biochemical Oxygen Demand and Zooplankton Density from Challawa River (July 2006-December 2007)

	Dissolved Oxygen (mg/L)				Biochemical Oxygen Demand (mg/L)				Zooplankton Density (Org/L)			
Month	**Site A**	**Site B**	**Site C**	**Site D**	**Site A**	**Site B**	**Site C**	**Site D**	**Site A**	**Site B**	**Site C**	**Site D**
July 2006	6.30	5.45	2.15	5.10	3.75	2.95	9.50	4.10	18.80	9.58	0.00	3.51
August	6.75	6.95	0.60	5.55	2.70	2.80	13.75	3.05	1.17	0.00	0.00	9.58
September	6.80	6.50	0.35	4.90	1.30	1.75	13.30	1.90	2.78	1.39	0.00	6.34
October	6.35	6.10	0.35	5.00	1.75	1.85	17.85	3.30	10.23	0.00	3.17	7.60
November	6.25	6.80	0.35	4.95	1.65	2.30	10.85	3.70	9.53	0.00	0.00	13.02
December	7.30	7.30	2.85	6.10	3.15	3.45	3.50	4.60	6.63	0.00	0.00	0.00
Jan. 2007	8.70	7.60	0.35	6.80	3.10	2.75	15.40	3.30	7.15	8.87	0.00	2.51
February	8.20	8.15	0.20	6.35	2.70	3.20	15.15	2.85	1.21	2.81	0.00	0.00
March	7.25	7.00	0.40	5.90	2.25	2.20	9.35	3.45	10.23	11.25	0.00	6.84
April	7.35	7.00	1.10	2.90	2.70	2.35	12.85	2.15	33.88	13.92	0.00	0.00
May	6.90	7.15	0.30	3.55	2.85	3.15	16.40	2.40	4.96	5.65	4.34	0.00
June	7.20	6.45	2.95	4.80	2.45	2.15	8.00	3.30	2.28	5.71	1.39	2.76
July	7.45	6.55	4.85	4.85	2.20	2.00	14.60	4.25	13.77	7.95	4.94	2.38
August	7.40	7.35	6.10	6.35	2.10	3.05	19.80	5.15	35.91	45.30	11.93	16.45
September	5.42	7.63	0.57	5.53	2.52	2.43	16.53	3.17	13.97	8.25	5.30	3.26
October	8.20	8.15	4.80	5.95	1.45	1.65	14.20	2.95	9.33	3.18	0.00	2.30
November	7.90	7.65	3.85	5.15	3.25	3.20	16.40	4.25	1.81	5.84	0.00	2.82
December	9.15	8.85	6.60	6.25	3.95	3.75	15.40	3.10	0.00	19.62	24.53	0.00
Mean	**7.27**	**7.15**	**2.15**	**5.33**	**2.55**	**2.61**	**13.49**	**3.39**	**10.26**	**8.30**	**3.09**	**4.41**

Table 4: Checklist for the Occurrence, Distribution and Relative Abundance of Zooplankton Species at the Sampling Sites (July 2006 - December 2007)

		Site					Frequency
S/No.	**Taxon**	**A**	**B**	**C**	**D**	**Total (Org/L)**	**(%)**
	Protozoa						
1	*Loxodes sp.*	1.24	-	-	-	1.24	25.00
2	*Urocentrum sp.*	3.75	-	3.17	-	6.92	50.00
3	*Vorticella sp.*	5.13	-	-	8.87	14.00	50.00
4	*Coleps sp.*	5.13	-	-	-	5.13	25.00
5	*Sarcodina sp.*	-	1.39	-	-	1.39	25.00
	Insecta						
6	*Chaoborus sp.*	1.28	22.12	-	14.55	37.95	75.00
7	*Cypris sp.*	63.53	21.76	3.55	36.15	124.99	100.00
	Copepoda						
8	*Macrocyclops ater*	8.90	12.44	-	3.84	25.18	75.00
9	*Senecella calanoidea*	1.26	1.39	-	-	2.65	50.00
10	*Cyclops sp.*	5.13	5.30	-	-	10.43	50.00
11	*Limnocalanus macrurus*	-	2.83	-	-	2.83	25.00
12	Naplius I of copepoda	1.24	1.41	-	-	2.65	50.00
	Cladocera						
13	*Daphnia pulex*	6.94	11.30	-	3.26	21.50	75.00
	Rotifera						
14	*Brachionus sp.*	64.48	53.07	44.11	7.70	169.36	100.00
15	*Asphlanchna brightwelli*	1.24	-	-	-	1.24	25.00
16	*Stentor sp.*	15.39	10.60	4.77	2.47	33.23	100.00
17	*Rotararia sp.*	-	5.71	-	-	5.71	25.00
18	*Philodina sp.*	-	-	-	2.53	2.53	25.00
	Total (Org/L) (%)	**184.64 (39.38)**	**149.32 (31.84)**	**55.60 (11.86)**	**79.37 (16.92)**	**468.93 (100.00)**	
	Frequency/ Site (%)	**14 (77.78)**	**12 (66.67)**	**4 (22.22)**	**8 (44.44)**		**18 (100.00)**

Key: - means the species was not recovered

CONCLUSION

Challawa River appeared to have a low diversity of zooplankton species with relatively low densities perhaps primarily due to low transparency level among other factors that strongly limit light penetration and thus photosynthesis. However, the least diversity of the zooplankton recovered from the industrial effluent discharge site is a clear indication of the presence of pollution in a localized state, which needs special attention to stop its spread down stream as it can have a devastating effect not only on the aquatic flora and fauna but also on other terrestrial organisms including humans. Consequently, government should, through its appropriate organs ensure that manufacturers adhere strictly to the set emission guidelines of their wastes into the environment and governmental and non-governmental organizations should encourage and sponsor joint research on the general biological and physico-chemical condition of the Challawa River on a continual basis since it is essential for tracking adverse environmental changes in an aquatic environment which appeared to be neglected by the appropriate authorities.

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