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Impact of Anthropogenic Activities on Vandiyur Lake: An Ecological and Chemical Analysis

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ABSTRACT: This study investigates the environmental and ecological health of Vandiyur Lake in Madurai City, Tamil Nadu, India. GIS mapping reveals the lake's proximity to residential and commercial areas, contributing to pollution from various sources, including domestic, hospital, and industrial sewage. Chemical analysis shows alterations in the lake's pH, dissolved oxygen, CO_2, and phosphate levels. The lake also suffers from the overgrowth of the invasive species *Eichhornia crassipes*. Despite these challenges, the lake serves as a crucial source of groundwater and supports local fishing activities. The study underscores the urgent need for sustainable management practices to preserve this vital ecosystem.

KEY WORDS: Environmental Health, Sustainable Management, Urban Pollution, Vandiyur Lake, Water quality.

INTRODUCTION

Urban lakes and water bodies constitute integral features of urban landscapes, particularly in densely populated areas. Examining these water bodies is paramount for several reasons. Firstly, they serve as vital sources of drinking water for local communities, necessitating a thorough understanding of their quality and health to ensure a continuous and safe water supply. Additionally, these water bodies contribute significantly to hydrological balance by storing and releasing water, thereby mitigating the impact of severe conditions like droughts and floods. Moreover, urban lakes exert influence over the microclimate of their surroundings, moderating temperature, increasing humidity, and providing cooling effects. Beyond their functional aspects, these water bodies enhance the aesthetic appeal of urban environments and offer recreational opportunities such as boating, fishing, and birdwatching. However, anthropogenic activities pose significant threats to urban lakes. Urbanization leads to increased pollutant discharge into these water bodies, including industrial effluents, sewage, and agricultural runoff, resulting in pollution and eutrophication. Improper land use practices contribute to sedimentation, habitat loss, and encroachment, further exacerbating ecological degradation. Additionally, the introduction of invasive species and the impacts of climate change compound these challenges. Studying and conserving urban lakes are imperative for sustainable urban development, ensuring water availability, and preserving healthy ecosystems [1-3].

Madurai, an ancient city in Tamil Nadu, India, grapples with rapid urbanization and escalating real estate pressures, endangering its water bodies, notably urban lakes, threatened by pollution and encroachment. These lakes are critical freshwater reservoirs, vital for drinking water, sustaining aquatic ecosystems, and flood control. As Madurai's urban sprawl encroaches upon agricultural lands, the delicate equilibrium between water systems and urban development teeters. Studying these lakes becomes paramount to safeguarding water quality, preserving biodiversity, and maintaining ecological balance, ensuring sustainable urban growth and the well-being of both the city and its inhabitants. One such vital water body is Vandiyur Lake, nestled near K.K Nagar, serving as a serene haven just kilometres away from bustling city centres.

The present study was conducted to address multiple Sustainable Development Goals (SDGs) through a comprehensive assessment of Vandiyur Lake. The objective of the assessment was to identify and access adverse environmental impacts associated with the lake, particularly in urban areas to contributing to SDG 11: Sustainable Cities and Communities. A second step was to analyse the chemical parameters of the lake and its water quality, which aligns with SDG 6: Clean Water and Sanitation. Additionally, the study sought to identify and characterize pollution sources in the lake, contributing to SDG 14: Life Below Water, which focuses on preventing and reducing marine pollution. A further benefit of the study is that it indirectly supports SDG 15: Life on Land, especially Target 15.3, by recognizing the interconnectedness between lake ecosystem health and surrounding land, thus aiming for a land degradation-neutral world.

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MATERIALS AND METHODS

The study site, Vandiyur lake, Madurai was mapped using ArcGIS software [4]. The maps produced were used to analyse the size and perimeter of the lake, the depth of the lake, entry sites of sewage channels, other water channels and drinking water bores.
The lake is large and the accessible sites were few. Among these the most easily accessible three locations were identified and water samples were collected and analysed form there. The following parameter were analysed for the water samples – pH, dissolved oxygen, dissolved carbon dioxide, free phosphates and total dissolved solids (TDS) [5]. Regular visits and discussions with the local residents provided evidence for human activities in and around the lake. Photographs were taken as proof.

RESULT AND DISCUSSION

Vandiyur Lake, situated at coordinates 9.92°N and 78.11°E, serves as a significant water body in Madurai, Tamil Nadu, India. Despite not directly receiving water from the Vaigai River basin, surplus water from the lake contributes to the Vaigai River. The results are discussed under four main parameters: a) GIS mapping, b) Anthropogenic activities in and around the lake c) Chemical analysis of the water .

GIS Mapping:

To enhance understanding of the study site and acquire site-specific data, ArcGIS, a GIS software [4], was employed to generate the following maps.
The first map (Map No.1) illustrates the drainage patterns of water bodies into Vandiyur Lake. Despite not receiving water directly from the Vaigai river basin, surplus water from the lake contributes to the Vaigai River. The lake is replenished by water from the Sathiyar Dam originating from the upper catchment area, as well as surplus from the Sambakulam tank, Parasurampatti tank, and S. Kodikulam tank, flowing through the Parasurampatti Surplus channel. However, the Managiri surplus channel, previously carrying water from the Athikulam tank, Kosakulam tank, and Thallakulam tank, has been closed [6,7]. Vandiyur Lake itself is highlighted in red. The map encompasses all water bodies within a 5 km radius of the lake, many of which are historic irrigation tanks constructed by past rulers. These tanks serve the dual purpose of holding runoff and excess rainwater while also contributing to the recharge of the groundwater table. Madurai depends on the monsoons for water. The ancient kings built many tanks and ponds to store the rainwater. These are all interconnected by irrigation channels which enabled cultivation of crops all year round. Over the centuries these artificial water storage sites have become a wetland ecosystem unto themselves. The support a large number of resident and migratory bird populations as well as other wildlife. The ecosystem thrives as much as the urban human population around it.
The second map (Map No.2) depicts the area of Vandiyur Lake. The lake spans an area of 551.72 acres, with a bund length of 2077 meters. Its free catchment area measures 10.24 sq. km, while the combined area encompasses 96.89 sq. km. Equipped with three sluices, the lake boasts a capacity of 107.03 mc ft. and can discharge a maximum flood flow of 4059 cusecs. Notably, Vandiyur Lake serves as a primary source of groundwater for bore wells situated in its vicinity. The third map (Map No.3) shows Vandiyur Lake surrounded by many hospitals, houses, apartments, markets and industries that discharge their waste into it. Sewage from the flower and fruit market also makes its way into the lake (Map No. 4). Water from the lake is used for drinking purpose by the local residents and the corporation. Regular fishing is also done in the lake and fishermen sell fresh fish on the banks of the lake. Sampling activities were conducted at three distinct locations along the perimeter of Vandiyur Lake:

- Location – 1 (L1) (9°55'42.88"N, 78°09'26.70"E) is proximate to a school, petrol bunk, gas filling unit, and several prominent hospitals.
- Location – 2 (L2) (9°55'58.63"N, 78°09'55.18"E) is encompassed by individual housing units.
- Location – 3 (L3) (9°56'10.59"N, 78°09'57.31"E) hosts numerous apartment complexes and marriage halls, all of which experience constant activity.

A section of the lake's bank is cordoned off by a fence, rendering it inaccessible as it forms part of Sundaram Park. Notably, the stretch from K.K Nagar to Vandiyur Lake is bordered by ten prominent hospitals. Along the bank, between 78°09'57.68"E and 78°09'49.7"E, the Madurai Corporation has established a partial containment facility, serving as a quarantine pond for hospital waste.
Map No. 5 shows the number of bore wells drilled by the corporation on the banks of the lake. This is a point of concern as there is entry of sewage into the lake too and no Waste water treatment plant (WWTP) in sight. The water is pumped into plastic tanks and

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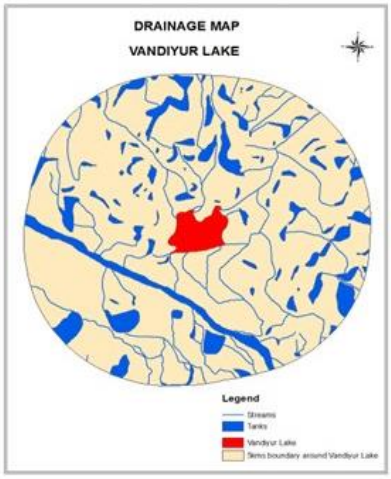
then loaded into tanker lorries and distributed. The people buying this water have no idea from where it is come. The plastic tanks are also not cleaned on a regular basis and the water is dirty at the best. Residents also complain of the tanks being left uncovered and dust accumulating here.

The depth of the lake is the most at its South-Western point (Map No.6). The maximum depth of the lake is measured to be between 132 to 134 meters deep. This part may have remined untouched by human activity but could serve as a collection point for the debris dumped in the lake. There would be natural water currents in the lake and movement of water would be thereby facilitated. Natural water currents allow circulation of plankton, food and nutrients in the aquatic ecosystem.

Map No. 1: Drainage map of Vandiyur Lake



Map No. 2: Area of Vandiyur lake

Map No 3: Sample points and surrounding settlements

Map No 4: Entry and Exit points of sewage channels

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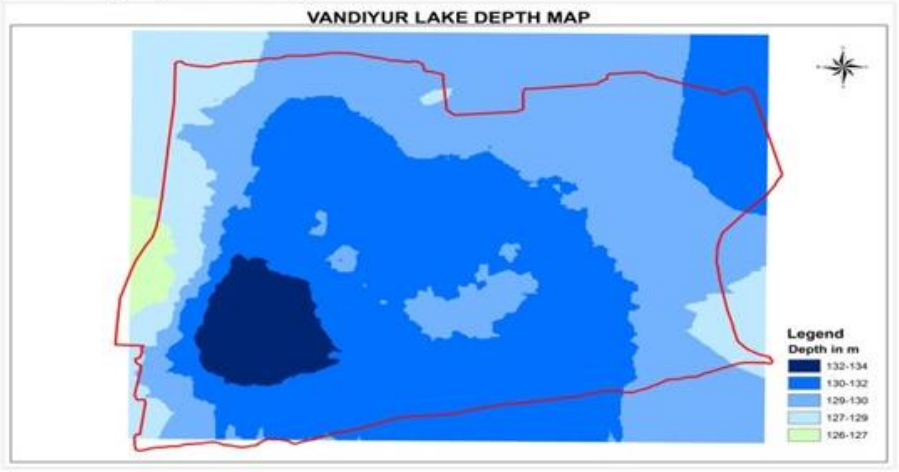
Map No 5: Location of borewells near sampling point 3

Map No 6: Deepest points of Vandiyur lake



Map No 7: Vegetation around Vandiyur lake

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There is surplus vegetation around the lake as shown in Map. No. 7. The largest cluster of vegetation is to the North-West of the lake. This also being done away so as to create more residential space. Fewer people prefer individual houses today and so more apartments and complexes are making their way here. This would mean fewer trees and more domestic sewage dumped into the lake as it the closest water body. It also means that more bore wells will be dug around the lake and larger number of people will consume this water.

2. Anthropogenic activities in and around the lake:

During the period of study, the following activities were observed around the lake and photographed for evidence. These activities have a direct bearing on the aquatic ecosystem of the lake and wildlife related to it.

a) Fishing and Aquaculture in the lake:

Regular fishing takes place in the lake and there are large number of local residents who prefer to buy this fresh fish. As few of the most bought species of fish are listed below (Table no.1). All the fish species have greater economic value. Some of the fish are considered aquarium species and others are food. Most of these species are able to survive in the polluted lake as they are uniquely adapted.

Table No. 1 : List of Fish species on sale, caught from Vandiyur lake. [6,8]

S. No.	Common Name	Scientific name	Status in the lake
1.	Nile Tilapia	*Oreochromis mossambicus*	Introduced
2.	Snake head	*Channa striatus*	Introduced
3.	Amazon sailfin catfish	*Pterycoplichthys pardali*	Introduced
4.	Spotted murrell	*Channa punctatus*	Native
5.	Indian glassy perch	*Parambassis ranga*	Native
6.	One spot barb	*Puntius terio*	Native
7.	Rohu	*Labeo rohita*	Introduced
8.	Mirghal	*Cirrhinus cirrhosus*	Introduced
9.	Glass carp	*Ctenopharyngodon idella*	Introduced
10.	Indian Carp	*Catla catla*	Introduced
11.	Dwarf Gourami	*Trichogaster lalius*	Native
12.	Gangetic tank goby	*Glossogobius giuris*	Introduced
13.	Pool barb	*Puntius sophore*	Native

The lake was listed among the ponds and lake that were leased out for aquaculture by the ministry of fisheries TN. In a bid to promote inland or freshwater aquaculture the government had started to lease out large waterbodies. It is quite viable for the farmer; all they do is thrown in the fingerlings and come back to harvest the adult fish. The fish feed off the lake and this saves the farmer a huge feed bill. The government has also promoted hardy but non-native varieties of fish like Nile Tilapia and Snake heads.

The presence of Amazon sailfin catfish in the lake is also of concern, It has been reported that aquarium enthusiasts buy these exotic species as pets, when they find they have out grown the tanks at home, they are dumped into the local water bodies. This is just a preliminary survey of the fish species and studies are being done to understand how these fish react to the pollutants in the lake.

It is with great concern we report that the fish market is thriving along the banks of the lake. People from surrounding residential complexes and areas throng to buy the fish, without care of where they grew and what they consumed. The concept of biomagnification of pollutants is lost or unheard off. Most respondents to our queries shrugged of the idea of contamination

b) Dumping of tablets on the banks of the lake:

Dumping of tablets on the shore and in lake seems to be a regular practice (Photo No.2.3). Unused bottles of tables were disposed on the banks of the lake in the month of July after the study started and remained there till the study was completed. The tablets were washed into the lake during the monsoon rain and presumably dissolved in the water. On closer inspection it was noted that the tablets had crossed expiry date.

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Anthropogenic activities : 1. Fishing in the lake, 2. selling of fish on the banks of the lake, 3. Tablets dumped on the lake bund, 4. Sewage channels from SIDCO and flower market choked with plastic and other debris,

5. Area isolated for hospital sewage by the Madurai Corporation work underway.

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This seems to be a common practice in Tamil Nadu, a similar matter was reported in Chennai [9] in November 2019 where the pharmaceutical company dumped the expired drugs on the roadside. The Tamil Nadu Drugs Control Department had then instructed all its assistant directors in the State to ensure that pharmaceutical manufacturers adhere to rules for safe disposal of expired drugs. These guidelines and rules are also applicable to corporate of private hospital administrations. Administrators must take steps to monitor if rules and regulations are being followed by the ground staff.

An article in the Times of India (2011) stated that based on recommendations of a high-level panel for amendments to the Drugs and Cosmetics Act, the Tamil Nadu government had instructed Pharmaceutical companies, Drug stores and hospitals that unsold medicines were to be disposed of properly with 15 days of the date of expiry of the drug. Drug inspectors were to be empowered to cancel trade licenses of the irresponsible establishment [10].Years later the same is happening unchecked. This can cause harm to the environment.

Accumulation of drugs can happen in the ecosystem and the chemicals can enter the food chain and intime lead to biomagnification too. It is not only pesticides that are harmful. Synthetic chemical molecules used as drugs can be broken down to harmful molecules in the environment. A study done in lake Michigan for signs of pharmaceuticals in the water showed surprisingly the presence metformin, a diabetes drug in huge quantities. The study also showed that that metformin could be having a feminising effect on male fish, and may decrease their ability to reproduce [11]. Lake Michigan is far from being an isolated case. A 2014 global review of pharmaceuticals in the environment, commissioned by Germany's environment ministry, found that of the 713 pharmaceuticals tested for, 631 were found above their detection limits. They are found all over the world — in 71 countries across all of the United Nations' five regional groups. They were found mainly in surface waters, such as lakes and rivers, but also in groundwater, soil, manure and even drinking water. Scientists are studying the effect of these drugs on ecosystems, and are trying to find ways of preventing the problem, for example by the correct disposal of unwanted medicines, improving the treatment of sewage and, ultimately, designing more environmentally friendly drugs [12]. We probably have an incomplete picture of the problem, however, because we don't have detection methods for all of the thousands of pharmaceuticals in use around the world, and the analytical methods are not standardized internationally, so detection limits may vary. Some drugs are worse than others because of their potential to affect wildlife or people. They include antibiotics, antidepressants, anti-inflammatories and analgesics, beta-blockers, oral contraceptives and hormone replacement therapies. Not many such studies have been done in India and none in this study area. Further studies on this are needed in Vandiyur lake regarding the pharmaceuticals found in the lake, their entry into the food chain and their effect on organisms, flora and fauna alike.

c) Open defecation on the banks of the lake:

Although the Indian government has been campaigning against the practise of open defecation it still persists in the area. Madurai is now considered a 'tire two' city and to see such practises are disheartening. The practise is along the banks of the lake and the faecal matter does contaminate the lake. The government has built a rough path for exercise enthusiasts and because of this problem and no regular upkeep the path is not used as it was envisioned. Sadly, news reports are misleading about the city having declared it a 'NO' open defecation zone [13, 14].

d) Sewage channels ending in the lake:

Domestic, hospital and industrial sewage still enters the lake untreated and uncontrolled. The photos (Photo No.2.4) show the entry of sewage through government authorized channels from SIDCO into the lake. The channels have not been cleaned in years and are clogged with plastic waste. The SIDCO industrial estate in Madurai, is the second largest Industrial Estate in Tamil Nadu with a total area of 550 acres and above 85 units of Industries functioning. SIDCO is said to give employment to above 14000workers as the available data on the Madurai corporation website on date [15]. SIDCO comprises rubber manufacturing unit, wood-manufacturing unit (TANSI), steel component – chemical processing units, engineering industries, plastic processing units, Carton paper box manufacturing units and few textile units [16]. Many of these industries use heavy metals and other harsh chemicals in their working and the untreated effluent has been dumped in Vandiyur lake for decades. Sewage from industries pollutes water with toxic materials, which is highly poisonous to aquatic lives. A few studies have been done on industrial effluents in the lake [6,7,16]. There are unauthorized channels to dump domestic sewage too in the lake (Photo No. 2.4). Domestic sewage consists of both organic and inorganic constituents like metal ions, nitrates, ammonia, faecal matter, paper, cloth fibres, bacteria, large amounts of detergents and alkalis. All of this is dumped into the lake. Suspended impurities mainly consist of sand and clay. Being rich in biodegradable or organic matter, domestic sewage stimulates microbial growth for the decomposition process to occur. This increases biochemical

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oxygen demand of water and stimulating mineral pollution or eutrophication. It imparts bad colour and odour to the water body and also paves way for waterborne diseases [17].

Photo No. 2.5 shows the area roped off by the Madurai Corporation to collect the sewage form the surrounding hospitals. Sewage from hospitals may contain pathogenic bacteria which could lead to outbreak of diseases [18]. Hospital effluents have been confirmed to be sources of metal, antibiotic resistant genes and bacterial markers in other countries [19]. It must be noted that the block is temporary and during the monsoons when water is more there is mixing of the water. The sludge gate can also be opened if needed. There are no scientific studies of this kind done in this area so far.

e) Abundant weeds:

The lake is clogged with over growth of the invasive species *Eichhornia crassipes*, Water hyacinth. This fast-growing invasive weed covers the water body, resulting in poor water transparency. It competes with other aquatic (floating and submerged) plants and algae for mineral nutrition, sunlight, resources, etc. thereby inhibiting the growth of other aquatic and algal organisms [20 - 23].

Over growth Water hyacinth in Vandiyur lake happens every year and during the study period the lake was partially cleaned by the Madurai Corporation and environmental activists. Despite all efforts to control the weed it flourishes. A newspaper article quotes the PWD Superintending Engineer criticizing the outpouring of domestic sewage in the said lake as a cause for the overgrowth of the weed [24].

Chemical Analysis:

Analysing water quality is crucial for preserving and protecting natural ecosystems. Water quality is a vital concern for humanity as it directly impacts human welfare [25].

pH: The pH of Vandiyur Lake remained constant at 9 across all three locations throughout the study period. Despite the basic nature of this pH level, which is at the higher end of the optimal range for aquatic organisms, the lake supports a large number of aquatic organisms [6,7]

Dissolved Oxygen (DO): DO levels remain relatively low from July to December, with values below 5 mg/L across all locations. However, there is a significant increase in January, reaching 28.6 mg/L at L-1 and 19.3 mg/L at L-3, while L-2 shows a modest increase to 2.688 mg/L (Figure No.1). The sudden spike in DO in January is likely due to excessive rainfall and the influx of freshwater, which introduces more oxygen into the lake [26].

Dissolved Carbon Dioxide: levels fluctuated throughout the study period, with the highest concentration observed in October at L-2 (52.8 mg/L). In other months, levels vary, generally staying between 22 mg/L to 37.4 mg/L at L-1 and L-2, while L-3 shows a slight decrease in January to 3.072 mg/L (Figure no. 2). The peak in October at L-2 suggests increased respiration and decomposition of organic matter, which releases carbon dioxide. Lower levels in January may be due to dilution from rainfall [27].

Phosphates: Phosphate levels are highest at L-2, peaking at 0.5678 mg/L in October. L-1 and L-3 show lower and relatively stable phosphate levels throughout the study period, with minor fluctuations (Figure no. 3). The elevated phosphate levels at L-2 are likely due to household activities such as the usage of detergents to wash clothes, vessels etc. This introduces phosphates into the lake via the sewage channels. The lower and stable levels at L-1 and L-3 could be due to less domestic runoff [28,29].

Total Dissolved Solids (TDS): TDS levels vary significantly across different locations and months (Figure no. 4). The dramatic increase in TDS at L-3 during October and November suggests a significant influx of dissolved solids, possibly due to increased runoff, pollution, or other anthropogenic activities. The levels at L-3 are significantly higher compared to L-1 and L-2, indicating localized sources of pollution or specific environmental conditions at L-3. The high TDS levels at L-3 in October and November are a cause for concern, as they could impact water quality and usability. Continuous monitoring and pollution control measures are essential to manage TDS levels and maintain the lake's health [28,29].

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Fig. No 1: Comparison of level of Dissolved oxygen (DO) during the period of study

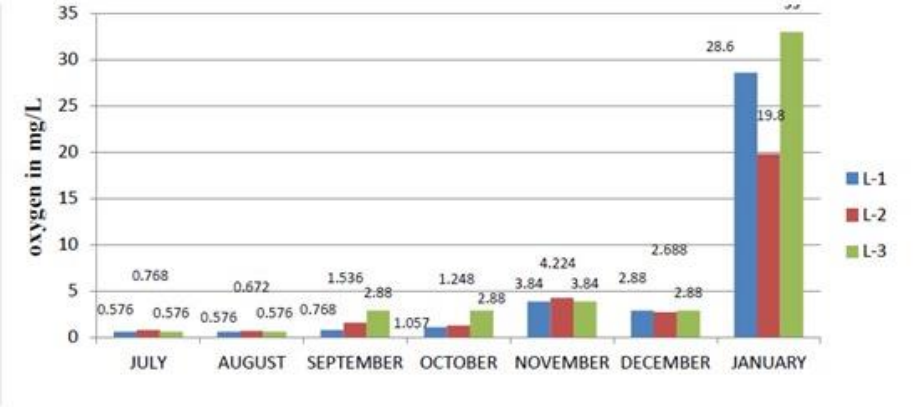

Fig. No 2: Comparison of level of Dissolved Carbon dioxide (DCO2) during the period of study

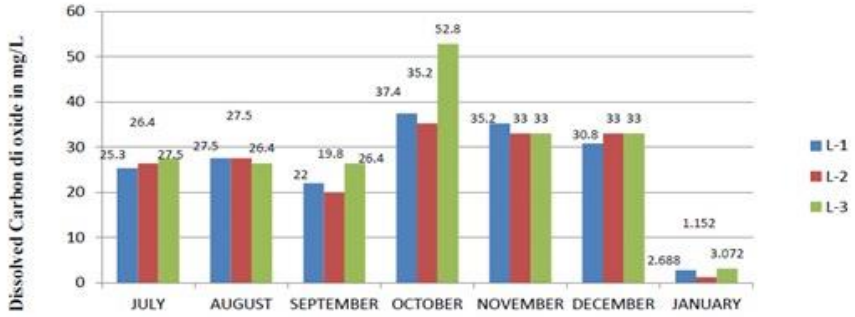

Fig. No 3: Comparison of level of Dissolved Phosphates during the period of study

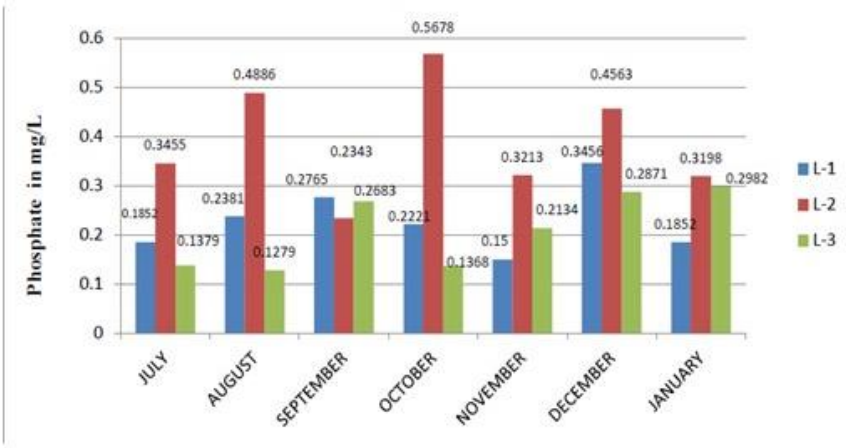

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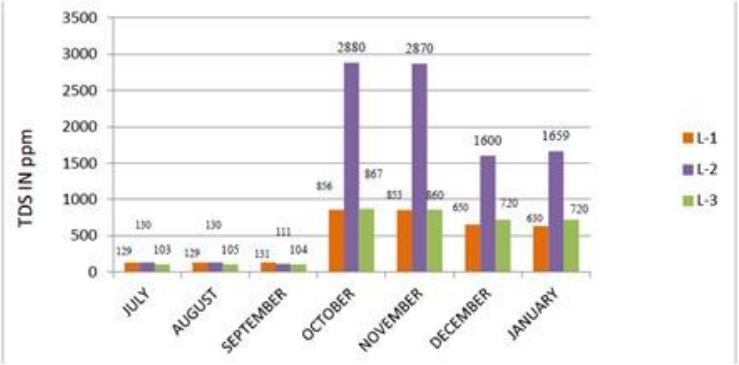
Fig. No 4: Comparison of level of Total dissolved solids (TDS) during the period of study



CONCLUSION

This comprehensive study on Vandiyur Lake in Madurai City reveals significant anthropogenic influences impacting the lake's environmental and ecological health. The lake, surrounded by residential complexes, hospitals, and commercial establishments, is subjected to various pollution sources, including domestic, hospital, and industrial sewage. The chemical analysis indicates alterations in the lake's pH, dissolved oxygen, CO_2, and phosphate levels, suggesting the presence of pollutants. The proliferation of the invasive species *Eichhornia crassipes* further exacerbates the lake's ecological balance. Despite these challenges, the lake remains a crucial resource, providing groundwater and supporting local fishing activities. The study underscores the urgent need for sustainable management practices to preserve this vital ecosystem. It also highlights the importance of regular monitoring and remediation efforts to mitigate the impacts of pollution. The findings align with several Sustainable Development Goals, emphasizing the need for clean water, sustainable cities, and the preservation of life below water and on land. This research serves as a call to action for policymakers, conservationists, and the local community to work together towards the sustainable management of Vandiyur Lake.

Conflict of Interest: None.

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Author Contributions:

- Marie Serena McConnell: Conceptualization, Design, Experiments, Analysis of data and Writing of the paper.
- P. Meenakshi: Survey, Collection of samples, Photographs and Experiments

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