On the Dominant Behavior of Zooplankton in Different types of Domestic Sewage Oxidation Ponds

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ABSTRACT

Plankton are small microscopic organisms, comprising diatoms and algae, which form the basis of primary production, whereas zooplankton are mainly crustaceans, rotifers and larval stages of larger animals which constitute the higher aquatic food web. Both are bio-indicators of a water body, constituting the main food for the carnivorous and omnivorous fishes in the aquatic ecosystem. In the present work, a detailed analysis of zooplankton diversity along with variations in species, and seasonal abundance with average and total population density was carried out in different types of domestic sewage oxidation ponds. Similar analysis for a comparison was done in a freshwater control pond situated in Bhopal India. In this study out of 8 ponds, 4 were selected for zooplankton analysis two being primary and two being secondary sewage oxidation ponds and one freshwater control pond was selected for comparative analysis. The results indicated that the number of zooplankton in all ponds ranged from 162 to 14776 org/L, seasonally it was observed that the sewage oxidation ponds had the maximum population of zooplankton in winter, followed by rainy and summer seasons. Regarding the population of zooplankton in the individual oxidation ponds, it was found that sewage secondary pond IIIB had the maximum zooplankton followed by IIIA. Interesting observations on the cascading effects of physicochemical parameters on plankton dynamics, including the variations in the diel population of various species of zooplankton have been recorded. The phenomenon of plankton grazing in different types of domestic sewage ponds is being reported for the first time.

KEY WORDS: COMPARATIVE ANALYSIS, TROPICAL SEWAGE PONDS, ZOOPLANKTON

INTRODUCTION

Plankton are small aquatic plants or minute animals which float and drift on the surface or are found at the bottom of water bodies. Phytoplankton forms the basis of primary production and zooplankton mainly protozoa, crustaceans and rotifers are excellent natural food for fishes in such nutrient-rich aquatic ecosystems, (Park and Shin, 2007, Ramachandra, 2009a, Ramachandra, 2009b, Goswami and Mankodi, 2012, Nanasaheb et al., 2012, Suresh et al., 2013, Yusuf, 2020).

Plankton are also present in the sewage ponds, due to their photosynthetic activity, release oxygen into the water which is then made available to increase the aerobic decomposition of the organic wastes by bacteria. As zooplankton is a good bio-indicator of water quality, and being more sensitive to organic pollutants, many studies have been conducted on the zooplankton diversity in freshwater lakes and ponds, however, there are very few studies on the seasonal abundance, population diversity of various species of zooplankton in sewage ponds (Jha, et al., 1997, Goswami & Mankodi, 2012, Yusuf, 2020, Grabicova, 2020, Tulsankar et al., 2021).

In the present work, a detailed analysis of zooplankton diversity, variations in species, and abundance with average and total population density was done in different types of tropical domestic sewage oxidation ponds along with a freshwater control pond situated in Bhopal India. Important physicochemical parameters which correlate with the growth of zooplankton were also studied seasonally, to know their cascading effects if any, on the zooplankton abundance and composition in both, wastewater oxidation ponds and the freshwater pond.

MATERIAL AND METHODS

Analysis of zooplankton was done in the domestic sewage oxidation ponds situated at Shahpura sewage ponds located

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10 km South-East of Bhopal City (25-17 L). There are 8 sewage oxidation ponds constructed in two series of primary and secondary as per specifications of the of National Environmental Engineering Research Institute (NEERI) Nagpur. Out of eight ponds, four were selected in the present study. (Two being primary, designated as IA & IIIA and two as secondary as IB & IIIB). One freshwater control pond was selected for comparative study. Each pond had an area of 0.4 hectares, designed to treat biologically 3 million gallons of sewage per day. Sewage from adjacent areas is collected in a sump and is pumped to the oxidation ponds where it is detained for a period of 15-20 days for microbial transformation and biological stabilization. The raw sewage enters the primary pond through 3 inlets and after the detention period the biologically treated effluent goes out from the secondary pond through outlet. The treated effluent is either let out into a small canal or into the fields for vegetable cultivation in an area extending more than 50 hectares. The morphometric features of the ponds are: Length = 100.65 mts /Breadth = 50.32 mts Average depth = 1.20 mts.

As large-scale fish mortality and unfavorable conditions occurred in the primary ponds 1A & 1B, fish culture experiments could not be carried out in these ponds and only two distant oxidation ponds, IIIA & IIIB along with a control freshwater pond with fish culture were analyzed in the present study. In our previous studies, various aspects of fish culture along with the role of nutrients in primary and secondary oxidation and control ponds have been reported, (Ali et al., 2020, 2021).

There was large-scale post-stocking mortality of fishes within 24 hours in the initial (primary) ponds i.e. 1A & 1B due to untreated heavy loads of sewage coming to these ponds, whereas only 10-15% fish mortality was observed in the secondary oxidation ponds III A & III B, which received biologically treated sewage. Hence in the present study, collection and identification and species enumeration of zooplankton (different species) were done only in two oxidation ponds (IIIA & IIIB) as per standard methods and compared with their composition in the control freshwater pond.

Physicochemical parameters like light penetration, water temperature, pH and dissolved oxygen were also studied in these oxidation and control ponds to know the quality of the water and their effect on the survival and growth rates of planktonic organisms. The physico-chemical parameters were estimated as per the procedure described in Standard Methods, 1995 (APHA & AWWA). The identification of zooplankton was carried out by using standard methods described by Palmar (1980), Wetzel (1983).

Table 1. Showing the average seasonal ranges of different physico- chemical parameters of different domestic sewage oxidation and control ponds (Data from Ali et al 2021).

Seasons	Ponds	Light penetration (cm)	Temperature (°C)	pH	Dissolved oxygen (mg/l)
Winter	IIIA	15.40-25.80	18.30-23.80	9.10-10.00	5.30-13.30
	IIIB	15.60-26.30	18.10-23.90	9.40-10.20	5.10-10.40
	CP	35.60-41.30	18.50-24.10	7.80-8.40	5.40-7.20
Summer	IIIA	12.60-14.80	29.00-34.70	8.70-9.90	3.00-17.30
	IIIB	9.20-11.60	32.00-36.20	8.60-9.90	3.80-10.50
	CP	39.30-77.00	32.34-36.50	8.20-9.00	4.50-7.20
Rainy	IIIA	11.00-12.90	24.30-28.10	9.20-10.20	3.60-12.80
	IIIB	11.00-13.10	23.60-27.70	9.60-10.00	4.30-16.90
	CP	26.60-30.30	24.50-28.30	7.80-8.60	5.20-8.40

(IIIA, IIIB – Sewage oxidation ponds: CP - Fresh Water control ponds)

RESULTS AND DISCUSSION

Important physicochemical parameters such as light penetration, water temperature, pH and dissolved oxygen were analyzed seasonal-wise in primary, secondary and freshwater control ponds and are depicted in Table No:1. Light penetration and the poor transparency, high presence of algae and solids and other undesirable materials are the reasons for low light penetration in the primary pond. Light penetration was found to be high in winter, followed by rainy & summer seasons in our studies, (Table No 1). These parameters are known to cause adverse effects on various species of zooplankton and their assessment. An important physiochemical variable in aquatic environment is DO, which plays a vital role in survival and growth of organisms such as zooplankton. DO levels are known to reach minimum levels in highly fertile ponds prior to sunrise.

During the course of study, it was observed that there were twenty-one species of zooplankton present in the primary and secondary oxidation ponds under investigation. These species of zooplankton comprised *Copepods, Rotifers* & *Brachionus*, out of which *Keratella, Cyclops, Daphnia, Brachionus, Eubranchiopus, Noupleus* larva regularly occurred in both type of oxidation ponds. The number of zooplankton in all ponds ranged from 162 to 14776 org/L, and seasonally it was observed that the oxidation ponds had the maximum population of zooplankton in winter followed by rainy and summer. Regarding the population of zooplankton in the individual oxidation ponds it was found that secondary pond IIIB had the maximum zooplankton followed IIIA. (Table No. 2) Cyclops (486 to 10965 org/L), Keratella (324 to 8748 org/L) *Brachionus* (1000 to 5000 org/L), *Naupleus* larva and *Daphnia* (162 to 106) were the dominant species recorded in these ponds.

On the other hand, the total number of zooplankton species in the fresh water control pond was only ten and the dominant ones were *Cyclops, Keratella, Daphnia* and *Naupleus* larva. The total population of zooplankton in the fresh water pond ranged between 162 to 3240 org/1. Thus, it is evident that the number of zooplankton in the fresh water control pond were many times less than the sewage secondary oxidation ponds. The average population density of zooplankton in the oxidation ponds was four times greater than that of the fresh water control pond. The seasonal dominance of the zooplankton in the fresh water control pond was seen more during winter followed by summer and rainy seasons (Table No. 2, 3).

Table 2. Showing the seasonal presence of various species of zooplankton in different domestic sewage oxidation ponds along with a freshwater control pond (numbers/litre) IIIA&IIIB- Sewage oxidation ponds CP- Fresh water control ponds

Season	Ponds	Cyclops	Keratella	Daphnia	Naupleous larva	Brachionus	Eubran chiopus	Total	Average
Winter	IIIA	2106	2430	810	972	2106	4212	12636	2106
	IIIB	2268	4212	0	0	1944	1296	9720	1620
	CP	810	972	0	324	648	0	2754	459
Summer	IIIA	648	810	810	648	1458	0	4374	729
	IIIB	1458	648	648	810	810	0	4374	729
	CP	810	972	486	324	648	0	3240	540
Rainy	IIIA	972	972	324	810	1296	0	4374	729
	IIIB	1134	810	162	324	1134	648	4212	702
	CP	810	486	162	162	648	0	2268	378

Another interesting observation made regarding zooplankton of fresh water pond was total disappearance of some of the species in the pond during the course of study. It was observed that *Daphnia* and *Eubrachiopus* maintained their absence in summer and rainy also whereas Daphnia occurred during summer and rainy in the fresh water pond though its population decreased to half in rainy from summer (Table No. 2). During the diel study of zooplankton, it was observed that the following species of *Cyclops, Keratella, Daphnia, Naupleus* larva and *Brachionus*, were most of the time found during night hours, preferring 10 PM to 2 AM period in the types of different oxidation ponds, their population was greater by about two times in night than day (Table No. 2). The variations in the diel behaviour of the zooplankton population during different seasons in various oxidation ponds are shown in (Table 3).

In the present investigation more than twenty one species of zooplankton have been found to be present in different types of oxidation ponds, ie primary and secondary, ranging from 162 to 14,726 cell in thousands / L, where dominant species belonged to the groups of *Rotifera, Copepods* and *Cladocerans* (Table No. 3). The most frequently recorded species were of *Cyclops, Keratella, Brachionus*, *Naupleus* larva and *Daphnia*. The zooplankton found in the oxidation ponds had considerable influence of the season. Maximum zooplankton were found in winter followed by rainy and summer, and the ponds which had maximum population were of following order- IB > IA > IIIB > IIIA. An interesting feature observed in the seasonal influence on the population density of zooplankton with that of phytoplankton density. Maximum phytoplankton had minimum zooplankton, whereas minimum phytoplankton had maximum zooplankton. The control pond zooplankton species comprised only the following two groups Rotifera and Copepods, which had about ten species in dominance.

An interesting feature observed in the present study was the seasonal influence on the population density of zooplankton on plankton, being vice versa in population density in the oxidation ponds which were highly nutritious. The control pond zooplankton species comprised only the following two groups Rotifera and Copepods, which had about ten species in dominance. The seasonal order of zooplankton dominance in freshwater was maximum in winter followed by rainy and summer. It has been observed that oxidation ponds generally do not have excessive growth of zooplankton (Havel and Shurin, (2004, Rajagopal et al., 2010, Goswami and Mankodi, 2012, Pearson & Duggan, 2018).

Table 3. Showing the presence of total zooplankton in secondary sewage oxidation pond and fresh water control pond (in thousands /litre)

Season	Month	Total Zooplankton Copepods		Cladocerans		Density	
		OP	CP	OP	CP	OP	CP
Rainy	June	44	10	20	7	11	0
	July	32	10	21	7	16	2
	Aug	30	11	26	7	18	4
	Sept	29	11	30	8	20	4
Winter	Oct	89	21	62	15	46	8
	Nov	92	22	64	15	48	10
	Dec	100	24	60	18	50	11
	Jan	103	24	62	21	54	11
Summer	Feb	69	11	46	10	35	5
	Mar	71	14	49	12	39	6
	Apr	73	14	51	12	40	6
	May	64	15	47	12	42	6

OP- Oxidation Pond (sewage pond), CP- Control fresh water pond

The low population of zooplankton as reported by these workers has also been observed in the present investigation. However in the oxidation ponds, we have observed significantly low population of zooplankton, which greatly enabled a bio-equilibrium of prey and predators, exhibiting the phenomenon of plankton grazing in sewage pond which is being reported for the first time. As the algae form the trophic base for the secondary production it is obvious that the grazing and predator relationship would influence their population density and as such an inverse relationship of zooplankton with that of phytoplankton density, particularly that of grazing in fresh water bodies, as observed presently is in full corroboration with the earlier findings of (Michael, 1968, Singh et al., 2021, Ramaekers et al., 2022).

The most pronounced effect seen was that the zooplankton had on phytoplankton, in an aquatic environment was grazing. In the present investigation, the reduction of the algal standing crop with the resultant increase of zooplankton indicates the grazing of phytoplankton by zooplankton. There have been conflicting reports regarding the effects of grazing of plankton in nutrient-enriched environments. Some workers found that heavy grazing depressed primary production (Kvale et al., 2021, Zheng, 2022). Whereas few studies detected little or no effect of herbivory on primary productivity (Chenillat et al., 2021).

Other results showed a positive correlation between the density of grazers and chlorophyll concentration (Goswami and Mankodi, 2012) or primary productivity (Pearson & Duggan, 2018). These results suggest that there is a unimodal response of primary productivity to zooplankton grazing. The data of the present finding support the view that grazing by zooplankton decreases the algal population thereby affecting the primary productivity and chlorophyll concentration.

CONCLUSION

It is concluded that about 21 species of zooplankton have been found in varying abundance in both the primary the secondary waste-stabilization or oxidation ponds as compared to the freshwater control pond. The reason for high and variable species of the zooplankton is attributed due to high and conducive nutrient levels which can offer excellent opportunities for natural survival and faster growth of the food chain including the poly carps in domestic tropical secondary oxidation ponds. Due to optimum levels of vital parameters such as light, pH, oxygen and excessive nutrients, along with conducive conditions present in the domestic sewage waters, secondary sewage oxidation ponds can offer excellent fish culture opportunities as a low cost economically viable concept of waste water aquaculture.

Conflict of Interest: The authors declare no conflict of interests.

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