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A Study on the Seasonal Variability of PH, D.O, Salinity and Nutrients of the Gauthami Godavari Estuary, East Coast of India

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KEYWORDS

Estuaries, Contamination, Dissolved oxygen, Nitrates.

ABSTRACT:

Estuaries serve as a zone of transition where some continental material is moved to the open sea and where it is trapped. A complex interplay of physical and geochemical processes determines the chemical composition and variability of suspended particulate matter (SPM) in estuaries. Throughout the research region, temperature and pH exhibited an increasing tendency from post-monsoon (winter) to pre-monsoon (summer) in line with variations in air temperature. In every site, dissolved oxygen (D.O.) showed an increasing tendency from the pre-monsoon (summer) to the post-monsoon (winter). This is explained by the interaction of increased photosynthetic activity in the post-monsoon season and winter cold.

Introduction

The Godavari River, which spans 330 km in the state of Andhra Pradesh, is the third-largest river on India's east coast. It begins at an elevation of approximately 1600 meters in the Western Ghats near Triambak, Maharashtra, and travels approximately 1,530 kilometers eastward across the Indian peninsula before draining into the Bay of Bengal between latitudes 16°.15′ to 16°.45′ N and longitudes 81°.45′ to 82′.25′ E. During the monsoon season, it discharges a significant amount of fresh water and creates estuarine conditions in the Bay of Bengal's adjacent coastal water. The river is joined by a number of minor tributaries, including Manjira, Kaudaliar, Dunda, Purna, Penaganga, Wardha, Indravathi, Sabari, and Sileru.

The Godavari River's freshwater runoff is mostly influenced by the monsoons that are currently occurring in India. When the southwest monsoon is in effect, from June to September, the fresh water discharge reaches its peak. After thereafter, the discharge steadily drops until it reaches its lowest point in January through May. The Godavari River is 1,530 km long, with 770 km of the length flowing through Andhra Pradesh. At Dowlaiswarm, 65 km from the coast, the Godavari River splits into two distributaries, Gauthami and Vasistha. A setulate system of tidal creeks connected the Gauthami proper, Nelarevu Gauthami, and Vrudha Gauthami, which again divided into Gauthami. Once more, the Vasishta splits into Vainateyam and the actual Vasishta.

These mudflats have produced vegetation that could withstand saltwater over a long length of time. The shallowing of Kakinada Bay encouraged the mangroves to grow even more. There are mangroves in the Coringa region and at the mouth of the Godavari River close to Bhairavapalem. They can be categorized as a combination of Riverine (Gaderu, Coringa), Fringe (towards the Bay of Bengal and south-western Bay), and Basin (towards the land side) types based on the functional classification. This is likely the only location in India where mixed forests with three different species of Avicennia—Avicennia officinalis, Avicennia marina, and Avicennia alba—can be found.

The study area, site locations from where surface and bottom water collected in the estuarine water of Gautami Godavari is described below.

Site 1 is situated at Kotipalle, the head of the estuary, in the middle of the Gauthami Godavari stretch. The estuary's mouth is 41 kilometers away, and there is minimal tidal activity there. Less salinity means that most of the water is fresh. There are villages and vast

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areas of farmed land on both banks of the river. Human inputs from these settlements and agricultural areas are more prevalent in the river during the monsoon season.

Site 2 is situated in Dangeru, in the middle of the Gauthami Godavari River, 8 km below the Kotipalle. There are villages and agricultural land on both sides. There is a considerable fishing activity there. The station is eight meters deep on average.

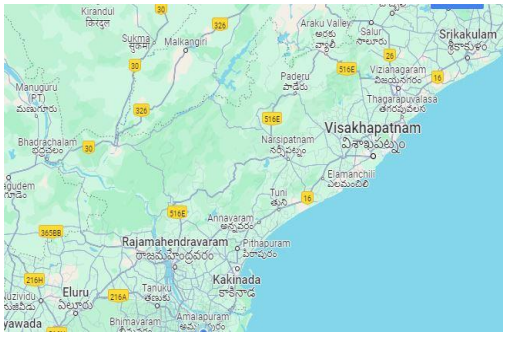
Site 3 is situated 22 kilometers from the estuary's mouth in Yanam, in the middle of the Gauthami Godavari Estuary. The estuary receives the majority of the discharge from household wastewater. The term "boat jetty" refers to the group of anchored fishing boats in the estuary. The average depth at this site is 12 meters, and the tidal influence is greater.

Site 4 is situated five kilometers down to Yanam in the middle of the Gautami Godavari river at Vrudha Gautami. This area is dotted with several waterways. This station is six meters deep on average.

Site 5 is situated near Balusutippa, in the middle of the river channel. The distance to the estuary's mouth is 12 kilometers. There are shrimp and fish farms in the vicinity, which discharge a significant proportion of their wastewater into the nearby streams before entering the main estuary.

Site 6 is situated in the middle of the mangrove forest area's watercourse. On both sides of the creek is a dense mangrove vegetation. The creek is four meters deep on average.

Site 7 is situated at the center of the estuary's mouth. It is connected to the Bay of Bengal's coastal water, which are generally rather clean. There is an oil industry on the north side of this station, while a mangrove forest lies on the south. This station is eight meters deep on average.



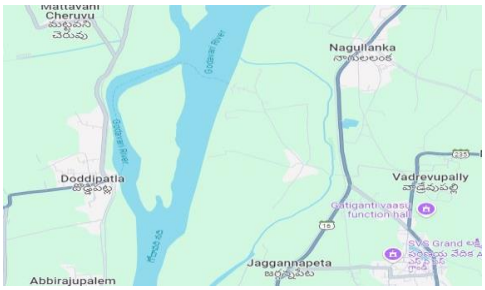


Fig 1. Source: Google maps

Experimental

The pH of the seawater was measured right away after the samples were brought to the lab using a combination calomel glass electrode and a Toshniwal digital (Type 335) pH meter with an accuracy of ± 0.01. Just before usage, the device was calibrated using standard buffers with pH values of 4.00, 7.00 and 9.20.

Today, the majority of salinity estimates are based on electrical conductivity measurements due to their speed, precision, and ease. However, marine chemists continue to mostly accept the original Mohr-Knudsen titrimetric approach. Because the author's laboratory has limited resources, this method was used to determine the chlorinity. The UNESCO formula, S (‰) = 1.80645 x Cl ‰, was used to convert the chlorinity data to salinity values. Comparing the precipitable halides (Cl- & Br-) in the sample to those precipitated by silver ions from a standard seawater sample (Laboratoire Hydrographique Copenhagen) is the basic idea behind the procedure. Potassium chromate was used as an indicator while titrating an aliquot (10 ml) of the material with a silver nitrate solution containing halides.

A modified Winkler's method was used to determine the dissolved oxygen content [1]. This method works on the idea that manganese (II) in a strong alkaline media chemically binds dissolved oxygen in a determined volume of water. When the latter undergoes oxidation to manganese (IV), the D.O. was fixed on board. When extra iodide is present, acidification releases an equivalent quantity of tri-iodide, which can be used as an indicator to titrate standard thiosulphate.

The process of measuring nitrite in seawater involves reacting it with an aromatic amine to generate a diazonium molecule, which is then coupled to an electron-rich substrate (often another aromatic amine) to form an azo dye. The technique used in this study to measure the amount of nitrite in seawater was first

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presented by Bendschneider & Robinson in 1952, provided a modified version of the technique [2]. This procedure involved reacting an aliquot of seawater sample with sulphanilamide in an acidic medium, and then coupling the resultant diazonium ion with N (1-naphthyl) ethylene diamine dihydrochloride to produce a vivid pink dye.

Results & Discussion

pH:

River, estuary, and marine pH is primarily regulated by dissolved carbonate species of CO_3^{2-} and CO_2 aq. with borate, orthophosphate, and silicate anions having a minor role. Table 1 provided the station-by-station summary statistics of pH readings in the Gautami Godavari estuarine water for the study period. While the pH values in the bottom water ranged from 7.52 to 8.62 with an average of 8.10, the pH values in the surface water varied from 7.40 to 8.32 with an average of 7.95.

Because seawater predominates at the estuary's mouth (Bhairavapalem), higher pH values were generally seen there, but river water predominates at the head of the estuary (Kotipalle), resulting in lower pH values. The bottom incursion of seawater in all stations and seasons may be the reason for the pH values' increasing tendency from surface to bottom at all stations. Seasonal variations in pH levels are caused by a variety of processes, including the breakdown of organic materials, the dilution of estuarine water by the influx of freshwater, and the removal of CO_2 through photosynthesis [3]. The Vellar Estuary [4], the Mahanadi Estuary [5], the Rushikulya Estuary [6], the Pichavaram mangrove area [7], and the Kaduviyar Estuary [8] have also been found to exhibit similar seasonal changes in pH levels.

Salinity

The distribution of metal concentration in water and sediment is primarily influenced by salinity, which is also highly dependent on the inflow of river water from the estuary's head and the entry of seawater from the mouth. One measure of the tidal effects and mixing processes in estuaries has been the salinity of the water. Table 2 provided the salinity readings at each station for the Gautami Godavari estuarine water during the study period. The Gauthami Estuary's salinity values varied, ranging from 0.24 to 32.83 x 10^{-3} on average in surface water and 5.63 to 33.28 x 10^{-3} in deeper water.

Between the surface and the bottom, the salinity gradient varied from 2.43 to 3.00 x 10^{-3} in the pre-monsoon, 2.50 to 4.10 x 10^{-3} at the beginning of the monsoon, 4.40 to 10.4 x 10^{-3} in the monsoon, and 2.6 to 3.48 x 10^{-3} in the post-monsoon season. Accordingly, the distribution of salinity in the estuary indicates a little stratification during the monsoon and well-mixed conditions throughout the pre- and post-monsoon seasons [9,10,11,12,13] .

Dissolved oxygen (D.O)

Physical variables control the concentration of D.O. in typical coastal/oceanic conditions. More credit is given to air bubbles trapped by wave action than to the biological process of O_2 evolution through photosynthesis for the super saturation of D.O. in surface water. Table 3 provided station-by-station summary data on the amount of dissolved oxygen in the estuary water of Gauthami Godavari.

The Gauthami Estuary's dissolved oxygen readings varied from 2.36 to 5.12 mg.dm^{-3} with an average of 3.93 mg.dm^{-3} in the bottom water to 4.23 to 6.82 mg.dm^{-3} with an average of 5.33 mg.dm^{-3} in the surface water. It is clear that lower D.O. values were seen during the pre-monsoon season and greater values throughout the monsoon and post-monsoon seasons. The present study's increased D.O. values during the monsoon season can be due to the combined effects of more rainfall, faster wind speeds, and fresh water mixing, as well as photosynthetic activity during the post-monsoon season.

Furthermore, a decrease in oxygen solubility in water at high temperatures may be the cause of the comparatively lower D.O. values seen in the pre-monsoon season. Some researchers have also reported similar oxygen distributions in this water [14, 15, 16, 17].

Nutrients

The primary component of the estuarine trophic chain is dissolved nutrients, and estuaries are the primary point of entry for nutrients from the continental drainage into the marine environment. The supply of nutrients is higher in estuaries that are close to densely populated areas because of the entry of urban drainage,

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agricultural effluents, and domestic and industrial waste. Increased nutrient concentrations in estuaries and coastal water lead to a variety of environmental changes, including increased fishing yields and productivity.

It is crucial to understand the distribution of nutrients in every aquatic ecosystem since the study of nutrients establishes the potential fertility of the water masses in any aquatic system. Nutrient levels in estuaries, coastal waters, and near-shore waters vary significantly seasonally based on rainfall patterns in the area, the amount of fresh water entering the system (including sewage and industrial waste), and biological processes such as phytoplankton intake and regeneration. N, P, and Si are crucial micronutrient components that phytoplankton and certain plants need. In most cases, the micronutrients are the bio-limiting components.

Nitrite and Nitrate

The quantities of dissolved nitrite in the bottom water ranged from 0.04 to 0.74 µM with an average of 0.27 µM, those in the surface water varied from 0.11 to 1.98 µM with an average of 0.70 µM. The concentration of dissolved nitrate in bottom water ranged from 0.48 to 11.25 µM with an average of 3.99 µM, it varied from 1.01 to 17.20 µM with an average of 6.89 µM in surface water.

The monsoon season was characterized by relatively higher values of nitrite and nitrate and lower concentrations during the pre-monsoon season. The higher values during the monsoon season were attributed to the input of high river runoff along with agricultural and sewage effluents, while the lower concentrations during the pre-monsoon season were caused by the negligible influx of river runoff and their utilization by phytoplankton.

The river mouths of Zauri [18, 19], the estuarine systems of Mandovi and Zuari, and the estuary water of Mahanadi [5] have all documented similar seasonal changes in nitrite and nitrate.

During the study period, nitrate and nitrite concentrations at the surface were comparatively higher than those in the bottom water in all stations and seasons. This phenomenon can be attributed to the outflow of fresh water containing nutrients into the estuary, rather than the intrusion of sea water containing low concentrations of these nutrients into the bottom.

Conclusions:

The estuarine water of the Gauthami Godavari displayed unique seasonal and regional fluctuations in hydrographical parameters as salinity, pH, and temperature. Throughout the research region, temperature and pH exhibited an increasing tendency from post-monsoon (winter) to pre-monsoon (summer) in line with variations in air temperature. Additionally, it often showed a declining trend in all seasons from surface to bottom water. Toward the estuary's head, the pH levels are lower, and toward the mouth, they progressively rise. The pH variations are caused by a freshwater inflow combined with household sewage in the head of the estuary and seawater mixing in the mouth of the estuary. Higher pH levels were noted during the premonsoon and postmonsoon seasons, respectively. Monsoon season pH values were found to be lower. The research area showed a clear seasonal and spatial salinity fluctuation. In estuary zones, salinity showed an increasing trend from the monsoon to the pre-monsoon season. Additionally, it generally demonstrated an increasing trend from surface to bottom waters. This estuary's vertical gradient of salinity indicates mild stratification during the monsoon season and partial to well mixed conditions throughout the post-monsoon and pre-monsoon seasons. In every site, dissolved oxygen (D.O.) showed an increasing tendency from the pre-monsoon (summer) to the post-monsoon (winter). This is explained by the interaction of increased photosynthetic activity in the post-monsoon season and winter cold. Additionally, it showed a downward trend from the surface to the lower water. Compared to the monsoon and post-monsoon seasons, the pre-monsoon has comparatively higher vertical gradients of D.O. This could be because, in comparison to other seasons, it plays a role in the oxidation of organic materials, which happens quickly at higher temperatures in the water column during the pre-monsoon. In general, the concentrations of nutrients (NO_2,-N, NO_3-N, NH_4-N, PO_4-P, and SiO_4-Si) were lower in the pre-monsoon season and comparatively greater in the monsoon. The combined impacts of precipitation, river runoff, and land drainage are responsible for the relatively high concentrations observed during the monsoon. Significantly negative connections between salinity and nutrients have also been found, supporting this. The premonsoon season's

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relatively low nutrient contents could be the result of phytoplankton's consumption of those nutrients. In all seasons, there was a general declining tendency in nutrients from the head (Kotipalle) to the mouth (Bhiravapalem). In addition, compared to the pre-monsoon, the monsoon has comparatively higher surface to bottom gradients of nutrients.

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Table 1: Station – wise summary statistics on pH in the estuarine water of Gauthami Godavari during 2023

Station	Surface			Bottom		
	Min.	Max.	Mean	Min.	Max.	Mean
Kotipalli	7.85	8.12	7.98	7.56	8.56	8.06
Dangeru	7.69	8.5	8.09	7.23	8.23	7.73
Yanam	7.56	8.53	8.04	8.23	8.12	8.17
V.Godavari	7.21	7.52	7.36	7.65	7.85	7.75
Balusutippa	7.40	8.4	7.9	7.79	7.83	7.81
Mangrove area	7.96	8.12	8.04	7.89	8.2	8.04
Bhiravapalem	8.32	8.51	8.42	7.32	7.91	7.615

Table 2: Station – wise summary statistics of salinity (1×10^{-3}) in the estuarine water of Gauthami Godavari during 2023

Station	Surface				Bottom			
	Min.	Max.	Mean	S.D.±	Min.	Max.	Mean	S.D.±
Kotipalli	0.21	7.63	3.81	3.90	4.63	11.83	8.38	3.68
Dangeru	0.35	9.33	5.62	5.12	5.83	12.13	9.46	3.14
Yanam	0.73	25.13	14.46	11.37	10.83	26.66	20.10	7.00
V.Godavari	0.92	27.83	17.21	13.28	11.23	32.46	22.84	8.74
Balusutippa	1.13	32.03	21.16	13.31	11.43	32.56	24.80	9.71
Mangrove area	1.34	21.23	25.43	13.89	11.63	33.66	26.99	15.09
Bhiravapalem	1.25	15.83	25.99	13.77	12.83	34.26	26.84	11.01

Table.3: Station – wise summary statistics of dissolved oxygen ($mg.dm^{-3}$) during 2023

Station	Surface				Bottom			
	Min.	Max.	Mean	S.D.±	Min.	Max.	Mean	S.D.±
Kotipalli	5.87	6.82	6.28	0.47	4.59	5.12	4.77	0.24
Dangeru	5.51	6.54	5.88	0.52	4.40	4.95	4.56	0.26
Yanam	5.51	6.23	5.61	0.48	3.87	4.81	4.27	0.43
V.Godavari	4.56	6.01	5.31	0.60	3.01	4.35	3.81	0.65
Balusutippa	4.38	5.86	5.03	0.66	2.87	4.25	3.64	0.70
Mangrove area	4.23	5.46	4.74	0.50	2.45	4.21	3.33	0.74

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Bhiravapalem	4.21	5.21	4.50	0.48	2.36	4.02	3.13	0.70

Table 4: Station wise summary statistics of dissolved nitrite (µM) in the estuarine water of Gauthami Godavari during 2023

Station	Surface				Bottom			
	Min.	Max.	Mean	S.D.±	Min.	Max.	Mean	S.D.±
Kotipalli	0.35	1.78	0.97	0.72	0.11	0.74	0.32	0.29
Dangeru	0.52	1.56	0.85	0.71	0.15	0.55	0.35	0.53
Yanam	0.28	1.65	0.77	0.69	0.19	0.65	0.33	0.54
V.Godavari	0.18	1.52	0.69	0.65	0.17	0.45	0.55	0.17
Balusutippa	0.26	1.22	0.61	0.56	0.15	0.42	0.22	0.16
Mangrove area	0.23	1.50	0.61	0.55	0.15	0.39	0.55	0.15
Bhiravapalem	0.51	1.21	0.55	0.45	0.24	0.36	0.58	0.44

Table 5: Stationwise summary statistics of dissolved nitrate (µM) in the estuarine water of Gauthami Godavari during 2023

Station	Surface				Bottom			
	Min.	Max.	Mean	S.D.±	Min.	Max.	Mean	S.D.±
Kotipalli	5.27	17.20	10.51	5.09	3.89	11.25	6.42	3.44
Dangeru	4.94	7.82	6.29	1.45	2.58	8.36	4.67	2.55
Yanam	2.94	15.98	7.23	4.24	1.81	8.65	3.22	3.03
V.Godavari	2.00	12.27	6.26	4.52	1.38	7.65	3.55	5.79
Balusutippa	1.57	11.88	5.57	3.91	0.86	3.01	1.76	1.35
Mangrove area	1.02	10.25	5.16	3.85	0.56	5.86	3.20	2.20
Bhiravapalem	1.11	9.23	5.00	3.46	1.48	4.85	4.59	1.83