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Assessment of Spatial Variations in Water Quality and Environmental Impacts on Freshwater Ecosystems: A Case Study of Lakes Around Puducherry

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Abstract

This study examines the water quality of Kanagan Lake, Osuteri Lake, and the Chunnambar River to evaluate environmental changes and their significance to Puducherry's ecosystem. A multidisciplinary approach was employed to assess key water quality parameters, including pH, dissolved oxygen, nutrient levels, and pollutant concentrations, providing a comprehensive understanding of the ecological health of these water bodies. The analysis revealed significant spatial variations in water quality across the sites, driven by anthropogenic activities, climate change, and natural processes. The results demonstrate that these water bodies play a vital role in sustaining Puducherry's environment and socio-economic framework. They provide freshwater for agriculture, aquaculture, and drinking water, serving as lifelines for local communities. However, the study highlights the growing threats to these resources from urbanization, industrial discharges, and inadequate waste management practices, which are accelerating degradation. By identifying critical factors influencing water quality, this research emphasizes the importance of integrating science-based strategies with sustainable management practices. Conservation efforts should prioritize reducing pollution, promoting community participation, and implementing effective policies to mitigate the impact of human activities on these ecosystems. The findings also underscore the role of climate change in exacerbating water quality issues, urging the need for adaptive measures to enhance resilience. This comprehensive analysis contributes to understanding the environmental patterns in these aquatic systems, providing valuable insights for policymakers and stakeholders. The study highlights the necessity of preserving these water bodies for Puducherry's long-term ecological balance and socio-economic development. By forming the foundation for future conservation initiatives, it underscores the critical importance of sustainable management practices to safeguard these water resources and their benefits for future generations.

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Keywords: Water quality, environmental changes, Kanagan Lake, Osuteri Lake, Chunnambar River, Puducherry ecosystem, pollution assessment, climate change impact, sustainable water management

INTRODUCTION

Osuteri Lake is located in Tamil Nadu's Puducherry Union. This lake, which is situated near the settlement of Ossudu, is also known as Ossudu Lake. The lake is 800 ha in size, with 390 ha located in Puducherry and the remaining portion in Tamil Nadu. It is the largest lake [1]. Human-caused Osuteri Lake is regarded as one of Asia's most significant wetlands. This lake is home to a variety

of migratory bird species all year round, which is why it is designated as an Important Bird Area (IBA) [2]. The Osuteri wetlands in Puducherry were designated as a bird sanctuary in 2008 [3], while the wetlands in Tamil Nadu were designated as such in 2015 [4]. One of Puducherry's most popular tourist destinations is the lake. In the lake, the Puducherry Tourism Department Corporation established a small boat club for visitors. The Puducherry government put forward the idea of establishing Osuteri as a national park. Observing the birds and developing the area as an ecotourism destination, it has also been suggested that telescopes be installed.

For the people of Puducherry, Kanakan Lake, a crucial freshwater resource, is aesthetically pleasing and useful. However, the lake suffers from serious environmental problems because of the ongoing release of untreated sewage and industrial waste. Although the lake's state has somewhat improved because of the Puducherry Tourism Department's intervention through reformative methods, these efforts are insufficient. More all-encompassing solutions are needed to guarantee the long-term preservation of the lake, including strong conservation plans and new laws. Analyzing the lake's water quality in comparison to data from prior years offers important insights into how this important body of water is changing, enabling the monitoring of changes and evaluation of the success of conservation initiatives.

The Sankaraparani River flows through Tamil Nadu in southern India, with its source on the western slopes of the Gingee Hills in the Viluppuram District. The river is 78.5 kilometers long and runs south-east, with 34 km passing through Puducherry. The river continues its voyage for the last 2-kilometer stretch before hitting the Bay of Bengal at Paradise Beach. After receiving its last tributary, the Guduvaiyar River, also known as the Chunnambar. In a clearer, more fluid narrative format, this succinct statement maintains all the important geographic measures and data.

Study Area

Samples were collected from Kanagan Lake, which is situated in Kathirkamam, Osuteri Lake situated in Ossudu village, and Chunnambar River situated in Nonankuppam, 8 km from Puducherry. The location of the study area is shown in Figures 1–3.

METHODS OF PREPARATION

Calcium

Owing to the high pH in this procedure, titration should be performed immediately after adding the alkali and indicator. Using 50 ml of the sample or a smaller portion diluted to 50 ml, the calcium content was approximately 5–10 mg. For hard waters with alkalinity greater than 300 mg/l $CaCO_3$, a smaller aliquot was used, diluted to 50 ml, neutralized with acid, boiled for one minute, and cooled before starting the titration. Add 20 ml of sodium hydroxide solution (sufficient to achieve a pH of 12–13). Stir the mixture, then add 0.1 to 0.2 g of the murexide-sodium chloride mixture (or 1 to 2 drops if using a solution). Alternatively, 1 g of a Patton and Reeder's reagent mixture with sodium sulfate or potassium sulfate was used. The EDTA titrant was slowly added with continuous stirring until the proper endpoint was reached. The endpoint was confirmed by adding 1 to 2 drops of titrant in excess to ensure that no further color change occurred (Figure 4).

Chloride

The Mercuric Nitrate Method was used. Because soluble, slightly dissociated mercuric chloride is formed, it can be titrated with mercuric nitrate. By forming a purple compound with excess mercuric ions, diphenyl carbazone signals the endpoint in the pH range of 2.3 to 2.8. Utilize a sample fraction that will reach the endpoint with fewer than five milliliters of the titrant. Pour the mixture into a 1 ml beaker and then pour in about five milliliters of the combined indicator reagent and well mix. Purple is an appropriate color. Nitric acid (0.1 N) was added dropwise until the color turned yellow. Titrate the initial permanent dark purple color using 0141 N mercuric nitrate. The same process is used to titrate a blank of distilled water Figure 5 [5–7].

Figure 1. Kanagan Lake.

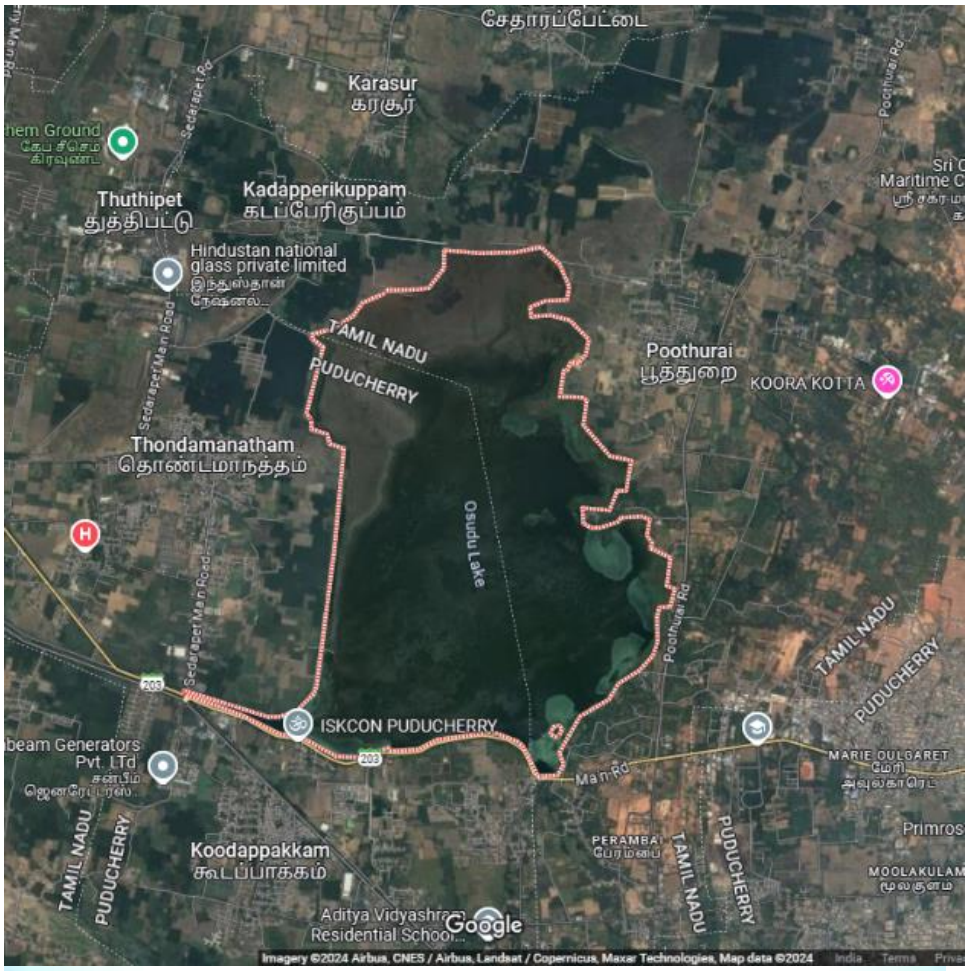

Figure 2. Osuteri Lake.

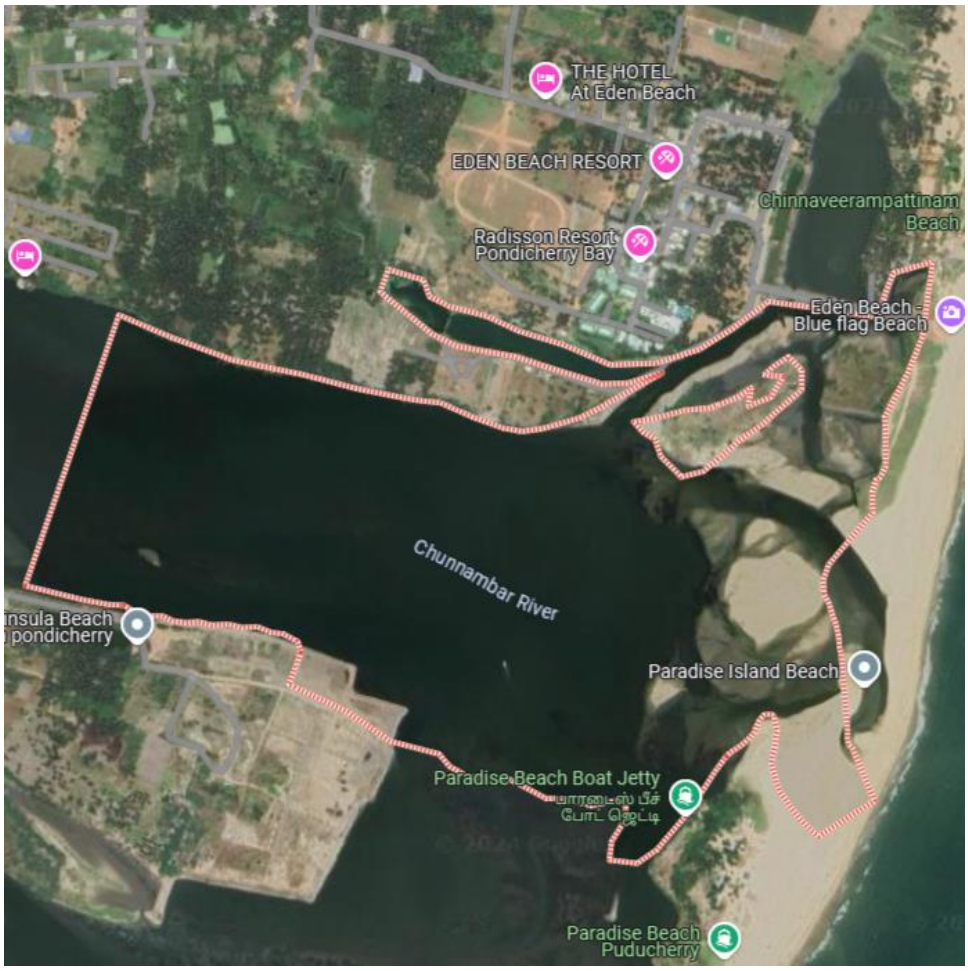

Figure 3. Chunnambar Lake.

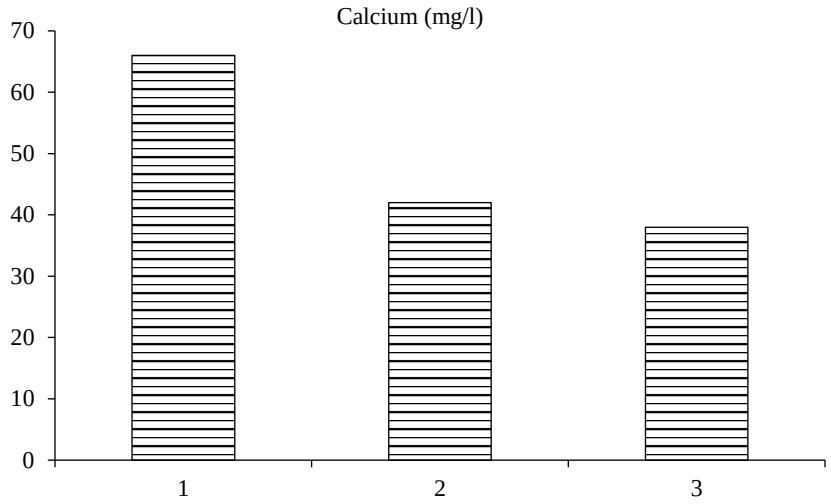

Figure 4. Graph interpretation of calcium content values taken from different regions of Puducherry.

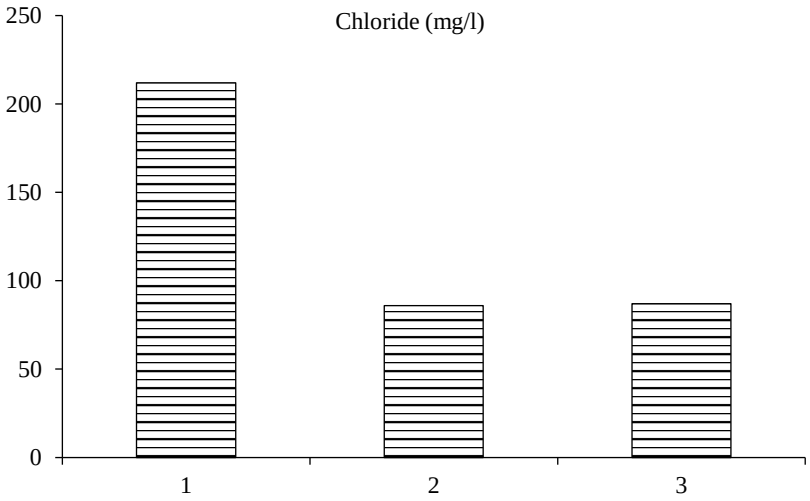

Figure 5. Graph interpretation of chloride content values taken from different regions of Puducherry.

Iron

The iron content was determined using the atomic absorption method. In contrast to total recoverable iron, which needs HNO_3–H_2SO_4 digestion prior to aspiration, dissolved iron can be measured by aspirating filtered samples straight into the atomizer. Depending on the sensitivity of the instrument, the operating range of the procedure can vary, although it is usually between 0.1 and 10 mg/l. The standard iron solution was diluted with nitric acid (1 499) to 100 ml in volumetric flasks to create a series of iron standards with concentrations ranging from 0 to 60 µg/l for calibration.

These standards were transferred to 150 ml beakers. Twenty-five milliliters of $CaCl_2$ solution were added to each volumetric flask. A reagent blank was prepared in the same way using ten milliliters of water. The zero reading was adjusted, and the reagent blank was aspirated to start the analysis. The standard solutions were aspirated one after the other and the absorbance measurements at 248.3 nm. A calibration curve was generated, and the absorbance values were plotted against micrograms of Fe per 100 ml final volume. If required, the standard solution volumes were modified, and the curve was confirmed to be linear. It should be noted that the volume increase caused by the addition of $CaCl_2$ solution should be ignored when estimating micrograms of Fe [5].

Magnesium

Two distinct titrations were used in the Volumetric EDTA technique to measure the amount of calcium and magnesium. In the first titration, Eriochrome Black T was used as an indicator to titrate the water sample with EDTA at pH 10 to quantify both calcium and magnesium simultaneously. In the second titration, either Murexide or Patton and Reeder's indicator was titrated with EDTA at pH 12–13 to measure calcium alone. The difference between these two titration measurements can then be used to compute the Mg concentration [5].

Nitrates

Using Deadra's alloy as the reducing agent, the Deadra's Alloy Reduction Method uses hot, alkaline conditions to reduce nitrate and nitrite to ammonia. Nesslerization and acidimetric determination are two methods for quantifying the resultant ammonia, which is obtained by distillation into a boric acid solution. This technique specifically analyzes nitrogen nitrate and nitrite. Starting with dilution with ammonia-free water to 500 ml for samples in which ammonia has not been previously identified by distillation. Sodium hydroxide (6 N) was used to obtain a pH of 9.5 after adding 25 ml of borate buffer. A meter or short-range pH paper was used to confirm the pH. Collect 250–300 ml in a dry receiving flask for the initial distillation and then discard this portion.

In the last step of distillation, ensure that the condenser tip is above the liquid level. Add 1 g of Deadra's alloy to the remaining solution and then add enough distilled water without ammonia to reach a total volume of 350 ml. Fifty milliliters of boric acid absorbent per milligram of anticipated nitrate nitrogen was placed in the receiving flask, and then the condenser end was immersed in the mixture. After bringing the distillation flask to vigorous boiling, the heat was lowered to maintain the distillation rate between 5 and 10 ml per minute until at least 150 ml of distillate was collected. The receiver was lowered until the condenser tip was above the liquid during the last one to two minutes of distillation to clean the condenser. Finally, nesslerization was used to ascertain the ammonia nitrogen concentration [5].

Sulfate

Sulfate levels in surface and groundwater were measured using the Turbidity Method for concentrations ranging from 1 to 40 mg/l; larger concentrations necessitate the proper dilution of the sample. Barium chloride was used to precipitate sulfate ions in a hydrochloric acid medium, producing barium sulfate crystals of uniform size. A nephelometer or transmission photometer (turbidity meter) was used to measure the absorbance of the resulting suspension (Figures 6–8). The measurements were then compared with a standard curve to determine the sulfate concentration [5].

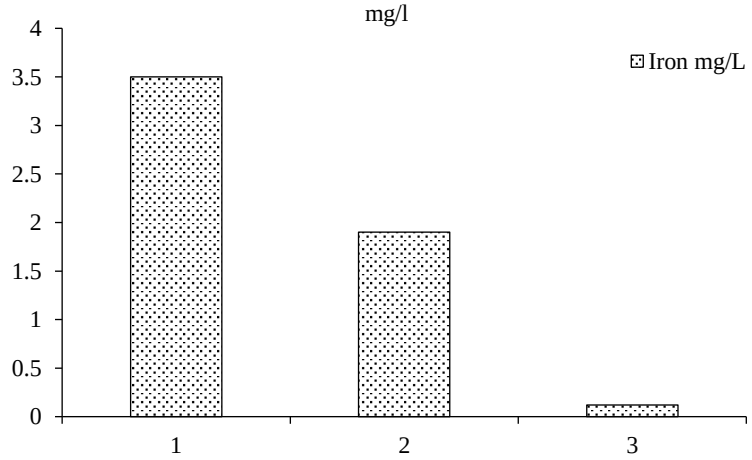

Figure 6. Graph interpretation of iron content values taken from different values of Puducherry.

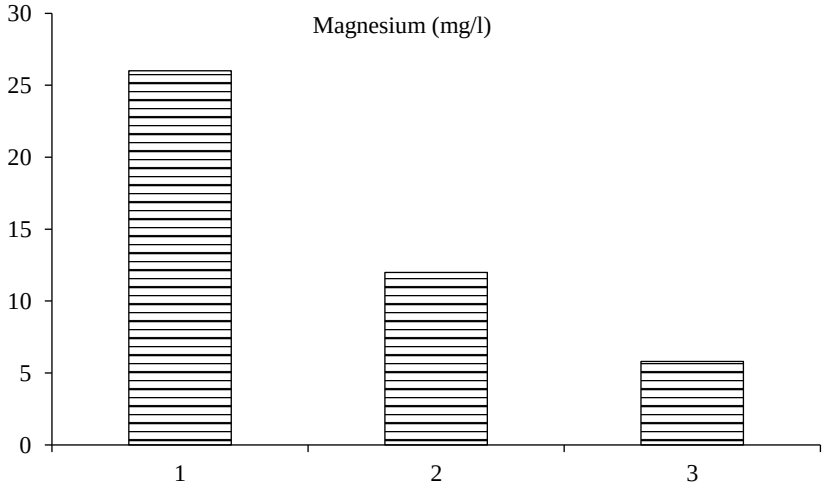

Figure 7. Graph interpretation of magnesium content values taken from different regions of Puducherry.

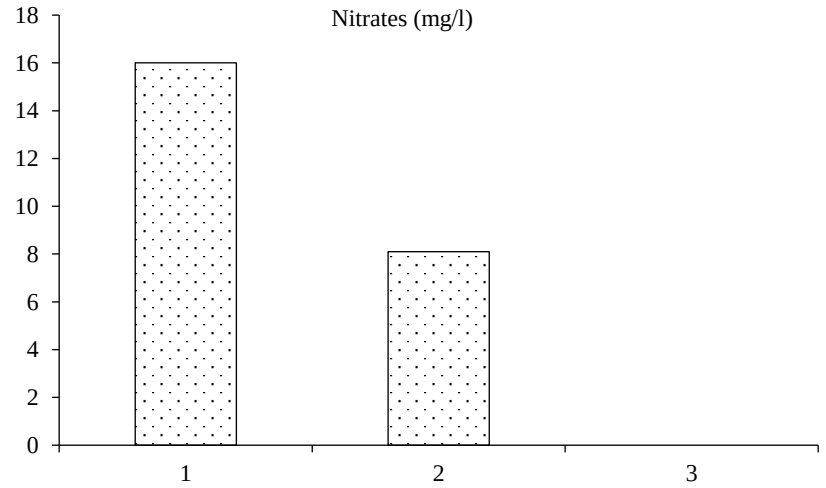

Figure 8. Graph interpretation of nitrate content values taken from different regions of Puducherry.

Total Alkalinity

Transfer 20 ml of the sample, or a suitable portion, into a 100 ml beaker using the indicator method. Two to three drops of phenolphthalein indicator were added to samples that had a pH higher than 8.3 and then titrated with regular sulfuric acid until the pink hue simply moved away (this is equivalent to a pH of 8.3). Note the amount of sulfuric acid used. Next, the same solution was titrated with a standard acid until a light pink color appeared (equivalent to pH 3.7), and then two to three drops of mixed indicator were added. After the phenolphthalein endpoint, an additional amount of acid was used [5, 8, 9].

Total Hardness

Transferring up to 50 ml of the water sample into a 150 ml beaker or porcelain dish and adjusting the volume to approximately 50 ml is the first step in determining the hardness of drinking water. Reach a pH range of 10.0–10.1, add 1 ml of hydroxylamine hydrochloride ($NH_2OH.HCl$) solution, and then 1–2 ml of buffer solution.

Add 2 ml of sodium cyanide or sodium sulfide inhibitor solution if required to compensate for interference from manganese (more than 0.025 mg), copper, zinc, lead, cobalt, nickel, or iron (greater than 0.25 mg) (Figures 9 and 10) [10–12].

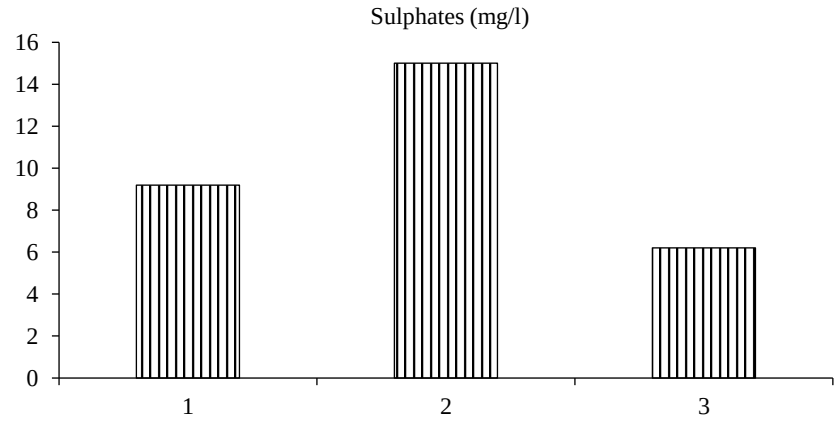

Figure 9. Graph interpretation of sulfate content values taken from different regions of Puducherry.

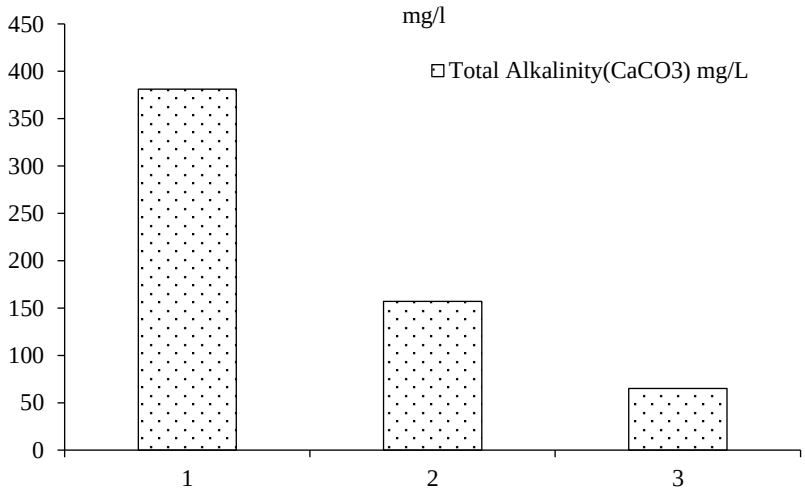

Figure 10. Graph interpretation of total alkalinity.

Furthermore, one or two tiny crystals of potassium ferricyanide [$K_4Fe(CN)_6.3H_2O$] were added to precipitate manganese if it was present, stirring, and waiting for at least five minutes. Titrate with standard EDTA solution, stirring quickly at first and slowly toward the end, after adding 2 ml of Eriochrome Black T indicator solution. When the red and purple hues completely vanish and the solution turns cloudless sky blue, the endpoint is reached. A parallel blank titration was performed for comparison with the same manganese settings, stirring, and waiting for at least five minutes [5].

pH

Several indicators and buffer solutions are used in the colorimetric method to visually assess the pH level of a water sample. First, a hard glass tube was filled with 100 ml of sample. The approximate pH value was determined using universal indicators. Then, a solution of the matching indicator corresponding to the initial pH reading (approximately 1/20 of the sample volume) was obtained. A series of buffer solutions with known pH values and the same percentage of indicators in each solution should be compared to the resultant color. Rounding to the closest 0.1 unit, report the pH of the buffer solution that most closely resembled the hue of the sample. Significantly higher water productivity is indicated by higher pH values [5, 13, 14].

Total Dissolved Solids

The substance was filtered using the gravimetric method, and the filtrate was evaporated in a heated, tared dish in a steam bath.

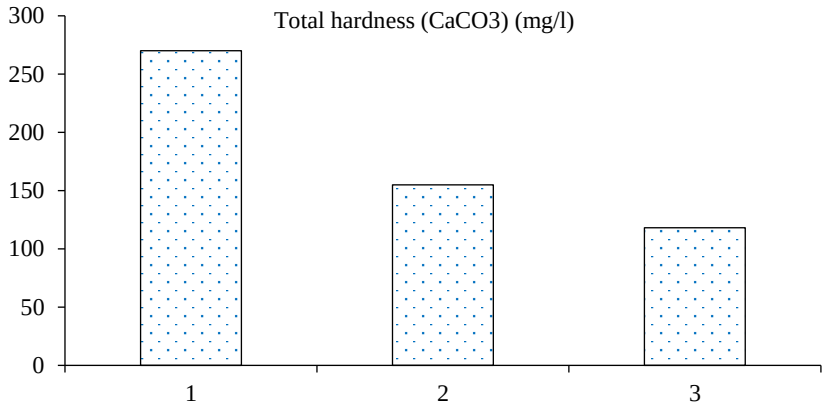

Figure 11. Graph interpretation of total hardness.

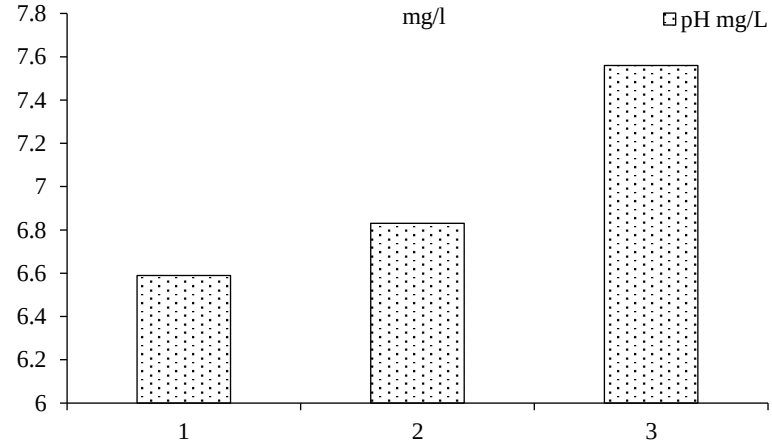

Figure 12. Graph interpretation of pH content values taken from different regions of Puducherry.

The residue was then dried at 103–105°C or 179–181°C until the mass remained constant. After heating to 180°C for 1 h and cooling in a desiccator, the dishes were weighed before storage. A suitable volume of the sample was filtered using the recommended filter to produce 25–250 mg of residue, preferably 100–200 mg. The volume was determined by applying the specific conductance values.

To obtain a detectable residue, if required, add repeated aliquots of the filtered sample. The chosen volume was placed in a drying oven set to 98°C or in a weighed evaporating dish in a steam bath. Make sure to evaporate gently to avoid boiling and splattering. The dish was dried in an oven preheated to either 103–105°C or 179–181°C until the water evaporated and the mass was consistent (successive weight difference <0.5 mg). Drying usually takes one to two hours. Trial runs were necessary to ascertain the ideal drying duration for comparable samples. Stop hygroscopic residues from absorbing moisture from the desiccant and weigh the cooled dish as soon as possible (Figures 11 and 12) [5].

Turbidity

By comparing the intensity of the light scattered by a sample to that of a standard reference suspension under the same conditions, the nephelometric method determines the turbidity of water. Turbidity increases with the intensity of the dispersed light. The formazine polymer is a widely used standard that is dependable and repeatable. Although there may be slight differences, the concentration of the formazan suspension is defined as 40 Jackson turbidity units (JTU), which is in close agreement with readings from a Jackson candle turbidimeter. Measurement standards on a turbidimeter within an appropriate range to guarantee accuracy. This process confirms the accuracy of the calibration if the instrument is precalibrated in standard turbidity units (Figures 13 and 14, Table 1) [5].

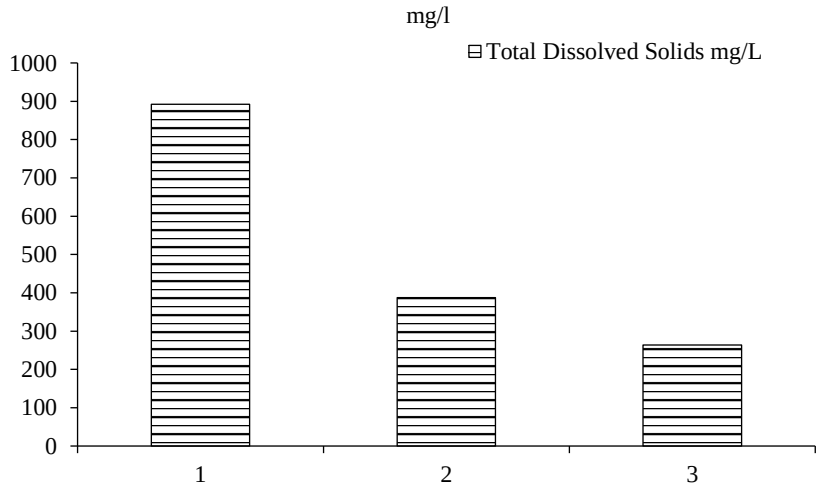

Figure 13. Graph interpretation of total dissolved solids.

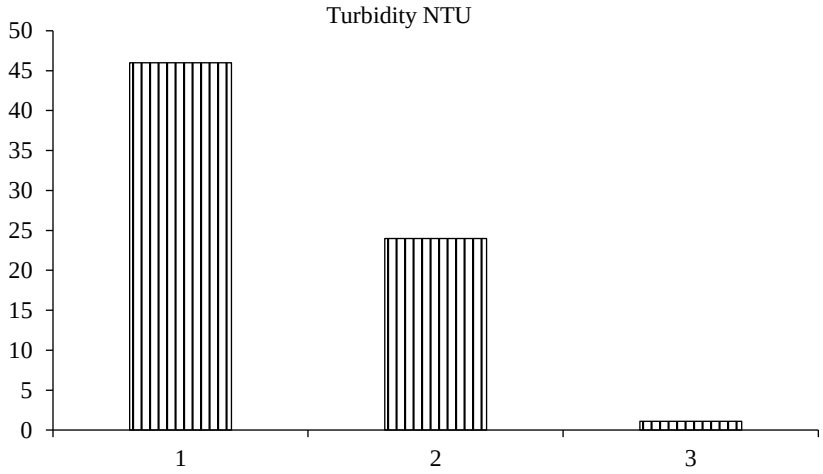

Figure 14. Graph interpretation of turbidity.

Table 1. Three lake water samples.

S.N.	Parameter	Unit	Place: Puducherry		
			Nonnkuppam	***Kathirkamam***	***Ossudu***
			Sample 1	*Sample 2*	*Sample4*
1	Calcium	mg/l	66	42	38
2	Chloride	mg/l	212	86	87
3	Iron	mg/l	3.5	1.9	0.12
4	Magnesium	mg/l	26	12	5.8
5	Nitrates	mg/l	16	8.1	0
6	Sulfates	mg/l	9.2	15	6.2
7	Total alkalinity ($CaCO_3$)	mg/l	381	157	65
8	Total hardness ($CaCO_3$)	mg/l	270	155	118
9	pH	mg/l	6.59	6.83	7.56
10	Total dissolved solids	mg/l	892	387	264
11	Turbidity	NTU	46	24	1.1
12	Phosphorus	mg/l	1.8	11	0.08

Phosphorus

The analytical process uses the stannous chloride method, which is a sensitive approach that allows accurate reading. This process begins with the formation of molybdophosphoric acid, which is then reduced by stannous chloride. Accurate quantification is made possible by the highly pigmented molybdenum blue produced by this reduction reaction [5].

RESULT AND DISCUSSION

Calcium

Rock erosion, including that of limestone, is the primary source of calcium. Overabundance of this mineral may hinder the body's ability to absorb other minerals. Overdosing calcium can result in deposits that resemble crystals and eventually solidify and become stones. Because hypercalcemia affects the central nervous system, it may interfere with the electrical impulses that regulate the heartbeat. There is a permissible limit [14]. Water naturally contains calcium; however, the inclusion of sewage waste may also be responsible for the rise in calcium levels. This reduction could be the result of wintertime calcium absorption by living organisms. Calcium levels in samples 2, 3, and 4 were below the limits of this analysis (Figure 15 and Table 2).

Table 2. Parameters.

Parameters	WHO limit
pH	6.5–8.5
Chloride	250
Total dissolved solids	500–1,500
Turbidity	3–5 NTU
Alkalinity	30–400
Hardness	80–200
Calcium	75–200
Magnesium	50–100
Sulfate	200–250
Nitrate	45
Iron	0.3

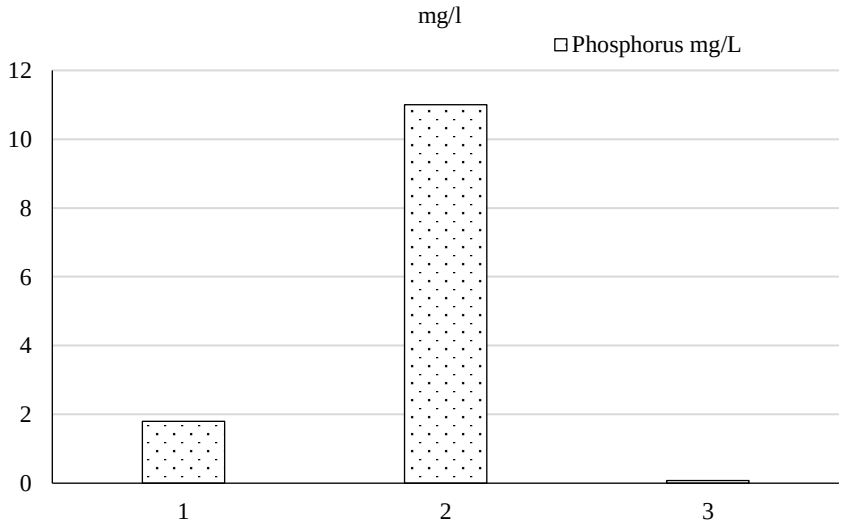

Figure 15. Graph interpretation of phosphorus content values taken from different regions of Puducherry.

Chloride

Chloride is a mineral that occurs naturally in soil and water. Depending on the alkalinity of the water, excessive chloride can accelerate the rate at which metals in the distribution system corrode. Groundwater contains chlorides from the use of seawater intrusion, septic tank effluent, leachates, animal feed, industrial effluents, irrigation drainage, and inorganic fertilizers in coastal locations [8]. Increased chloride levels in water are harmful to the kidney and cardiac conditions [9].

Iron

The Earth's crust contains naturally occurring mineral iron. The typical concentration of iron in drinking water is less than 10 mg/l. However, water can turn reddish-brown as low as 0.3 mg/l from this substance. Additionally, it is unsuitable for food and beverage processing, dyeing, bleaching, and other processes, and stains clothing and cutlery [9]. Individuals with high blood pressure, kidney illnesses, and other medical issues may experience difficulties. The iron content was above the limit in samples 1, 2, and 3.

Magnesium

In addition to being a limiting element for phytoplankton growth, Mg is necessary for the growth of chlorophyll. Drinking water with high Mg levels can also be unpleasant. All samples in this analysis had Mg levels below this limit.

Nitrate

The nitrate concentration in water can reach 50 mg/l [4]. Methemoglobinemia, sometimes referred to as "blue baby syndrome," can be brought on by ingesting too much nitrate, which can alter the way the blood delivers oxygen [14]. The permissible limit was 50 ppm. Additionally, blue baby illnesses and methemoglobinemia can be caused by elevated nitrate levels. All samples in this analysis had nitrate levels below this limit.

Sulfate

Sulfate is a common component in almost all water sources. The analysis revealed that sulfate levels in all samples were well within acceptable limits, not exceeding 400 mg/l, thus preventing potential gastrointestinal issues.

Alkalinity Total

The total alkalinity of water is due to the presence of extremely alkaline water and salts of weak acids. A body of water with a high alkalinity level might reduce the pH variations caused by pollution, acid rain, and other factors. 200 mg/l is the permissible limit [14]. Plant and organism death results from the disruption of photosynthesis caused by the entry of organic pollutants and sewage waste into the lake. The subsequent degradation of organic matter increased carbonate and bicarbonate levels, resulting in heightened alkalinity values.

Total Hardness

The presence of Ca and Mg results in permanent hardness, which is eliminated by ion exchange processes [10]. The introduction of large quantities of sewage waste and organic pollutants into lakes significantly impairs photosynthetic processes, resulting in the mortality of aquatic plants and organisms. Furthermore, the degradation of this organic matter may also contribute to increased concentrations of carbonate and bicarbonate ions, subsequently elevating alkalinity levels.

pH

The permissible limit for the potential of hydrogen in water is 6.5–8.5 [4]. When carbon dioxide and water are combined to generate carbonic acid, the pH of the water is affected [4]. A higher pH value can make the chlorination procedure for drinking water disinfection more challenging [6].

Total Dissolved Solids

The total concentration of dissolved ions is measured by total dissolved solids (TDS), such as minerals, salts, and metals, in water, usually expressed in mg/l. TDS sources include natural environments, sewage, urban runoff, water treatment processes, industrial wastewater, and the materials used in water distribution systems. Dissolved solids can rise because of evaporation-induced water concentration and water contamination from municipal and industrial waste disposal [12]. Excessive particulate matter in water is a sign of pollution, which may have a laxative impact [13].

Turbidity

The optical characteristics of water that cause light to be dispersed by its particles are called turbidity. The usual ISI requirement for turbidity in drinking water is less than 0.1 NTU. More than 5 NTU of turbidity is considered unhealthy. The materials used in water distribution systems, sewage, urban runoff, industrial effluents, water treatment procedures, and natural habitats are all sources of TDS. The concentration of dissolved solids can increase as a result of evaporation and water contamination from municipal and industrial waste disposal.

Phosphorus

This encourages the growth of microorganisms. Phosphorus quality standards are used only to prevent undesired algal growth in water.

CONCLUSION

In conclusion, the health of our world and the welfare of future generations depend on the achievement of Sustainable Development Goal 14—Life Below Water. Millions of people depend on the ocean for their livelihood, biodiversity, and climate regulation. However, pollution, overfishing, habitat degradation, and climate change pose hitherto unheard-of risks. Cooperative international action, sustainable practices, and innovative ocean management are crucial to safeguard marine ecosystems and guarantee their resilience. We can protect marine life, improve food security, and make the world more sustainable and just for everyone if we give SDG 14 top priority. More specifically, SDG 14 seeks to lessen the effects of human activity on the oceans, in addition to protecting marine and coastal ecosystems. This involves addressing the issue of plastic pollution and enhancing waste management.

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