The Pharma Innovation Journal 2022; 11(12): 1021-1026

www.ThePharmaJournal.com

The Pharma Innovation

ISSN (E): 2277-7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2022; 11(12): 1021-1026

www.thepharmajournal.com
Received: 15-09-2022
Accepted: 16-10-2022

Shanmuga sundaram A
Ph.D. Scholar, Department of Wildlife Science, Faculty of Basic Sciences, Madras Veterinary College, Tamil Nadu Veterinary and Animal Sciences University, Chennai, Tamil Nadu, India

Palanivelrajan M
Assistant Professor, Department of Wildlife Science, Faculty of Basic Sciences, Madras Veterinary College, Tamil Nadu Veterinary and Animal Sciences University, Chennai, Tamil Nadu, India

Sreekumar C
Professor and Head, Department of Wildlife Science, Faculty of Basic Sciences, Madras Veterinary College, Tamil Nadu Veterinary and Animal Sciences University, Chennai, Tamil Nadu, India

Ghadevaru Sarathchandra
Professor and Head, Pharmacovigilance Laboratory for Animal Feed and Food Safety, Directorate, Centre for Animal Health Studies, Tamil Nadu Veterinary and Animal Sciences University, (TANUVAS), MMC, Chennai, Tamil Nadu, India

Venkataramanan R
Associate Professor, Livestock Farm Complex, Directorate, Centre for Animal Production Studies, TANUVAS, MMC, Chennai, Tamil Nadu, India

Ananda Chitra M
Associate Professor, Central University Laboratory Directorate, Centre for Animal Health Studies, TANUVAS, MMC, Chennai, Tamil Nadu, India

Corresponding Author:
Palanivelrajan M
Assistant Professor, Department of Wildlife Science, Faculty of Basic Sciences, Madras Veterinary College, Tamil Nadu Veterinary and Animal Sciences University, Chennai, Tamil Nadu, India

Effect of urbanization on the quality of water in water bodies inhabited by avifauna

Shanmuga sundaram A, Palanivelrajan M, Sreekumar C, Ghadevaru Sarathchandra, Venkataramanan R and Ananda Chitra M

Abstract
The present study was initiated with the objective to compare the quality of water in two lakes, one situated in Kumizhi in rural Kancheepuram adjacent to Umanancheri reserve forest and the other in Madhavaram, Chennai city. Both the lakes host more than 80 species of resident and migratory birds. Water samples from these lakes were collected and analysis was carried out on the parameters such as total hardness, chemical oxygen demand, dissolved oxygen, pH, NO_3, NO_2, PO_4, NH_3, total alkalinity, total hardness and salinity. The study revealed that Madhavaram Lake recorded significantly high values of COD, nitrate, ammonia, phosphate, total alkalinity, hardness and salinity in comparison with Kumizhi lake. Overall, 134 variety of bird species were recorded at both Kumizhi Lake and Madhavaram Lake. Among which 68 bird species were common in both lakes whereas 18 unique bird species were recorded at Madhavaram lake, and 48 unique bird species were recorded at Kumizhi lake. From this study, it can be concluded that water quality of the Madhavaram lake is can potentially pose a threat to ecosystem. Further, rapid urbanization and industrialization can accelerate water pollution in the near future. Systematic and periodical awareness camps may be organized to educate the local public of Madhavaram, Chennai to maintain the ecology and consequently water quality of the lakes for not only the welfare of the avifauna hosted by the water bodies but also their own betterment.

Keywords: Waterbodies, anthropogenic pressure, physio-biochemical parameters, avifauna, pollution

Introduction
Rapid industrialization around lakes, tanks, and other water bodies became unavoidable due to various anthropogenic compulsions resulting in gradual deterioration of the water bodies. Encroachment and pollution by letting domestic wastewater, industrial effluents, dumping of solid waste and negligence aggravates the degradation of water of the lakes causing considerable reduction in the surface water quality. The rural and suburban lakes are continuously being subjected to the invasive and aggressive burden of expansions.
Waterbodies are also important ecological niche for feeding, breeding and general survival of avifauna Therefore, the anthropogenic activities, including water pollution is a serious threat to the birds. The cities like Chennai and Chengalpattu are imposing serious threat to the avifauna due to water pollution. Chennai city is one of the metropolitan urban areas with high density of human habitation and numerous industries. Chennai has long been a haven for bird watchers. The city has several waterbodies within the urban limit, which are also inhabited by more than 200 residents and wintering bird species. With the drastic decline in the groves and open scrub and ponds and similar waters in the city, there has been a directly proportional decline in the bird life of Chennai, but many of the birds are still to be seen here and there, mainly in south Chennai. The anthropogenic activities like generated wastewater, solid waste, toxic materials, noise and artificial light pollution can affect the bird communities. Due to increase in industrialisation around lakes, tanks and other water bodies, various anthropogenic activities result in gradual deterioration of the water bodies. The presence of environmental pollutants in their habitats (including water bodies) can adversely affect the health of both resident and migrant avifauna apart from the human population. This results in change in physicochemical parameters of surface water and increased transmission of diseases among the avifauna hosting the water bodies. This can impact their reproduction leading to a decline in their population. It is therefore essential to monitor the lake water quality at regular intervals of time. The present study compares the quality of water in two water bodies, one located in the urban area and under severe anthropogenic pressure and the other near reserve forest with minimal human activities.

Materials and Methods

Study Area

Two lakes, one near a reserve forest without much anthropogenic pressure and another in the heart of Chennai under severe anthropogenic pressure and pollution, but both supporting substantial avian population were chosen for the study. (Fig. 1). Kumizhi lake is from the outskirts of Chennai in Kancheepuram district (12.802532 N and 80.121993 E) and spreads over 39 acres. It is situated adjacent to Umanancheri reserve forest and is surrounded by small hillocks. Water is received in the lake directly from the surrounding forest, thus is free from pollution caused by human inhabitation. A small portion of the lake has water lily growth.

Madhavaram lake, (13.1755 N and 80.1040 E) situated in Chennaiwas a 150-acre lake in the Manali-Mathur-Madavaram area of Chennai, receiving its water from the rainwater of Chennai city. Due to encroachment, indiscriminate dumping of garbage and sewage, the lake has shrunk to less than 100 acres. This lake is surrounded by human inhabitation and is under regular fishing using nets, rod, reels by locals. A substantial portion of the lake is covered by water hyacinth. Kumizhi

Both migratory and resident birds were recorded throughout the year in these two lakes. Both lakes are classified as 'birding hotspots' by eBird an online repository maintained by the Cornell Lab of Ornithology (https://ebird.org/home), indicating that they regularly host numerous resident and migrant birds. As per eBird, around 85 species of birds have been recorded in Madhavaram lake. Similarly, 114 species have been spotted at Kumizhi lake.

Considering these factors, a comparative study was done between Madhavaram and Kumizhi lake for various parameters indicative of pollution.

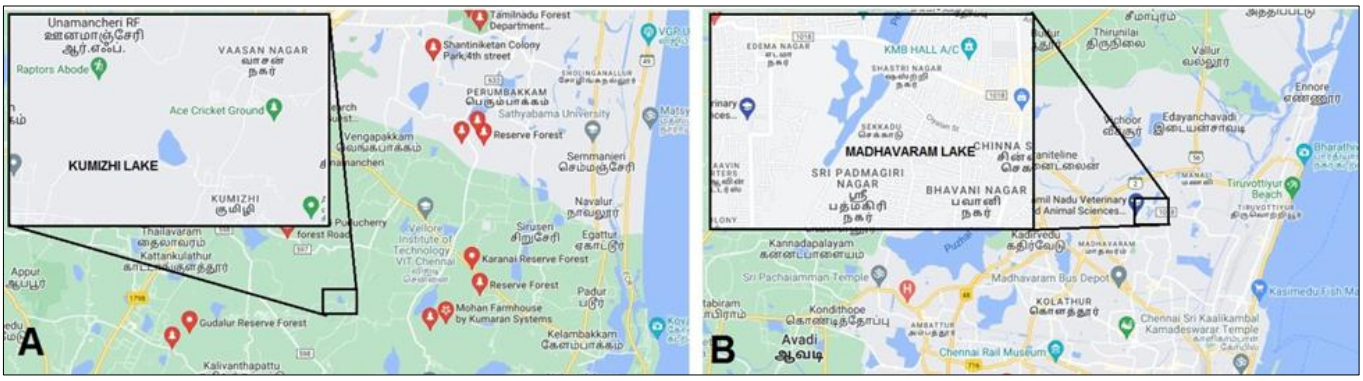

Fig 1: Map of Chennai showing the location of (A) Kumizhi lake (surrounded by reserve forest) and (B) Madhavaram lake surrounded by dense human habitation.

Fig 2: The serene Kumizhi lake (A) surrounded by hillocks and reserve forests with barely any human habitation around. A small portion of the lake contains water lily. The Madhavaram lake (B) by contrast, is surrounded by human habitation and substantial surface area is covered with water hyacinth.

Sample collection and analysis

Collection of water samples was done during the months of May and June 2022. The perimeter of each lake was assessed and divided into six equal sectors, from which six sampling stations along the borders of the lakes were chosen. The samples were taken from each sampling station by perambulation along the borders of the waterbody.

For physio-chemical analysis, the surface water sample was collected by grab-sampling method, about 10 cm below surface using plastic bottles (1000 mL). The water samples were kept in ice until further analyses. Standard procedures were followed for water sample collection and water sample analysis (APHA, 2005; Amadi *et al*., 2010) [2, 1]. Temperature, pH, salinity and Total Dissolved Solids (TDS) were measured using multiparameter instrument (Hanna Instruments, Mumbai). Dissolved oxygen (DO) was estimated using DO meter (YSI instruments, Mumbai). Nitrate, nitrite and ammonia – Nitrogen (NH_3-N) were estimated following the standard protocols (APHA, 2005) [2]. Total alkalinity and total hardness were estimated titrimetrically using phenolphthalein, methyl orange and eriochrome black-T as indicators, respectively (APHA, 2005) [2]. All the parameters were compared between the two locations using Student's t test.

Information on avifauna

The eBird database was used to collect the details. Data pertaining to birds of Madhavaram lake (https://ebird.org/hotspot/L8661351) and Kumizhi lake (https://ebird.org/hotspot/L12430887) between the year 2019 to 2022 were accessed and used for analysis.

Results and Discussion

The summary of values of different parameters of water from both lakes is in table 1. The higher values of parameters are linked with some particular pollution in the catchment and lake surroundings of the Madhavaram.

Table 1: Water quality parameters of Kumizhi and Madhavaram lake

Sl. No.	Parameters	Unit	Location		P. Value
			Kumizhi	Madhavaram	
1	TDS ^{NS}	mg/l	114.83±9.63	112.58±2.27	0.825
2	pH**		9.03±0.07	7.42±0.02	0.000
3	COD **	mg/l	5.15±0.06	6.03±0.06	0.000
4	DO**	mg/l	5.63±0.06	5.22±0.06	0.001
5	NO_3**	mg/l	3.92±031	8.40±0.09	0.000
6	NO_2 ^{NS}	mg/l	0.21±0.03	0.26±0.00	0.115
7	NH_3**	mg/l	0.19±0.01	0.87±0.02	0.000
8	PO_4**	mg/l	0.01±0.00	0.04±0.00	0.000
9	Total Alkalinity**	mg/l	68.33±1.09	200.00±2.58	0.000
10	Total Hardness**	mg/l	100.67±0.42	210.00±4.47	0.000
11	Salinity**	mg/l	0.02±0.00	0.95±0.00	0.000

Mean of six observations
Means bearing different superscript in the same row differ significantly
NS- Nonsignificant, ***p* < 0.01
Total Dissolved Solids (TDS)

There were no significant (*p*> 0.01) differences between Madhavaram lake (112.58±2.27) and Kumizhi (114.83±9.63) lake in TDS values. The palatability of water with a total dissolved solids (TDS) level of less than about 600 mg/l is generally considered to be good; drinking-water becomes significantly and increasingly unpalatable at TDS levels greater than about 1000 mg/l (Report, 2022) [10]. TDS is not generally considered as an indicator of primary pollution and is not associated with health effects.

pH

There was significant (*p*< 0.01) difference between the pH values between the two lake waters. The Kumizhi lake (9.03±0.07) water showed excess alkalinity in comparison to that of Madhavaram lake (7.42±0.02). Higher pH values of studied lake water during summer could be ascribed to increased photo synthetic assimilation of dissolved inorganic carbon by planktons (Kistan *et al*., 2015). The pH value at the range of 5.0-9.0 is suitable for fisheries, though 6.5-8.5 is preferable for drinking purpose (Report, 2011) [9]. Aquatic organisms are affected by pH because most of their metabolic activities are pH dependent (Wang *et al*., 2002). Optimal pH range for sustainable aquatic life is pH 6.5 – 8.2 (Murdock *et al*., 2001).

Chemical oxygen demand (COD)

There was significant (*p*< 0.01) difference between the Madhavaram and Kumizhi lake in the COD values. The mean value of COD of Madhavaram lake was 6.03±0.06 mg/l which is higher when compared to Kumizhi lake with 5.15±0.06 mg/l. COD measures the chemically oxidizable organic matter in water. The most common application of COD is in quantifying the number of oxidizable pollutants found in surface water (e.g. lakes and rivers) or wastewater (Gana, 2022) [3]. As the Madhavaram lake is located amidst human inhabitation and industries there is the possibility of higher pollution e as against the isolated virgin forest niche of the Kumizhi Lake.

Dissolved oxygen (DO)

There was significant (*p*< 0.01) difference between the Madhavaram and Kumizhi lake in the DO values. DO in Kumizhi lake was 5.63±0.06 mg/l whereas in Madhavaram Lake the value was lower with 5.22±0.06 mg/l. Generally, contaminated water has moderate level of DO when compared with potable water standards (6 to 10 mg/l). Thus, lower levels of DO, indicate the greater problems of lake water species and this level of DO is permissible level for domestic and some other purposes and not fit for drinking purposes. As per the BIS both levels are well within the level (2 mg/l) for Wildlife and Fisheries. In some water bodies, DO levels fluctuate periodically, seasonally and even as part of the natural daily ecology of the aquatic resource. Whereas DO less than 2.5 mg/l is described to be hypoxic condition (Laponite and Clark, 1992).

Nitrate and Nitrite

There was significant (*p*< 0.01) difference in nitrate level between Madhavaram lake (8.40±0.09 mg/l) and Kumizhi lake (3.92±031 mg/l) whereas there was no significant (p > 0.01) difference in nitrite level between Madhavaram lake (0.26±0.00 mg/l) and Kumizhi (0.21±0.03 mg/l) respectively. High level of nitrate encourages growth of algae and other organisms. Nitrate and nitrite are naturally occurring ions that are part of the nitrogen cycle. Nitrification causes decrease in pH (Wilczak *et al*., 1996) [12] and this might be reason for low pH in Madhavaram lake than Kumizhi lake. In many ground waters, an increase of nitrate levels has been observed due to the intensification of farming practice. In the present study the nitrate content (45 mg/l) is found to be well within the permissible limit (Ganesan and Sultana, 2009). Nitrite levels above 0.75 mg/l in water can cause stress in fish and greater than 5 mg/l can be toxic (Noble and Summerfelt, 1996) [7].

Ammonia

There was significant (*p*< 0.01) difference in ammonia level between Madhavaram lake (0.87±0.02 mg/l) and Kumizhi lake (0.19±0.01 mg/l). At doses ranging from 0.53 to 22.8 mg/L, it has been shown to be hazardous to freshwater species. The pH and the temperature both affect toxic levels. Low pH and low temperature both cause an increase in toxicity. (http://www.state.ky.us/). Ammonia can enter the aquatic environment through direct means such as municipal effluent discharges and the excretion of nitrogenous wastes

from animals, and indirect means such as nitrogen fixation, air deposition, and runoff from agricultural lands. Soler *et al.* (2021) mentioned that one of the frequently found pollutant in aquatic ecosystems is ammonia which can cause physical damage in fish, alter its behaviour, even causes mortality.

Phosphate

Phosphate concentration in Madhavaram lake (0.04±0 .00 mg/l) was significantly ($p< 0.001$) higher than that of Kumizhi lake (0.01±0.00 mg/l) which is free from runoff from agricultural sites and location near reserve forest. The acceptable and permissible limits of the phosphate in drinking water are 0.1 and 1.0 mg/l. Phosphorus is a limiting nutrient which controls the growth of algae in lakes. Fertilizers, human and animal wastes and detergents are the sources of phosphorus (Raji and Abraham, 2018) [8]. Natural waters contain a phosphorus concentration of approximately 0.02 parts per million (mg/l). Decomposition of plant tissue, waste solids or other organic material could have contributed to the higher level of phosphate component in water collected from Madhavaram lake.

Total alkalinity

There was highly significant ($p< 0.001$) variation in total alkalinity between Kumizhi (68.33±1.09 mg/l) and Madhavaram lake (200.00±2.58 mg/l) respectively. Total alkalinity indicates the quantity of base present in water – bicarbonates, phosphates, hydroxides, etc. (Wurts, 2002) [14]. The low total alkalinity was the reason for high pH variation in Kumizhi lake which in turn results in poor biotic component at the Kumizhi lake. The total alkalinity concentration should not be lower than 20 mg/l in production ponds and pond pH will widely fluctuate between 6 to 10 when alkalinity concentration is too low. Large daily fluctuation in pH can cause poor growth, stress and even mortality in fishes.

Hardness

There was high significant ($p< 0.01$) difference in total hardness between Kumizhi (100.67±0.42 mg/l) and Madhavaram lake (210.00±4.47 mg/l) respectively. When compared to various standards, the present water samples are well above the permissible limit of WHO (Report, 2022) [10]. Hardness represents the overall concentration of divalent salts (calcium, magnesium, iron, etc.). The hardness of water reflects the nature of geological formation with which it has been in contact (Garg *et al.*, 2007).

Salinity

There was high significant ($p< 0.01$) difference in salinity between Kumizhi lake (0.02±0.00 mg/l) and Madhavaram lake (0.95±0.00 mg/l). Salinity is the total concentration of the ions present in lake water and is usually computed from the sodium, potassium, magnesium, calcium, carbonate, silicate, and halide concentrations (Williams and Sherwood, 1994). Several important bodies of inland waters, often called inland seas, have very high salinities. These ions are steadily introduced to lakes from rivers and rainwater, where they concentrate because of the evaporative loss of relatively pure water.

Avifauna

Overall, 134 variety of bird species were recorded at both Kumizhi lake and Madhavaram lake. Among which 68 bird species were common in both lakes whereas 18 unique bird species were recorded at Madhavaram lake, and 48 unique bird species were recorded at Kumizhi lake (Table 2). An additional 48 unique species observed at Kumuzhi makes it a better niche in terms of species diversity. The significant differences in terms of water quality between the two lakes were in pH, DO, COD, NO_3 $N0_2$, NH_3, PO_4, total alkalinity, total hardness and salinity. Kumizhi lake is surrounded by reserve forest and is a part of the Vandalur Scrub, which acts as a catchment for the lake. Moreover, the diversity of flower and fruit bearing trees in the forest explains the presence of additional species like Loten's Sunbird, Baya Weaver, Thick-billed flowerpecker, Red-whiskered Bulbul, Jerdon's Nightjar, Blue-faced Malkoha, were observed in the region.

The additional unique species observed at Madhavaram lake were mainly waders such as Fulvous Whistling-Duck, Black-winged Stilt, Yellow-wattled Lapwing, Eurasian Spoonbill, Glossy Ibis, Cinnamon Bittern, Black Bittern, Yellow Bittern, etc which are mainly dependent on fish, insects and other invertebrates. This lake in urban location is surrounded by buildings and as the water parameters indicate the lower pH, DO and higher COD, NO_3 $N0_2$, NH_3, PO_4, total alkalinity, total hardness and salinity of water collected from Madhavaram compared to Kumizhi are all indicative of poor water quality with higher organic matter. However, the Madhavaram lake with higher organic matter is able to harbor more fish, planktons, benthos which in turn available to feed the 86 bird species (68 common plus 18 unique species). This shows the low species diversity at Madhavaram lake compared to that of Kumizhi lake mainly because of urbanization.

Table 2: Bird species observed at Kumizhi and Madhavaram lake

Sl. No.	Common species at both lakes	Unique species at Kumizhi lake	Unique species at Madhavaram lake
1	Lesser Whistling-Duck	Fulvous Whistling-Duck	Northern Pintail
2	Indian Spot-billed Duck	Black-winged Stilt	Blue-faced Malkoha
3	Indian Peafowl	Yellow-wattled Lapwing	Gray-bellied Cuckoo
4	Gray Francolin	Gray-headed Lapwing	Jerdon's Nightjar
5	Little Grebe	Pheasant-tailed Jacana	Indian Nightjar
6	Rock Pigeon	Common Sandpiper	Eurasian Coot
7	Eurasian Collared-Dove	Yellow Bittern	Indian Thick-knee
8	Spotted Dove	Cinnamon Bittern	Common Snipe
9	Laughing Dove	Black Bittern	Pin-tailed Snipe
10	Greater Coucal	Glossy Ibis	Green Sandpiper
11	Pied Cuckoo	Eurasian Spoonbill	Whiskered Tern
12	Asian Koel	Black Kite	Indian Cormorant
13	Common Hawk-Cuckoo	Eurasian Hoopoe	Black-headed Ibis
14	Asian Palm Swift	Black-headed Cuckoo shrike	Osprey

15	Eurasian Moorhen	Yellow-eyed Babbler	Black-winged Kite
16	Gray-headed Swamphen	Indian Pied Starling	Oriental Honey-buzzard
17	White-breasted Waterhen	Red Avadavat	Short-toed Snake-Eagle
18	Red-wattled Lapwing	House Sparrow	Eurasian Kestrel
19	Greater Painted-Snipe		Indian Pitta
20	Bronze-winged Jacana		Ashy Wood swallow
21	Asian Openbill		Common Wood shrike
22	Painted Stork		Common Iora
23	Oriental Darter		Ashy Drongo
24	Little Cormorant		Bay-backed Shrike
25	Spot-billed Pelican		Long-tailed Shrike
26	Gray Heron		Jerdon's Bushlark
27	Purple Heron		Jungle Prinia
28	Great Egret		Sitting Cisticola
29	Intermediate Egret		Booted Warbler
30	Little Egret		Red-romped Swallow
31	Cattle Egret		Red-whiskered Bulbul
32	Indian Pond-Heron		White-browed Bulbul
33	Black-crowned Night-Heron		Lesser Whitethroat
34	Indian Spotted Eagle		Tawny-bellied Babbler
35	Shikra		Brahminy Starling
36	Barn Owl		Orange-headed Thrush
37	Spotted Owlet		Indian Robin
38	Common Kingfisher		Blue-throated Flycatcher
39	White-throated Kingfisher		Pied Bush chat
40	Pied Kingfisher		Pale-billed Flowerpecker
41	Asian Green Bee-eater		Thick-billed/Pale-billed Flowerpecker
42	Blue-tailed Bee-eater		Loten's Sunbird
43	Indian Roller		Baya Weaver
45	Coppersmith Barbet		Indian Silverbell
46	Black-romped Flame back		White-romped Munia
47	Rose-ringed Parakeet		Western Yellow Wagtail
48	Indian Golden Oriole		White-browed Wagtail
49	Black Drongo		
50	Indian Paradise-Flycatcher		
51	Brown Shrike		
52	Rufous Treepie		
53	House Crow		
54	Large-billed Crow		
55	Common Tailorbird		
56	Ashy Prinia		
57	Plain Prinia		
58	Blyth's Reed Warbler		
59	Barn Swallow		
60	swallow sp.		
61	Red-vented Bulbul		
62	Yellow-billed Babbler		
63	Common Myna		
64	Asian Brown Flycatcher		
65	Oriental Magpie-Robin		
66	Purple-romped Sunbird		
67	Purple Sunbird		
68	Scaly-breasted Munia		
69	Tricolored Munia		

Conclusions

Results of the study indicated more pollution and higher organic content in the urban located Madhavaram lake compared to Kumizhi lake located in the scrub jungle habitat. The avifauna recorded in these locations showed variation in species diversity. The Madhavaram lake though polluted, by virtue of its high organic content harboured fish, insects and planktons which formed a good food source for the avifauna especially waders. On the other hand, the bird species found at Kumizhi were dependent on the scrub jungle habitat harbouring flower and fruit bearing trees.

References

1. Amadi AN, Olasehinde PI, Okosun EA and Yisa J. Assessment of the water quality index of Otamiri and Oramiriukwa Rivers. Physics International 2010;1(2):116-123.
2. APHA. Standard Methods of Water and Wastewater. 21st Edn., American Public Health Association, Washington, DC., ISBN: 0875530478, 2005;pp: 2-61.
3. Gana AJ, Okunola AA and Ayomide SO. Determination of the biological oxygen demand (bod) and chemical oxygen demand (cod) of liquid waste generated from

landmark university student's cafeteria. *Sub-Sahara* African Academic Research Publications. 2022;23(9):2418-9325.
4. Ganesan S and Sultana M. A base line study of physico-chemical parameters and some trace metals in water of Chrompet lake, Chennai, India. Journal of Aquatic Biology. 2009;24(2)131-141.
5. Garg J and Garg HK. Impact of agricultural nutrients on algal diversity. In National Symposium on Biodiversity. 1997, 10.
6. Kistan A, Kanchana V, Ansari AT. Analysis of Ambattur Lake water quality with reference to physic-chemical aspects at Chennai, Tamil Nadu. Int. J Sci. Res. 2015;5(5)944-947.
7. Noble AC and Summerfelt ST. Diseases encountered in rainbow trout cultured in recirculating systems. Annual Review of Fish Diseases, 1996;6:65-92.
8. Raji PK and Abraham M. Comparative study of water quality of different lakes in Chennai. Rasāyan Journal of Chemistry. 2018;11(2)828-833.
9. Report. Environmental Protection Agency, Ireland 'Parameters of Water Quality- Interpretations and Standards (link), c2011.
10. Report. World Health Organization guidelines for drinking-water quality: incorporating the first and second addenda (link), c2022.
11. Wang WN, Wang AL, Chen L, Liu Y, Sun RY. Effects of pH on survival, phosphorus concentration, Adenylate Energy Charge and Na+–K+ ATPase activities of Penaeus chinensis Osbeck Juveniles. Aquatic toxicology. 2002;60(1-2):75-83.
12. Wilczak A, Jacangelo JG, Marcinko JP, Odell LH and Kirmeyer GJ. Occurrence of nitrification in chloraminated distribution systems. Journal- American Water Works Association. 1996;88(7):74-85.
13. Williams WD and Sherwood JE. Definition and measurement of salinity in salt lakes. *International* Journal of Salt Lake Research, 1994;3(1):53-63.
14. Wurts WA. Alkalinity and hardness in production ponds. World Aquaculture-Baton Rouge. 2002;33(1):16-17.