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WATER QUALITY INVESTIGATION USING GIS-BASED INTERPOLATION: A COMPARISON OF THE KOLLIDAM AND PALAR RIVER ESTUARIES

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ABSTRACT

Water is an indispensable renewable resource on earth and the quality of water directly forms the platform for a balanced socio-economic development and cannot be utilized until its quality is assessed. The life of the majority of aquatic plants and animals depends on pH, salinity, and temperature, making them crucial water monitoring parameters. In this current study, the pH, salinity, and water temperature for the Kollidam and Palar River estuary have been assessed using GIS. Interpolation being a vital tool in GIS was used to find the dispersion of pH, Salinity, and Water temperature throughout the study areas. Applying Inverse Distance Weighing, a total of 7 stations at Palar and 18 stations at Kollidam estuary was computed. The results show that water temperature ranged from 28°- 33.5° Celsius, pH varied from 7.3 to 8.4 and salinity ranged between 5 ppt and 35 ppt. The correlation between pH and Temperature was 0.408 and 0.251 and the correlation between pH and Salinity was -0.590 and -0.568 for Kollidam and Palar River estuaries respectively. This shows a strong relationship between pH and Temperature and a weak relationship between pH and salinity. The results highlight that the pH and salinity have slightly increased than the normal level and this may lead to marine organisms shifting or even extinctions in the future. This study shows the importance of looking into long-term solutions for preserving river estuaries' water quality. Policymakers aiming to monitor and evaluate water quality and use environmentally friendly technology in the future can find valuable insights from this study.

Keywords: Water Quality, River Estuary, GIS, Interpolation, IDW, Correlation Coefficient.

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INTRODUCTION

Water quality analysis is an important process for observing and understanding the environment. Water quality is defined in terms of its physical, chemical, and biological properties. Rapid industrialization and negligent utilization of chemical pesticides and fertilizers in agriculture are producing extensive and diverse contamination in the aquatic environment, which is lowering the quality of the water. Water quality has evolved as a result of several surface and groundwater sources being drained throughout time, with major portions of them affected by diverse reasons such as urbanization, population growth, and industrial expansion.[1] The main causes of degradation in water quality were noted to be significant anthropogenic activity, illegal discharge of sewage and industrial effluent, lack of basic sanitation, unprotected river locations, and urban runoff.[2] PH and temperature were extremely critical water quality characteristics for aquatic species.[3] The season, time of day, latitude, height of sea level, air circulation, cloud cover, water flow, and depth of water bodies all have an impact on the temperature of a water body.[3] The salinity distribution in the water altered the spread of aquatic species, due to changes in the environmental osmoregulation system with fish bodies.[4] Numerous elements, including the water circulation pattern, evaporation, precipitation, and river flow (run-off) nearby, affected the spread of salinity.[5] Such issues can be studied by monitoring the levels of water quality parameters. Aquatic life mainly depends on the parameters of temperature, pH, and salinity. These can be seen as having an adverse effect on the flora and/or fauna of a particular body of water. Locations of the Kollidam River estuary and Palar River estuary of Tamil Nadu were sampled during April 2023 to observe the water quality during the summer season. Physical parameters such as water temperature, pH, and salinity were taken for this study.

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The thermometer was used to measure water temperature; a pH meter was used to measure the pH and a Refractometer was used to measure the salinity of the water after the calibration concerning each sample location. GIS is a platform that has great potential to predict and solve various environmental problems. Interpolation is a GIS method that predicts values for all cells in a raster from known data points. It can be used to predict unknown values for any geographical location. Values for rainfall, cloud cover, and chemical concentrations can be predicted using interpolation. By utilizing values from nearby existing places, the interpolation method assists the user in predicting the unidentified values of specific sites and creating a continuous surface. A mathematical method to assess the missing data in between the available data is called interpolation. It facilitates bridging the points' gaps. For many professions, the job involves creating continuous surfaces from irregularly scattered data. Every approach has benefits and downsides of its own, which are mostly dependent on the features of the point data set.[6] There are several methods under interpolation, each method has its significance which uses different calculations. In the era of large data, we first need to organize the data, which requires us to find missing data or predict the trend, so we need operations including interpolation, etc. The method of interpolating involves using known, discrete data points to infer new data points within a range.[7] The interpolation approach is the most effective way to boost an image's resolution that contains a high-frequency component.[8] Depending on the spatial distribution, the samples can't be collected in every site in water. Instead, we can measure values at dispersed locations either randomly or at specific intervals based on our requirement, and then the values can be automatically assigned to other locations using this interpolation method. The interpolation methods in GIS have different sets of tools such as IDW, Natural neighbor, Kriging, Topo to Raster, Trend Spline with Barriers, and Spline.[9] Based on the application, the appropriate tool can be used. In this study, the IDW tool has been used to interpolate the values of pH, salinity, and temperature for the given study area. IDW averages neighboring cell values to interpolate cell values.[9] The inverse distance weighting (IDW) method is perhaps the most widely utilized for estimating missing data in hydrological and geographical sciences.[10] Thus, in this study, the water quality parameters of pH, salinity, and water temperature were analyzed and compared for the given study areas through the interpolation tool 'IDW'. ArcGIS 10.8.1 was used to perform this process. The values of pH, salinity, and water temperature were also correlated to find their relationship/influence concerning each other.

EXPERIMENTAL

Location and Geography

Kollidam is the northern distributary of the Kaveri River in Tamil Nadu. Kaveri is the largest river of Tamil Nadu running for about 800 km before draining its water into the Bay of Bengal. At the Grand Anicut, Kaveri divides into two streams, Kaveri and Kollidam, one flowing toward the northeast and the other toward the southeast. The Pazhayarai town, situated between the districts of Cuddalore and Nagapattinam, is where the Kollidam River empties into the Bay of Bengal.[11] A significant portion of the estuary is covered in mangroves, which represent the continuation of the mangroves in Pichavaram, one of India's most significant and ecologically sensitive zones. A total of 18 locations were sampled which were separated into six in fresh water, six in mangroves, and six in estuary regions to cover the diversity of the study location. The study area locations are shown in Fig.-1.

Palar River originates in Karnataka and flows for approximately 348 kilometers, of which 222 km are in Tamil Nadu. Palar Anicut provides water to two of Chennai's most important drinking water sources, Poondi Reservoir and Chembarambakkam Lake. Palar River flows south of Kalpakkam into the Bay of Bengal via the town of Vayalur.[12] The river gets a massive amount of sewage and industrial trash as it passes through the districts of Chengalpattu, Kancheepuram, and Vellore. The river mouth is only there temporarily; it closes during seasons without rain and opens up wide when rain falls. Approximately three kilometers from the mouth, the estuary has a check dam to regulate the overflow of water and mitigate flooding in the nearby villages during the monsoon season. The study area and the locations have been tagged in the Fig.-2.

Water Quality Analysis

pH

The potential of Hydrogen is a measure of acidic and basic levels of water. The range varies between 0 and 14, where less than 7 indicates acidity, greater than 7 indicates a base and 7 is neutral. The pH of water

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determines the solubility and biological availability of chemical constituents such as nutrients like nitrogen, phosphorus, carbon, and heavy metals like lead, copper, etc. Seawater has an average pH of 8.2, however it can vary based on regional factors to a pH of 7.5 to 8.5. Long-term effects of human activity, such as sewage spills or runoff, can be exceedingly detrimental to plants and animals. Short-term pH variations can also be substantial. Severe pH variations can cause stress to nearby species, which could eventually cause many of them to disappear or die. [10]

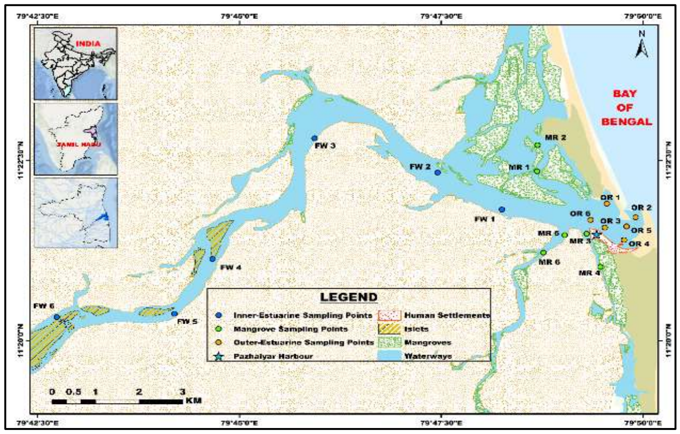

Fig.-1: Kollidam River Estuary Study Area Map

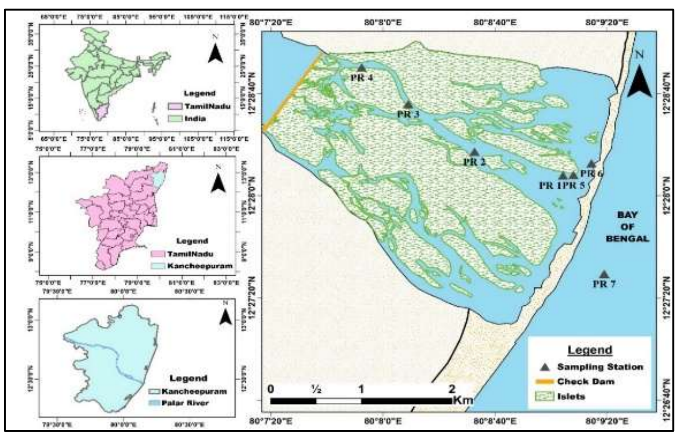

Fig.-2: Palar River Estuary Study Area Map sss

Salinity

Salinity in seawater is measured in parts per thousand (ppt) or practical salinity units (psu). Normal seawater has an average of 35 ppt whereas fresh water has 0.5 ppt or less. Salinity can affect the density of ocean water. This can affect the movement of ocean currents. Salinity levels affect the composition of local species, and both plants and animals are frequently sensitive to variations in salinity. Salinity variations can be caused by weather patterns, such as storms or droughts, or they can notify us of occurrences like increasing urban runoff and sewage discharge. These occurrences have the potential to alter the water's quality since they usually cause an increase in the concentration of dissolved mineral salts, which tends to lower overall water quality.

Water Temperature

Water temperature helps the researcher to understand the local weather and global climate patterns, the impact on marine life, and even the fishing methods. Water temperature is affected by depth, Atmospheric heat transfer, Confluence of water bodies (rivers, streams, storm drains, etc.), Turbidity (water cloudiness), Sunlight (solar radiation), and Anthropogenic (human-induced) factors. However, water temperature is essential to any water monitoring program and has a significant impact on almost all other water quality parameters that we are trying to monitor and quantify.

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Instruments Used

Table-1: The Instruments that Were Used to Collect Water Quality Data

Temperature	pH	Salinity
To determine body, liquid, and vapor temperature	Indication of alkalinity or acidity	The amount of dissolved salt in a body of water
Mercury Thermometer -10 to 50 temperature range Response in 2 seconds.	pH meter pen EcoTestr pH 2 pH range 0.0 to 14.0 pH Accuracy ±0.1 pH. IP67 Waterproof.	Refractometers- Erma Japan Range: 0-100%

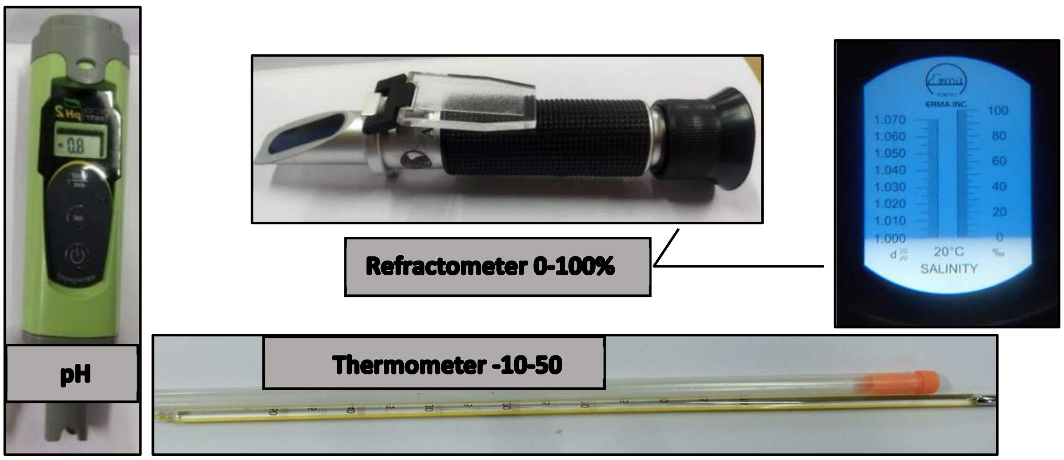

Fig.-3: Field Instruments Used to Collect Physio-Chemical Levels of Water

Inverse Distance Weighted (IDW)

This method's underlying idea is to prioritize close sites over far-off ones. By expressing the surface analytically as f(x,y), we obtain:

$$f(x,y) = \frac{\sum j=1\ldots N\ \varpi(dj)\upsilon j}{\sum j=1\ldots N\ \varpi(dj)}$$

Where $\varpi(d)$ is the weighting function, υj is the point j value, dj is the Euclidean distance with point j, and N is the total number of data points. Here are some thoughts on the benefits of employing this technique. The primary benefit is its ease of use; further benefits include the method's ability to produce reasonable answers for a broad range of data and its inability to produce results that fall outside of the significant value range.[6] ArcGIS 10.8.1 was used to perform the IDW interpolation. The data were exported as a .csv file and then converted into a shape file along with the sampling locations. IDW has advantages such as selecting the area of interest, the parameter to be interpolated, and the resolution of the output raster. Inverse distance weighting (IDW) is widely used and simple to automate, and this tool has been carefully designed to work accurately for this use case.[10] Once the process is completed, the output can be masked to the study area. By focusing on several connected measurement locations and reducing the pre-determined "search radius" size, the IDW technique can be made better.[13] The process is shown in Fig.-4.

Methodology

The flow chart for this study is displayed in Fig.-5. Initially, the ground truth data were gathered at the designated places using manual equipment. The respective locations have been noted using hand GPS. After that, the data were exported as.csv files into ArcGIS. The locations were classified based on the "z" values of salinity, pH, and water temperature that were interpolated using the tool "IDW". The greatest and lowest values were provided based on the designated areas to help better understand the effects of water quality components including pH, salinity, and temperature. The majority of aquatic plants and animals depend on pH, salinity, and temperature for their life, making these three factors crucial for water monitoring. The raster images interpolated were mapped appropriately. With ArcGIS, all post-processing of the data was completed. Further, the data were correlated using a correlation coefficient to find the impact of each parameter on the other

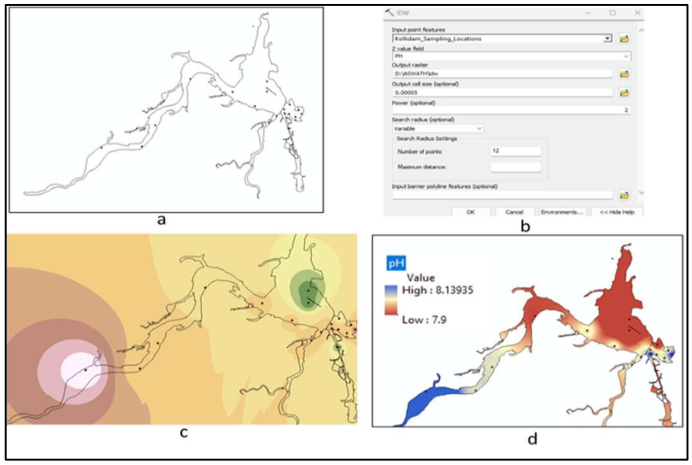

Fig.-4: (a) Exporting Sample Points, (b) IDW, (c) Output Raster, (d) Masking to Study Area

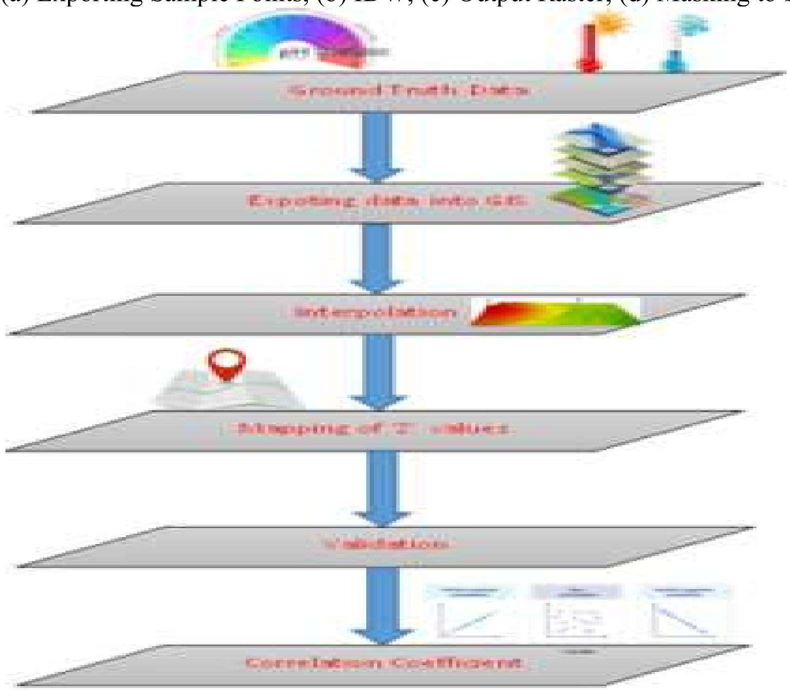

Fig.-5: The Flow Chart of Methodology

RESULTS AND DISCUSSION

pH

The pH of the Kollidam River estuary reached a maximum of 8.3 near the FW-6[FW-Freshwater Region] (highway bridge), where people are engaged in daily activities including bathing, cleaning cars, and washing clothes. The lowest pH, 7.6, was found in some of the mangroves in areas with fewer anthropogenic activities. The outer channel points and stations of MR-5 and MR-6[MR-Mangrove Region] had pH values near 8, slightly higher than freshwater indicating the influence of fishing boat's oil spills, letting out the used water near the jetty, etc. Comparatively, the Palar River estuary had a much lower range of pH values. Places inside the river had around 6.5, whereas, near the shore, pH recorded around 7. Except for the sampling location PR- 6[PR-Palar River] at the merging point of on-shore and off-shore, was recorded at 6.8 since it was low tide at the time of sampling. People were seen involved in the burning of Molluscs near stations PR-3 and PR-4 which justifies the pH level over there near 8. The interpolation results are shown in the Fig.-6 and 7.

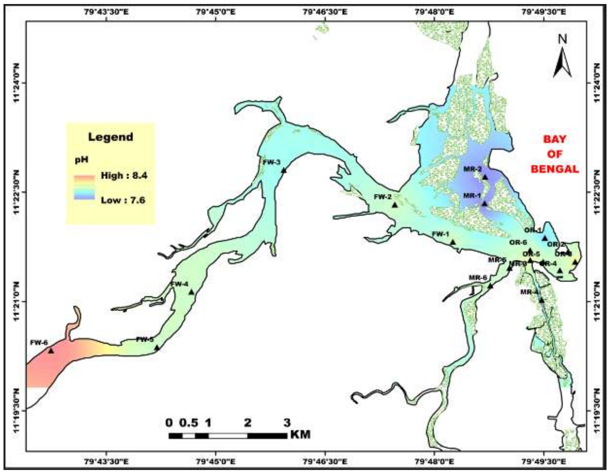

Fig.-6: Kollidam pH

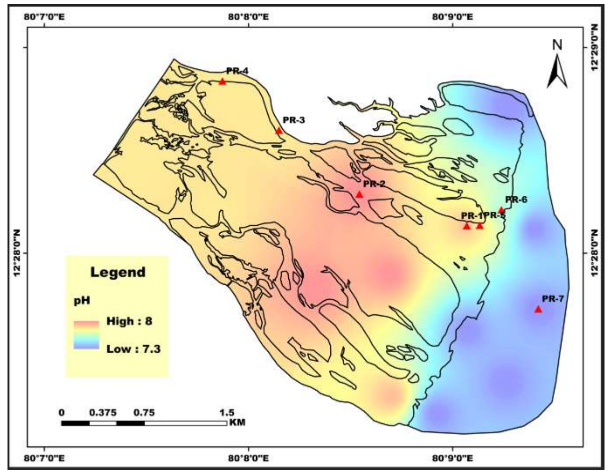

Fig.-7: Palar pH

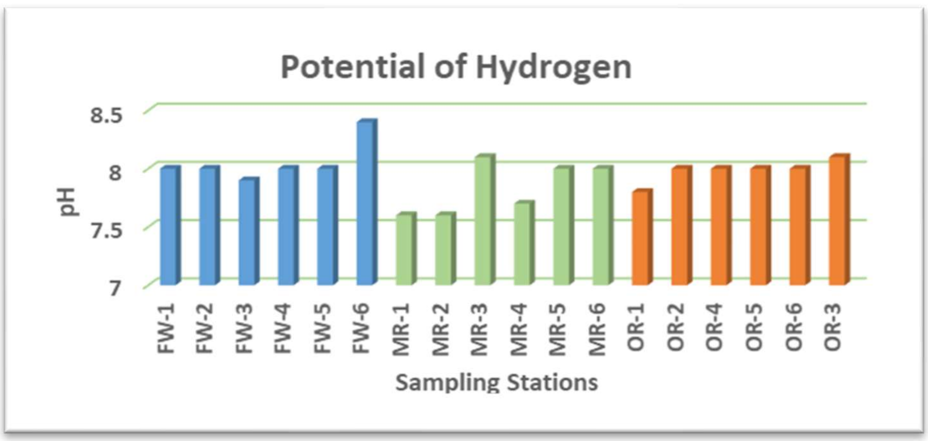

Fig.-8: Graph of Kollidam pH

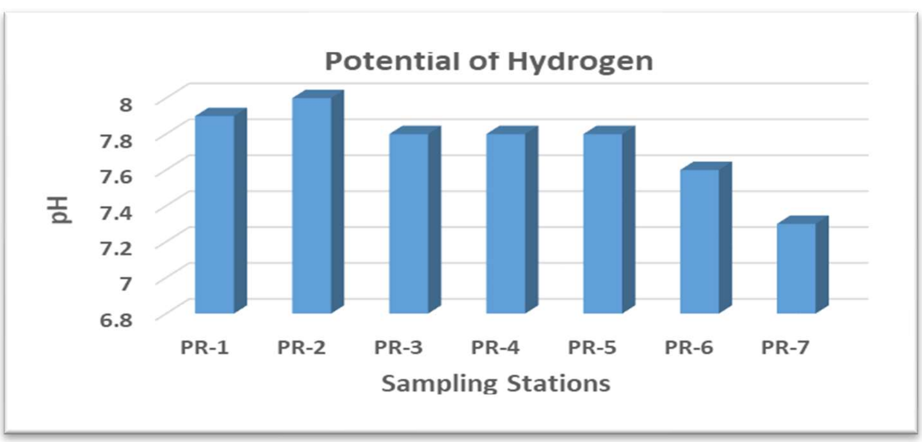

Fig.-9: Graph of Palar pH

Salinity

Estuaries can range in salinity from 0.5 to 30 ppt along their whole length, depending on how close they are to river inflows. At Kollidam River, the salinity started ranging from 3 ppt to 29 ppt as moved from the river towards the sea. Generally, brackish waters, mangroves, and swamps have a maximum salinity of 30 ppt. As so, the station MR-1 and 2 recorded 26 ppt and other mangrove points above 20 ppt. We could see people using the water for drinking purposes at FW-6 (near to highway bridge) where the salinity was just 3 ppt. Intrusion of ocean water influenced the salinity rate in the outer channel stations ranging from 20 ppt to 30 ppt. Comparatively, the Palar River estuary had salinity ranging above 30 ppt all over, except for the stations PR-3. PR-4, which was inside the river near the check dam, was observed less than 5 ppt. This was due to the low tide during the time of sampling and the presence of check dams and islets diverting the waters at PR-3 and PR-4. Due to this salinity range, all the sampling sites had pH values of more than 7, which indicates the presence of bicarbonate in both rivers, and it was confirmed by the local people. The interpolated Salinity maps and the graphs are shown below.

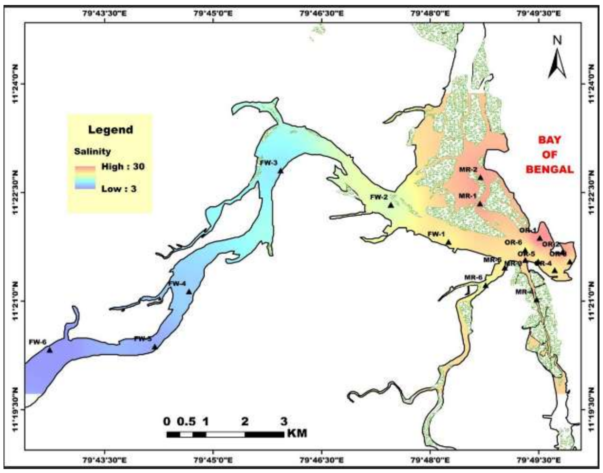

Fig.-10: Kollidam Salinity

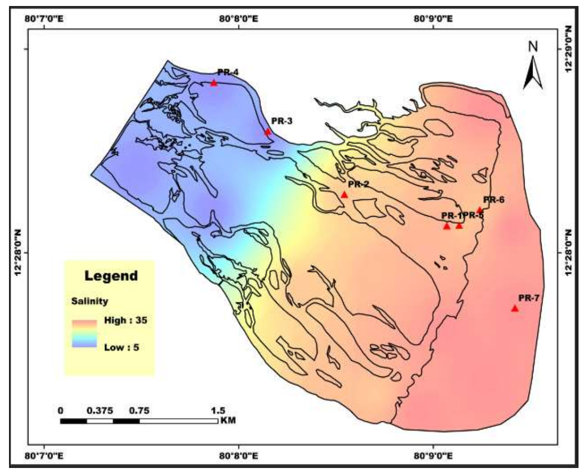

Fig.-11: Palar Salinity

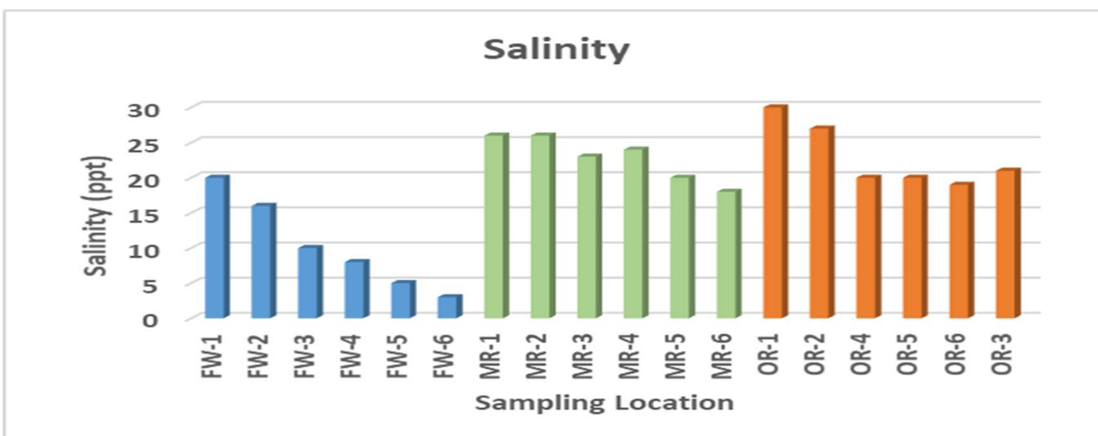

Fig.-12: Graph of Kollidam Salinity

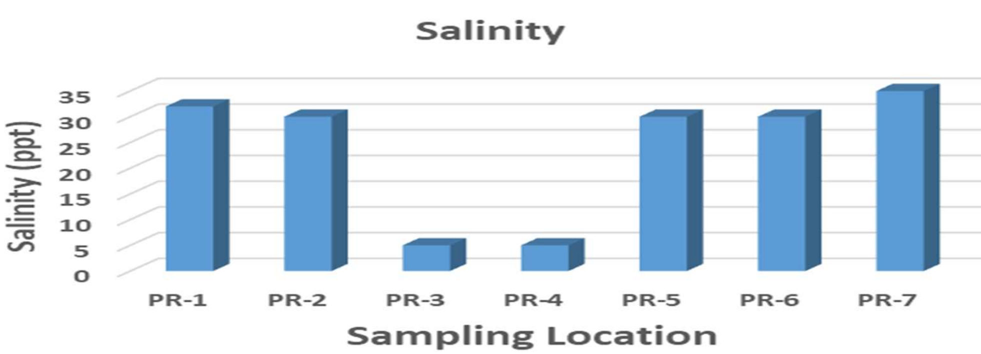

Fig.-13: Graph of Palar Salinity

Water Temperature

One of the most crucial aspects of water quality is the water's temperature. It affects the chemical qualities of water and how aquatic life works. Additionally, it influences the level of oxygen that can dissociate in water, the pace at which algae and other aquatic plants photosynthesis, the rate of metabolism of organisms, their vulnerability to harmful substances, parasites, and diseases, and the period of aquatic organisms' migration, reproduction, and aestivation. The result shows that the water temperature varies between 28°C - 33.5°C at Kollidam river estuary. The sampling was conducted during April which is the ideal summer season in Tamil Nadu. A total distance of 23 km was covered starting from the estuary in the morning and towards the river throughout the day. Hence the sampling locations FW-1, MR-1, and OR-1[1] recorded low temperatures such as 28°C, 29°C, and 29°C respectively as they were collected before 09:00 am. A maximum of 33.4°C was recorded near the other locations at mangroves and estuaries as the local weather at the time of sampling was hot and humid. Whereas, Palar River estuary was sampled between 10am to 1pm in the month of April. Hence all over the location, the water temperature range was between 31°C and 32.5°C. Sampling stations such as PR-3 and PR-4 near to the check dam recorded maximum of 32.5°C. As discussed under the pH topic, the burning of Molluscs by the people also influenced the local water temperature as the hot water was returned into the river in large amounts during the sampling time.

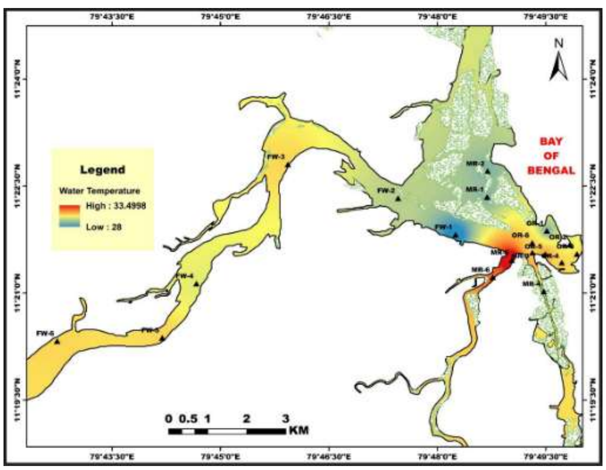

Fig.-14: Kollidam Water Temperature

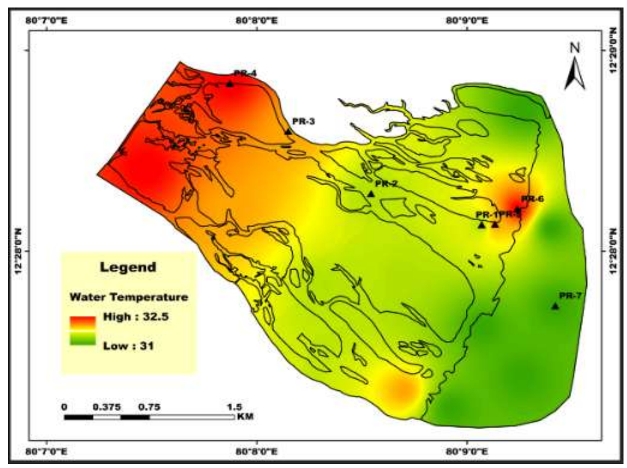

Fig.-15: Palar Water Temperature

Correlation between pH, Salinity, and Temperature

The correlation coefficient is a measure of the degree of correlation between the sets of both downstream and upstream vertices composing the borders in a network graph. ranging from -1 to 1. This range has been shown in the Table-2.

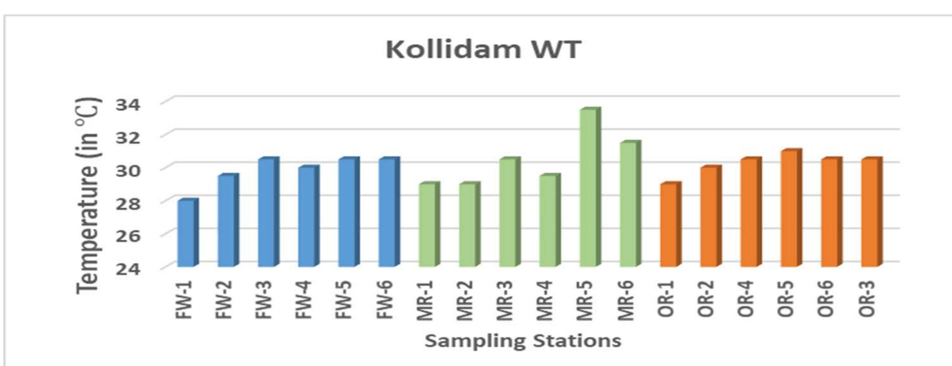

Fig.-16: Graph of Kollidam Water Temperature

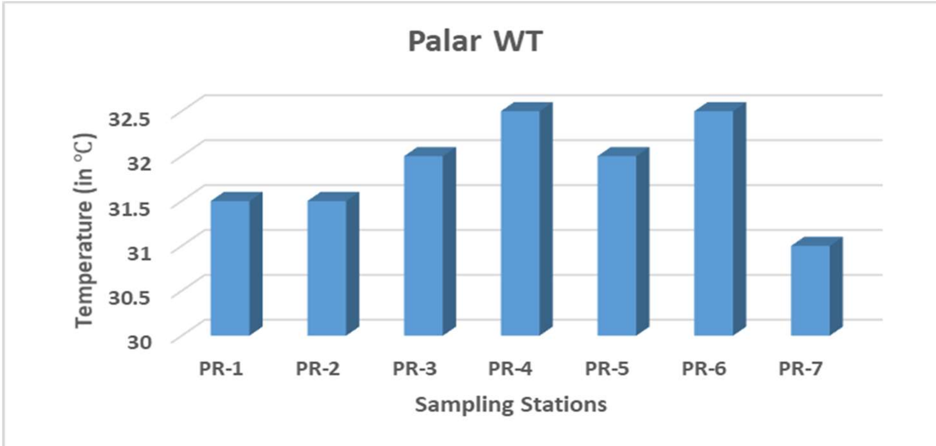

Fig.-17: Graph of Palar Water Temperature

Table-2: Correlation Coefficient Values and Levels of Correlation

Range of Correlation Coefficient Values	Level of Correlation	Range of Correlation Coefficient Values	Level of Correlation
0.80 to 1.00	Very Strong Positive	-1.00 to -0.80	Very Strong Negative
0.60 to 0.79	Strong Positive	-0.79 to -0.60	Strong Negative
0.40 to 0.59	Moderate Positive	-0.59 to -0.40	Moderate Negative
0.20 to 0.39	Weak Positive	-0.39 to -0.20	Weak Negative
0.00 to 0.19	Very Weak Positive	-0.19 to -0.01	Very Weak Negative

[14]Correlation was derived by using the formula,

=CORREL (A1: A7, B1: B7)

Where A1:A7 and B1:B7 are the data range of pH and salinity or pH and temperature.
In this study, the correlation coefficient between the pH and Salinity are -0.590 and -0.568 for the Kollidam and Palar River estuaries respectively. This shows a Moderate negative relationship between these two parameters and has a weak correlation too. A very slight vulnerability was identified in this preliminary analysis, to indicate if the pH increases the salinity. This indicates that variations in salinity have less of an impact on pH. The graphs are shown below (Fig.-18 and 19).
The correlation coefficient between the pH and Temperature were 0.408 and 0.251 for the Kollidam and Palar River estuaries respectively. This shows a positive relationship between these two parameters. Temperature is essential to any water monitoring program and has a significant impact on almost all other water quality parameters that we are trying to monitor and quantify.

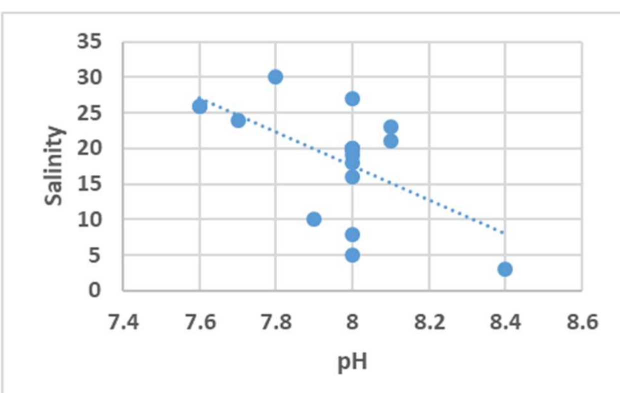

Fig.-18: Correlation pH and Salinity at Kollidam

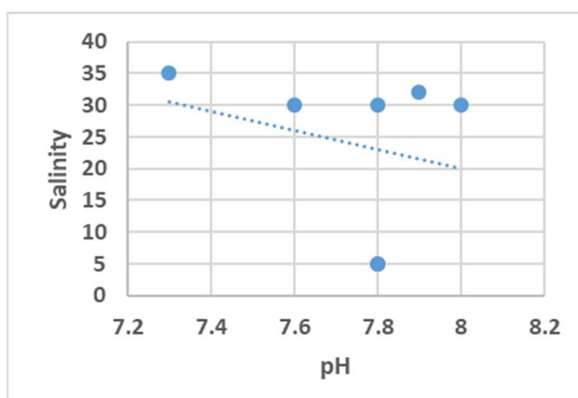

Fig.-19: Correlation pH and Salinity at Palar

For example, at PR-4 (Palar), both pH and temperature were high due to the anthropogenic activity of burning mollusks. Also, at Kollidam, stations MR-1 and MR-2 had both the pH and Temp at lower rates.

When one variable falls, the other likewise falls, or vice versa, when one variable rises, the other rises. The graphs are shown below:

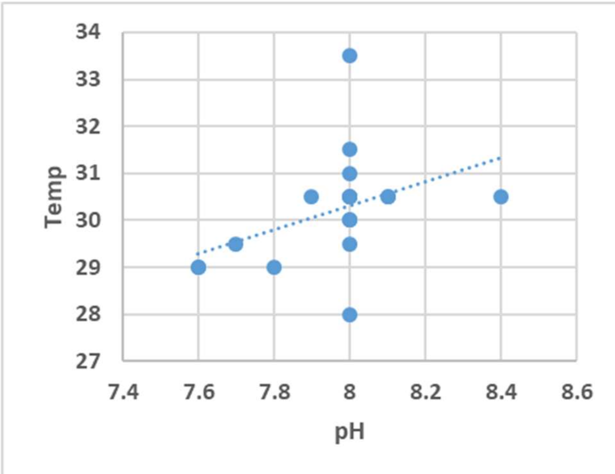

Fig.-20: Correlation pH and Temperature at Kollidam

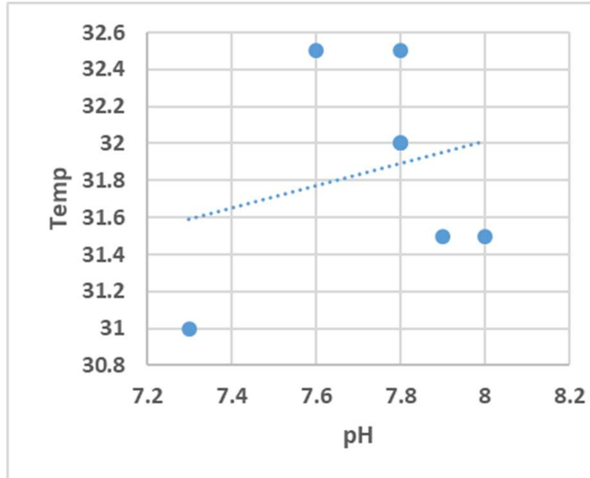

Fig.-21: Correlation pH and Temperature at Palar

Comparing the results of both the river estuaries, the Palar River estuary has a significant rise in salinity, water temperature, and pH. This may be due to the influence of the nearby semi-urban areas such as Vellore, Kancheepuram, and Chengalpattu located at a distance of 130 km, 70km, and 30km along the river respectively, where, regular sewage and certain industrial wastes enter the river all through the years. The presence of Pazhaiyar Jetty at the Kollidam river estuary, where more than 50 trawler boats visit each week to download collected fish from the ocean. It has a significant effect on the estuary region's contamination and also constant small-engine boats, which are involved in fishing along the river, close to the estuary is one of the factors too. In addition, people were involved in tasks including manual fishing, washing clothes and vehicles, and waste disposal in both the river estuaries. This shows how these anthropogenic activities have impacted the environment and indicate a dangerous alert for future conditions. Among the 25 stations adding both the river estuaries, more than 15 stations have recorded a pH of 8 and above. Only a limited range of pH shifts is suitable for the survival of living things. For most species, a pH between 7.0 and 7.5 is optimal and conductive. Hence, the current conditions of pH for this study area may affect the plants and animal species living in these environments and may lead to their death or extinction, if no proper solutions are taken. This indicates, that further analysis is to be taken in the future. Salinity and pH are majorly affected due to anthropogenic activities and can impact each other in any environment. Even though, in this study, the correlations have shown us that, the salinity has remained independent, meanwhile, pH and water temperature have been dependent on each other. Importance of GIS in water quality analysis: GIS has proven to be an ideal platform to perform water quality analysis. Even though only about 18 locations at the Kollidam river estuary and 7 locations at the Palar River estuary, were sampled, we were able to find out the values at un-sampled and even inaccessible locations using the limited known values. This was only possible when the interpolation technique came into the process. While compiling regional-wise data, we can easily find out the places of high and low values using interpolation. For this, 'IDW[2]' will be a great tool that has shown more accuracy and quality of outputs. Therefore, greater attention needs to be paid to monitoring, both the river estuaries' water quality, in order to maintain the ecological niche of marine life in these study areas.

CONCLUSION

The results show that the pH has varied between 7.3 and 8.4, salinity ranging between 5 ppt and 35 ppt, and water temperature ranging between 28° and 33.5° Celsius in the Kollidam and Palar River estuaries jointly. In addition, the correlation results show a positive relationship between pH and Temperature of 0.408 and 0.251 and a negative relationship between pH and Salinity of -0.590 and -0.568 in the Kollidam and Palar

River estuaries respectively. River estuary management and protection requires routine monitoring of water quality indices. Reducing human activities that are contaminating the river waters can help to maintain the level of pH and Salinity. This can also be accomplished by planting Mangroves close to the estuary where fringing mangroves are already present in the study areas. The findings are intended to serve as a scientific point of reference for additional studies in the study areas. The results of this study have been covered as pilot research, which will be compiled along with the other data for the entire Indian Coast, by the National Centre for Coastal Research (NCCR), MoES, and GoI for policy making.

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CONFLICT OF INTERESTS

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.
The authors declare the following financial interests/personal relationships which may be considered as potential competing interests.

AUTHOR CONTRIBUTIONS

All the authors contributed significantly to this manuscript, participated in reviewing/editing and approved the final draft for publication. The research profile of the authors can be verified from their ORCID ids, given below:

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