Eco. Env. & Cons. 29 (January Suppl. Issue) : 2023; pp. (S356-S363)
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ISSN 0971–765X

DOI No.: http://doi.org/10.53550/EEC.2023.v29i01s.055

Seasonal Species Diversity and Dominance of Phytoplankton in Different types of tropical Domestic Sewage Oxidation Ponds

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(Received 17 June, 2022; Accepted 13 August, 2022)

ABSTRACT

Planktons are small microscopic organisms, comprising diatoms and algae, which form the basis of primary production and the zooplankton, which are mainly crustaceans, rotifers and larval stages of larger animals. Both are the bio-indicators of a water body, constituting the main food for the carnivorous and omnivorous fishes in any aquatic ecosystem. In the present study, the species diversity, and their abundance with a total and average population of various species of phytoplankton have been studied in the primary and secondary domestic oxidation ponds along with a freshwater control pond situated at Shahpura. Bhopal, Madhya Pradesh, India. Physicochemical parameters like light penetration, water temperature, pH and DO were also analyzed along with the phytoplankton population in both types of ponds to assess their impacts. The samples were collected and identified using standard methods. The results revealed that the phytoplankton groups like *Chlorophyceae, Bacillariophyceae, Cyanophyceae* and *Euglenophyceae* were dominantly found in the sewage oxidation ponds along with about 20 species of phytoplankton in varying population densities in different seasons. A similar analysis was done in a freshwater control normal pond for comparison. Physico-chemical parameters in these secondary sewage oxidation ponds with a high nutrient load were found to be highly favourable for the growth of the plankton species. A comparatively low number of phytoplankton was recorded in the freshwater control pond, which was highly deficient in nutrients.

Key words : *Nutrients, Phytoplankton species diversity, Domestic sewage oxidation ponds.*

Introduction

Reclamation of nutrients using fish culture in domestic sewage waters is an alternative low-cost, sustainable and eco-friendly method which is in practice globally for ages. Tropical waste-water stabilization or oxidation ponds are recognized as effective and economical units in tropical countries to treat domestic sewage by reducing the nutrients present in such waters and boosting the reclamation of fish protein (Ghosh *et al.,* 1980; Ali, 1988, 1992; Ali *et al.,* 2020, 2021).

Planktons are small aquatic plants or minute animals which float and drift on the surface or 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 eco-systems, (Park and Shin, 2007, Goswami and Mankodi, 2012; Nanasaheb and Sarita, 2012; Suresh *et al*., 2013; Ramachandra *et al*., 2009 a &b; Yusuf, 2020).

As planktons are good bio-indicators of water quality and particularly phytoplankton are more sensitive to organic pollutants, many studies have been conducted on the plankton diversity in fresh water lakes and ponds, however there are very few studies on the abundance, or population diversity of phytoplankton in sewage ponds (Jha *et al.*, 1997; Suresh *et al*., 2013; Yusuf 2020; Grabicova *et al*., 2020; Tulsankar *et al.*, 2021).

In the present work, a detailed analysis of phytoplankton diversity, variations in species, abundance with average and total population density was done in different types of domestic sewage oxidation ponds along with a fresh water pond situated in Bhopal India. Important physiochemical parameters which correlate the growth of plankton were also studied to know their cascading effects on the plankton diversity.

Material and Methods

Analysis of phytoplankton was done in the domestic sewage oxidation ponds situated at Shahpura sewage ponds located 10 kms, South-East of Bhopal City (25-17). There are 8 sewage oxidation ponds constructed in two series of primary and secondary as per specifications 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 and IIIA and two as secondary as IB and IIIB). One fresh water control pond is selected for comparative study. Each pond is having an area of 0.4 hectare and are 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.

The raw sewage enters the primary pond through 3 inlets and after the detention period the biologically treated effluent goes out from secondary pond through the 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 ponds 1A and 1B, fish culture experiments were not carried out in these ponds and only two ponds IIIA and IIIB primary and secondary oxidation ponds along with a control fresh water pond were analyzed in the present study. In our previous studied fish culture, and presence of nutrient in primary and secondary oxidation and control ponds were conducted (Ali *et al.,* 2020) by stocking major carps *C. carpio, L. rohita* and *C. mrigala* as per standard ratios. As there was a 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, and only 10-15% fish mortality was observed in the secondary oxidation ponds III A & III B, which received biologically treated sewage. So in the present study, collection and identification and species enumeration of phytoplankton different species were done only in two oxidation ponds (III A and IIIB) as per standard methods and compared with their composition in the control fresh water pond.

Physico-chemical 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 bodies. The physico chemical parameters were estimated as per the procedure described in Standard Methods, 1995 (APHA and AWWA). The identification of phytoplankton was carried out by using standard methods described by Palmar, 1980; Wetzel, 1983).

Results and Discussion

Important physico-chemical parameters such as light penetration, water temperature, pH & dissolved oxygen were analyzed seasonal wise in primary, secondary and fresh water control ponds and are depicted in Table 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 primary pond. Light penetration was found to be high in winter, followed by rainy and summer seasons in our studies, (Table 1).

High water temperatures were recorded in summer followed by rainy and winter seasons in secondary oxidation pond IIIB and comparative low range of temperatures were observed in primary pond IIIA. Fresh water control pond exhibited a range of water temperature from 18.5 to 36.50 ^{0}C throughout our studies (Table 1).

In our studies pH range of primary oxidation pond (IIIA) was from (9.1 to 10.2) and in the secondary oxidation pond IIIB, the pH exhibited a range of

9.4 to 10.2, which shows that the waters were highly alkaline. On the contrary, in the fresh water control pond, the pH was 7.8 to 8.40. Dissolved oxygen (DO) values were found to change considerably during the entire study period. Positive DO values (5.10 to 10.40 mg/L) were found in secondary oxidation ponds (IIIB) in winter season followed by rainy (4.30–16.90 mg/l) and in the summer season (3.80 to 10.50) in secondary oxidation ponds where plankton growth was recorded in maximum in these ponds, as compared to the primary pond. Primary oxidation pond DO values were 5.30 to 13.30 mg/l in winter, 3.0 to 17.3 in summer and 3.6 to 12.8 mg/l in rainy season respectively, (Table 1).

In both types of oxidation ponds i.e., primary and secondary, about twenty species of phytoplankton have been found to be present in varying population, ranging from 972 to 54513 organisms per liter, out of many species recorded in varying members four dominant species of phytoplankton such as *Microsystems areiginosa, Spirulina platensis Novicula gracieis* and *Nitzschia palea* were conspicuous and the remaining phytoplankton species totaling 20 in number were observed both in dominant and subdominant populations, as shown in Table 2 and 3.

The order of phytoplankton dominance within the oxidation ponds has been found to be as follows: primary ponds, followed by secondary ponds. Seasonally it was observed that maximum phytoplankton was present in the oxidation ponds during summer and rainy seasons, whereas comparatively winter had a less dense population. An interesting observation in the population of *Microcystis areuginosa* was found to be two to three times greater than other dominant species. Regarding order of dominance in various ponds it was maximum in pond IIIA and IIIB. Regarding the seasonal order it was observed that *Microcystis* was found maximum in rainy (7956-7209 org/l) followed by winter and summer seasons.

The population of *Spirulina* in the oxidation ponds followed a similar pattern as of *Microcystis*. Seasonally it was observed that *Microcystis* and *Spirulina* had opposite affinities. The other dominant species found in the various oxidation ponds are as follows: *Navicula gracilis*, *Niztschia palea* and *Chlorella* sp. which had a range of 2268, 1169 and162 org/ litre being maximum in winter and minimum in rainy season in pond IIIA, whereas it was maximum in summer season and minimum in winter season in the primary pond (Tables 2, 3).

Nitzschia palea was another dominant phytoplankton which was recorded in significant numbers in all the found oxidation ponds throughout the study ranging from 1053 to 10693 which was inthe secondary pond. Seasonally the occurrence of *Nitzschia* was as follows in the primary pond. It was found maximum in summer (1458 org/l 1879 org/l), winter (1620-1169) and rainy (2187-1701 org/l) seasons whereas in ponds IIIA and IIIB. *Nitzschia* was dominant during the rainy season followed by the summer and winter seasons. (Table 3).

On the other hand, the freshwater control pond exhibited the occurrence of more than one species of phytoplankton in a varying population ranging from 405 to 5022 org/l. Out of many species recorded in varying numbers, *Synedra* (11016-1296 org/1) *Nodularia* (972-2592) and Chlorella (648-1944) were found to be dominant and regularly present in the freshwater pond. Seasonally it was observed that the maximum control phytoplankton was present in the freshwater control pond during the

Table 1. Showing the average seasonal ranges of different physico- chemical parameters of different domestic sewage oxidation and control ponds.

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)

Table 2. Season-wise phytoplankton population in sewage oxidation ponds (OP) and control pond (CP) (numbers in thousand/l)

Months	Chlorophyceae								Bacillariophyceae							Cyanophyceae					Eugleanaceae	
	Chlorella		*Closterium*		*Spirogyra*		*Navicula*		*Cyclotella*		*Diatoms*		*Microcystis*		*Nostoc*		*Oscillatoria*		*Euglena*	
	OP	CP	OP	CP	OP	CP	OP	CP	OP	CP	OP	CP	Exp	Cp	OP	CP	OP	CP	OP	CP
June	64	10	48	-	58	12	59	-	38	10	47	14	58	15	54	8	50	-	38	2
July	60	10	51	-	64	10	62	-	42	10	51	14	60	15	56	7	40	-	40	0
Aug	61	14	57	-	59	10	49	-	46	12	47	16	65	19	60	7	41	-	41	2
Sept	78	11	54	-	62	12	51	-	49	10	45	19	61	21	60	6	43	-	43	1
Oct	82	8	57	-	60	5	63	-	51	8	59	10	78	10	71	3	54	-	54	0
Nov	80	8	61	-	68	8	64	-	54	5	63	10	75	10	74	3	50	-	50	0
Dec	82	10	63	-	76	5	60	-	50	6	60	14	70	14	79	4	49	-	49	1
Jan	76	11	60	-	70	6	83	-	49	5	68	11	73	14	70	0	44	-	44	0
Feb	92	15	61	-	70	14	80	-	67	15	71	26	80	21	74	10	61	-	61	3
Mar	94	16	64	-	73	14	82	-	71	17	77	25	84	23	76	10	65	-	65	3
Apr	101	20	73	-	80	16	94	-	84	10	80	24	86	24	80	14	66	-	66	5
May	103	22	78	-	94	18	101	-	86	17	84	29	90	26	84	14	69	-	69	7

Oxidation Pond (Sewage Pond), Control Pond (Freshwater Pond)

winter and summer seasons, whereas the comparatively rainy season had a less dense population.

On comparing the phytoplankton of fresh water ponds with that of oxidation ponds, it was found that only a few species were dominant in the form and their number was 3 to 4 times less than the oxidation pond species. In all the seasons an interesting seasonal observation was that freshwater phytoplankton had a reverse seasonal affinity from that observed in the oxidation ponds. In the freshwater pond, the seasonal pattern for the presence of various species of phytoplankton was winter followed by summer and rainy whereas in sewage oxidation ponds it was summer followed by rainy and winter. (Table 2, 3, 4).

The subdominant species of oxidation ponds: As reported earlier about twenty species of phytoplankton have been recorded to be regularly present in the oxidation ponds. Among them, four were most regular and dominantly present. About sixteen species of phytoplankton we observed sub dominantly in the four oxidation ponds and it was found that among the three seasons the subdominant phytoplankton ranged between 162 to 4212 org/l where the minimal number was found in winter and rainy and the maximal number was recorded in the summer season. In contrast to the subdominant species, the dominant phytoplankton had a range of 972 to 54513 org/l. throughout the year (Table 2, 3, 4).

In the freshwater control pond apart from dominant phytoplankton species, there were eight subdominant phytoplankton species, which were present in different numbers in all the three seasons. The subdominant plankton had a maximum population of *Melosira, Scenedesmus* and *Cyclotella* which were beyond 1000 org/l. whereas *Anabaena, Fragillaria* and *Microcystis* were less than 1000 org/l in the freshwater control pond. Special mention is to be made of the range of *Microcystis* which was present only winter season the high range of 7452-7695 org/l. This is in extreme contrast to the enormous population of *Microcystis* which ranged between 486-648 org/l in the control oxidation ponds, suggesting a strong relationship between *Microcystis* proliferation.

Diel Analysis of Dominant and Subdominant phytoplankton: During the study, diel analysis of phytoplankton was also conducted once every month in the four oxidation ponds and freshwater control ponds. The analysis was started at 10 AM during which the sampling was done every four hours. Due to the paucity of space, only the seasonal diel analysis has been incorporated and interpreted in the present study. The purpose of the diel analysis was to have an idea regarding the population, nature and dominance of plankton species in the different ponds in relation to some of the important controlling factors, such as light, temperature, pH and dissolved oxygen which fluctuated duringly. During the analysis all the present phytoplankton have been studied however, only the dominant ones are reported here. As evident from the tabulated data *Microcystis, Spirulina, Navicula* and *Nitzschia* fluctuated significantly in population during various hours in different oxidation ponds.

The diel behaviour of the phytoplankton species was also studied with regard to their variation in population densities in different periods. It was observed that *Scenedesmus, Ankistrodesmus, Euglena Anabaena, Planctonica, Melosira* varied significantly in their population during the 24 hours period of analysis in the three seasons. (Table 2, 3). It was observed that *Scenedesmus sp, Ankistrodesmus, Euglena* were dominantly present during the night hours between 10 am to 2 pm and their population was just half that of the night during the daytime. *Melosira and Anabaena* were present day and night in equal numbers in the summer season and no significant differences were observed in their population in the diel cycle.

On the other hand, during the summer season *Scenedesmus* which was present in greater numbers during the night, reversed its behaviour and become densely populated during the day and thinly populated during the night. *Ankistrodesmus sp* and *Euglena sp* were present in greater numbers during the night in all the oxidation ponds, following a similar pattern as that of the winter season (Table 2, 3).

Melosira and Anabaena which in the winter season were present in almost equal numbers during the day and night in all the oxidation ponds showed a shift in their population density during the summer season. Both the species were present more during the day than at night. In the rainy season, an interesting observation was recorded regarding the sub-

Table 3. Showing the seasonal presence of various species of phytoplankton in different domestic sewage oxidation ponds along with a freshwater control pond (numbers/litre)

Season	Rainy			Winter			Summer		
Species of Phytoplankton	IIIA	IIIB	CP	IIIA	IIIB	CP	IIIA	IIIB	CP
Microcystis	8149.5	7956	486	7452	7695	648	7533	7209	0
Spirulina	2754	2997	0	2268	2511	0	2673	4131	0
Navicula	2835	1782	0	2835	2268	0	1903	1863	0
Nitzschia	2187	1701	0	1620	1169	0	1458	1879	0
Scenedesmus	1620	1944	972	648	486	324	2268	1620	486
Pediastrum	0	0	0	0	0	0	0	0	0
Asterignella	0	0	0	0	0	0	0	0	0
Synedra	1458	972	11016	648	486	1620	1296	1134	1296
Ankistrodesmus	810	972	324	1296	486	162	1620	810	324
Nodularia	1134	1944	972	0	810	648	0	486	2592
Chlorella	486	648	648	324	162	324	1620	648	1944
Chlosterium	0	0	0	0	0	0	0	0	0
Euglena	972	810	324	486	324	162	1782	1620	324
Cyclotella	0	1296	972	0	1134	1296	0	1620	1134
Merismopedia	1458	0	0	1296	0	0	972	0	0
Melosira	1458	972	1296	1134	810	972	2430	1782	2106
Fragillaria	1944	0	162	1782	0	324	1620	0	486
Achnanthus	648	972	0	810	1296	0	972	648	0
Oscillatoria	0	0	0	0	0	0	0	0	0
Anabaena	1620	810	486	2268	1458	972	2106	972	810
Total density	29533.5	25776	17658	24867	21095	7452	30253	26422	11502
Average	1476.675	1288.8	882.9	1243.35	1054.75	372.6	1512.68	1321.1	575.1

IIIA&IIIB- Domestic Sewage Oxidation Ponds, CP- Control freshwater pond dominant phytoplankton and their population in the oxidation ponds. *Scenedesmus sp., Snkistrodesmus sp. Euglena sp, Melosira Anabaena* and *Closterium* which were densely populated during the night hours become more densely populated during the day hours in the rainy seasons (Table 2, 3). The remaining phytoplankton species such as *Pediastrum, Asterionella, Synedra, noduleria, Spirulina, Chlorella, Cyclotella, Merismopedia, Fragillaria, Achnathus* and *Oscillatoria* were recorded unevenly and irregularly in all the oxidation ponds during the three seasons. They did not follow a definite nocturnal or diurnal pattern as the earlier mentioned species exhibited (Table 2, 3).

On comparing the diel behavior of phytoplankton from oxidation pond with fresh species. It was observed that there were only three phytoplankton: *Synedra, Nodularia and Chlorella,* which were densely and regularly present throughout the year. Their variations are also shown in all three seasons according to the order of dominance the phytoplankton in the freshwater pond was greatly dense in winter, followed by summer and rainy seasons. Phytoplankton which was present dominantly in oxidation ponds were found to be totally absent or irregularly present in freshwater control ponds (Table 2, 3).

On the other hand, species which were found in abundant numbers in freshwater control ponds were rarely present in the oxidation ponds, thereby clearly providing substantial evidence that oxidation ponds are species-specific in phytoplankton population and abundance (Table 3).

An interesting feature which was recorded during the study period was the shift in phytoplankton population observed in the two different ponds. During the first year in the rainy season, *Navicula gracitis* and *Nitzschia palea* were among the dominant species however, in the next year these species become subdominant and *Chlorella* sp. which was a subdominant species on oxidation ponds in the 1st year became a highly dominant species in the second year of investigation. In the winter season, *Navicula and Nitzschia* were also decreased in their dominance and in the first year and in the second year it showed a decrease in their population and shifted to subdominant group from dominant, whereas *Nodullaria*, *Chlorella* and *Synedra* were subdominant in the winter season in the first year and became dominant in the summer.

Several species of phytoplankton belonging to 4 classes were identified in secondary oxidation ponds in our studies. *Chlorella sp, Closterium sp, Spirogyra* sp of Chlorophyceae, *Navicula, Cyclotella* and diatoms of *Bacillariophyceae* and only one species of *Euglena* of *Euglenophycea* was found in the sewage oxidation ponds, details of occurrence of phytoplankton season-wise are shown in Table 3. All the above phytoplankton species were found maximum in the summer season, followed by the winter season (October to January) and low number in the rainy season (June to September) (Table 2, 3). Phytoplankton occurrence was found to bevery low in control freshwater pond as compared to the secondary oxidation pond, due to the presence of high nutrient loads.

More importance has been given to the studies of physico-chemical and biological parameters in the domestic secondary oxidation pond i.e., IIIB where fish growth was found to be high in our previous studies (Ali *et al*., 1998, 2020 and 2021). The primary oxidation recorded comparatively high physicochemical characteristicsdue to untreated sewage and unfavourable physical conditions present in the primary pond (Table 1). In the present study, greater light penetration and high water pH were found in the winter season, whereas higher water temperature was seen in the summer season with very high DO values in the secondary oxidation ponds (Table 1).

Phytoplankton was found to be present maximum in summer, medium number in winter and minimum in rainy seasons in the secondary oxidation pond, (Table 2, 3). The occurrence of maximum phytoplankton in summer is due to high temperature, favourable pond ecosystem pH. These conditions promote higher growth of algae and other phytoplankton. These findings are the same as those of previous workers. (Nanasaheb *et al*., 2012; Allen 1970; Mathivanan *et al*., 2007; Sulthana *et al.,* 2014; Suresh *et al.,* 2013), who have found high physicochemical related values in polluted water. The other reason for greater plankton diversity and population in sewage oxidation ponds is the presence of high nutrients which consequently lead to the high content of phytoplankton (Ali *et al*., 2020 & 2021; Park and Shin, 2007; Ramachandra 2009 a, b and Jin, 2017).

Season-wise, minimum phytoplankton occurrence in the rainy season, could be due to low light penetration in the oxidation ponds and more oxygen which is also required to oxidize the organic matter present in domestic sewage secondary oxidation ponds. More oxygen is consumed by the organic matter present in sewage water and it may affect the growth of phytoplankton. It is also found that phytoplankton is more sensitive than zooplankton to the pond physico-chemical parameters (Acharjee *et al.,* 1995; Ali *et al*., 1988, 2020, 2021; Allen and Hepher, 1976; Palmar, 1980). These conditions may be the reason for the low and high presence of phyto plankton in our present studies. This may be due to the high range of pH and maximum occurrence of DO in the presently studied secondary ponds (Table 1). These data also corroborate with the findings of earlier workers. Higher amounts of dissolved oxygen have been suggested to be good for the survival of various species of plankton and other favourable conditions of the pond support the growth of zooplankton, (Goswami and Mankodi, 2012; Jin, 2017).

Finally, it may be concluded that phytoplankton is found in abundance and are good for the survival and growth of fishes in domestic secondary oxidation ponds, partly due to the favourable physicochemical parameters and the non-toxic atmospheric conditions present in the waters. Moreover, it is known that along with the fish the plankton can grow luxuriously by adapting themselves better to such nutrient-rich environments (Krishnamoorthi *et al*., 1975; Mara 1976; Ghosh *et al*., 1980; Ali *et al*., 2020 & 2021).

Conclusion

It is concluded that large number of about 20 of various phytoplankton species are found in abundance in the tropical secondary waste-stabilization or oxidation ponds as compared to the fresh water control pond, due to high and conducive nutrient levels which can offer excellent opportunities for natural survival and faster growth of poly carps in domestic secondary oxidation ponds, due to optimum levels of vital physicochemical parameters along with the non-toxic conditions present in the domestic sewage waters. Conducive physico-chemical parameters in these secondary sewage oxidation ponds with a high nutrient load were found to be highly favorable for the highly, abundant growth of different types of plankton species.

Acknowledgements

The authors are thankful to the Secretary and Principal of Saifia Science College, Bhopal, India for providing the necessary facilities.

References

Acharjee, B., Dutta, A., Choudhary, M. and Parthak, B. 1995. Phytoplankton species Diversity indices in Dighali beel, Assam, India. *Enviorn. Ecol.* 13(3) : 660-662.

Ali, S. A., Raju, M. H. and Parveen, N. 2020. On the Analysis of Certain Biochemical Parameters of Carps Cultured in Domestic Sewage Oxidation Ponds. *Bioscience Biotechnology Research Communications.* 13(4): 2311-2318. DOI:10.21786/bbrc/13.4/103.

Ali, S. A., Raju, M. H. and Parveen, N. 2021. Seasonal analysis of certain biochemical parameters of carps cultured in domestic sewage oxidation ponds. *Journal of Applied Biology and Biotechnology.* 9(5): 1-5.

Ali, S.A. 1988. Management of productivity and production of fish in sewage pond effluents in urban areas. USDA (PL-480) Research Programme. In AES-208, FG in 623. *Final Technical Report.* 1-128.

Ali, S.A. 1991. Enhancement of food production and abatement of eutrophication through waste water fish culture. *The 6 world Fisheries Congress, Athens, Greece,* April 14-19.

Ali, S.A. 1992. Monitoring and Evaluation of Domestic. Aquaculture Research Needs for 2000 AD. 1992:355.

Ali, S.A., Khan, S.A., Qureshi, M.H., Khare, S., Raju, M.H., Ishrat, A., Ali, S.N. 1988. On the fecundity of carps cultured in waste stabilization pond. *All India Nat. Symp. Fish, Aquatic Boil.* Trivandrum.

Allen, G.H. and Hepher, B. 1976. Recycling of waters through aquaculture and constraints to wider application. *Advances in aquaculture.* FAO, Rome, Italy, 478-487.

American Public Health Association (APHA) 1995. *Standard Methods for the Examination of Water and Waste Water.* 15th Edition APHA, American Water Works Association, Water Pollution Control Federation, Washington D.C.

Ghosh, A., Rao, L.H. and Saha, S.K. 1980. Culture prospect of *Sarotherodon mossambicus* in small ponds fertilized with domestic sewage. *J. Inland Fish Soc. India.* 12(2): 74-80.

Goswami, A.P. and Mankodi 2012. P.C. – Study on Zooplankton of Freshwater Reservoir Nyari – II Rajkot District, Gujarat, India. *ISCA Journal of Biological Sciences*. 1(1): 20-34.

Grabicova, Grobic and Fedorava, 2020. Water reuse and aquaculture: Pharmaceutical bioaccumulation by fish during tertiary treatment in a waste water stabilization pond. *Environmental Pollution.* 267: 115593.

Jha, A.K., Latif, A. and Singh, J.P. 1997. River Pollution in India: An overview. *J. Environ. Pollution*. 4(2) : 143-151.

Jin Zhujing, 2017. Impact of Waste Water Treatment plant efficient on an Urban River. *Journal of Fresh water Ecology*. 32, 2017, issue-1.

Krishnamoorthi, K.P., Abdulappa, M.K., Sarkar, R. and Siddiqui, R.H. 1975. Productivity of sewage fertilized fish pond. *Water Research.* 9: 269-274.

Mara, D. 1976. *Sewage Treatment in Hot Climates*. London, John Wiley & Sons.

Mathivanan, V., Vijayen, P., Sabhanakyam, S. and Jeyachitra, O. 2007. An assessment of Plankton Population of Cauvery River with Reference to Pollution. *Journal of Environ. Biol.* 28 (2 Supple): 523-526.

Nanasaheb, C. Kankal and Sarita Warudkar 2012. Biodiversity of Phytoplankton, Zooplankton and Zoobenthos in East Coast, Bay of Bengal near Nellore, A.P. (India). *Int. J. Pharm; Med. & Bio. Sc.* 1, 2, October (2012).

Palmar, C.M. 1980. Algae and Water Pollution. Castle House Publication Ltd., England.

Park, K.S. and Shin, H.W. 2007. Studies on Phyto and Zoo plankton composition and it's relation to fish productivity in a west coast fish pond ecosystem. *Journal of Environmental Biology*. 28 (2): 415-422.

Ramachandra T.V. 2009b. Essentials in Urban lake Monitoring and management, CISTUP Technical Report-1, Urban Ecology, Environment and Policy Research, Centre for Infrastructure, Sustainable Transportation and Urban Planning, Inst. Ind. Sci. Bangalore.

Ramachandra, T.V. 2009a. Conservation and Management of Urban Wetlands; strategies and Challenges, ENVIS Technical Report: 32, Environmental Information System, Centre for Ecological Sciences, Bangalore.

Sulthana, A., Latha, K.C. and Rathan, R. 2014. Factor analysis and discriminant analysis of waste water quality in vidyaranyapuram sewage treatment plant, Mysore, India: a case study. *Water Sci Technol.* 69: 810-818 Cross ref, Pubmed, Google Scholar.

Suresh, B., Manjappa, S. and Puttaiah, E.T. 2013. Dynamics of Phytoplankton succession in Tungabhadra river near Harihar, Karnataka (India). *J. Microbiol. Antimicrobials*. 5(7) : 65-71.

Tulsankar, S.S., Cole, A.J., Gagnon, M.M. and Fotedar, R. 2021. Temporal variations and pond age effect on plankton communities in semi-intensive freshwater marron (*Cherax cainii*, Austin and Ryan, 2002) earthen aquaculture ponds in Western Australia. *Saudi Journal of Biological Sciences*. 1;28(2) : 1392-400.

Wetzel, R.G. 1983. Limnology 2nd Edition. Saunders College Publishing, USA, 767.

Yusuf, Z.H. 2020. Phytoplankton as bioindicators of water quality in Nasarawa reservoir, Katsina State Nigeria. Acta Limnologica Brasiliensia. 10: 32.