

Assessment of Coastal Water Quality through Weighted Arithmetic Water Quality Index around Visakhapatnam, Bay of Bengal, India

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ABSTRACT: Water quality is of influential and significant importance because of its role to human health, aquatic life, ecological integrity and sustainable economic growth. Thus, continuous assessment and monitoring of water bodies is important. This study is aimed at monitoring the water quality of coastal waters of Visakhapatnam coast. 'Weighted Arithmetic Water Quality Index' (WQI) is a numeric expression used to evaluate the quality of a given water body and to be easily understood by managers and public. High values of WQI were observed in sampling stations of S1 and S4 indicating poor quality of water, whereas, low values of WQI were recorded in all other field stations indicating suitability of those areas for human activities like recreation. Thus, 'Weighted Arithmetic Water Quality Index' proved to be a good measure for categorizing quality of coastal waters of Visakhapatnam.

KEYWORDS: 'Weighted Arithmetic Water Quality Index' (WQI), Seasonal variations, Coastal waters, Visakhapatnam.

I. INTRODUCTION

The coastal environment, as a complex system is mainly influenced by various physical, chemical biological processes. Water quality impacts both directly and indirectly on the diversity and abundance of marine communities as well as recreational use of the coast. Thus, monitoring programs of aquatic systems play a significant role in water quality management.

However, the water quality is difficult to be evaluated from a large number of samples, each containing varying concentrations of various water quality variables. The Water Quality Indices (WQI) is among the most effective ways to communicate the information on water quality trends for the water quality management. The present investigation was carried out to calculate the Water Quality Index (WQI) in order to assess the quality of Coastal waters of Visakhapatnam.

In [1], the author gave a detailed account of water quality and some aspects of pollution in Visakhapatnam harbour, consequent to the rapid industrialisation and urbanisation of the city. Assimilative and healing capacities of coastal waters were studied by [2]. However, their studies have not enumerated the water quality indices on this coast with seasonal variations. The present study focuses on comparison of water quality at different coastal areas along Visakhapatnam coast through "Weighted Arithmetic Water Quality Index".

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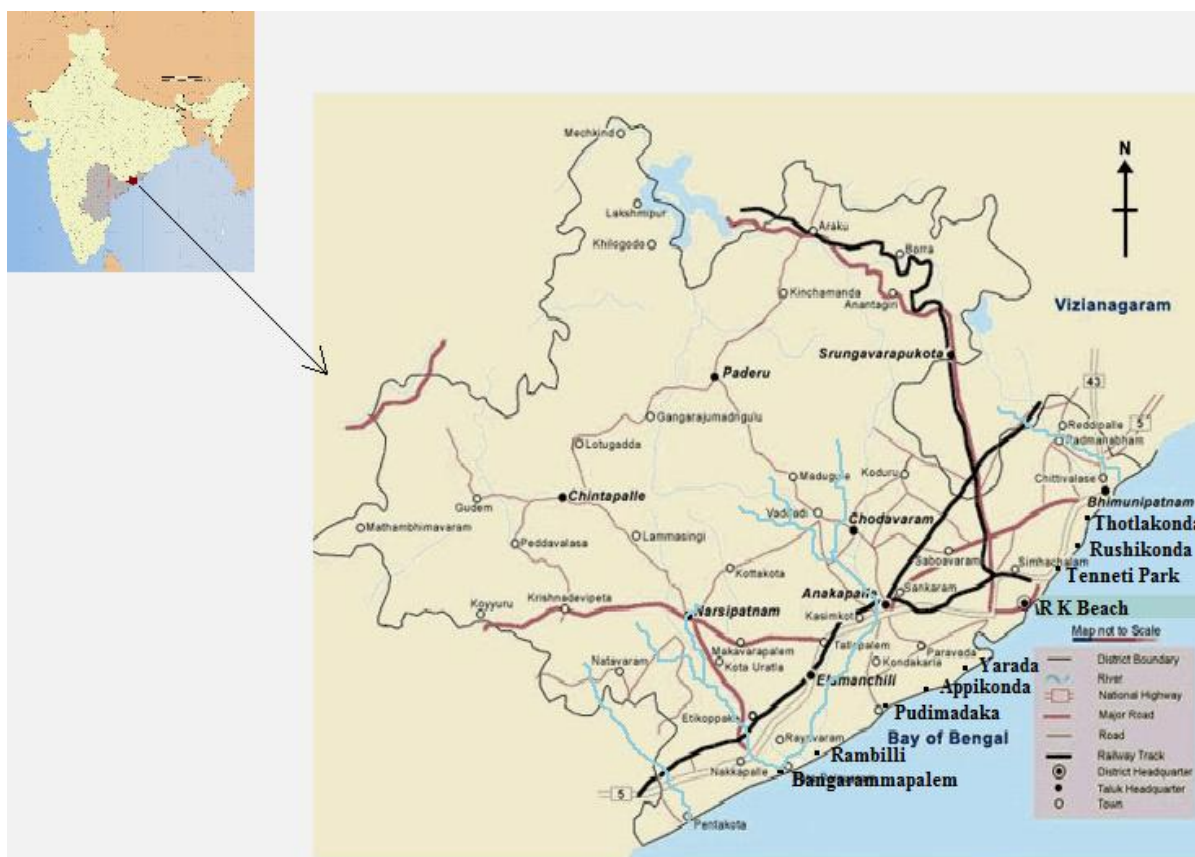
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II. MATERIALS AND METHODS

Study Area

The study area of Visakhapatnam Coast of Bay of Bengal, is located in North Eastern part of Andhra Pradesh between 17°15' and 18° 32' Northern latitude and 82° 54' and 83° 30' in Eastern longitude.

Figure 1: Map showing the field stations in the present study area of Visakhapatnam



Visakhapatnam coastline from Bangarammapalem in the south to Bheemunipatnam in the north comprises of shallow water bays formed due to the protruding hills of 'Eastern Ghats complex' into the sea. The Bangarammapalem – Bheemunipatnam coast is associated with several drainage channels that carry nutrients and sediments to the coast, the Sarada River at Bangarammapalem and Gosthani River at Bheemunipatnam, being the major sources as such. For the present study, ten sampling stations were selected along with their geographical positions given in (table 1) below.

Table 1: Sampling stations and their Geographical locations.

| S.No | Sampling Station | Geographical Position |
|------|------------------|---------------------------|
| 1 | Bangarammapalem | 17°24'56"N and 82°52'04"E |
| 2 | Rambili | 17°27'28"N and 82°57'09"E |
| 3 | Pudimadaka | 17°28'29"N and 82°59'38"E |
| 4 | Appikonda | 17°34'09"N and 83°10'14"E |
| 5 | Yarada | 17°39'47"N and 83°17'01"E |

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| | | |
|----|-------------------|---------------------------|
| 6 | Ramakrishna Beach | 17°42'40"N and 83°19'09"E |
| 7 | Tenneti Park | 17°44'53"N and 83°21'01"E |
| 8 | Rushikonda Beach | 17°47'25"N and 83°23'22"E |
| 9 | Thotlakonda | 17°49'43"N and 83°24'59"E |
| 10 | Bheemunipatnam | 17°53'26"N and 83°27'24"E |

Water Sampling and Analysis:

The water samples were collected in pre-cleaned plastic polyethylene bottles for physico-chemical analysis throughout the year in four seasons from April, 2013 to March, 2015. The coastal water samples were analyzed for temperature pH, conductivity, turbidity salinity, dissolved oxygen, biological oxygen demand, ammonical nitrogen, nitrites, nitrates, phosphate-phosphorus, silicates and trace metals (iron, copper, chromium, zinc, cadmium and lead) following standard procedures recommended by the [3].

Traditional approaches to assess water quality are based on a comparison of experimentally determined parameter values with existing guidelines.

Table 2: Standards and permissible limits for Coastal Waters

| S.No | Parameter | Prescribed Standards |
|------|---------------------------|--|
| 1 | Temperature | 26-30°C** |
| 2 | pH | 6.5 – 8.5 * |
| 3 | Electrical Conductivity | |
| 4 | Turbidity | 30 NTU* |
| 5 | Salinity | - |
| 6 | Total Suspended Solids | - |
| 7 | Dissolved Oxygen | 4.0 mg/l or 50% saturation value whichever is higher* |
| 8 | Biochemical Oxygen Demand | 3 mg/lit * |
| 9 | Ammonia Nitrogen | 0.021 mg/l ** |
| 10 | Nitrite Nitrogen | - |
| 11 | Nitrate Nitrogen | 0.01-0.06 mg/l as Nitrate** |
| 12 | Phosphate-Phosphorus | 0.001 – 0.01 mg/lit as Phosphate** |
| 13 | Silicate | 2.8 mg/l(avg)** |
| 14 | Iron (Fe) | 3mg/l** |
| 15 | Copper (Cu) | 0.5mg/l** |
| 16 | Chromium (Cr) | 0.05mg/l** |
| 17 | Zinc (Zn) | 0.5mg/l** |
| 18 | Cadmium (Cd) | 0.005 mg/l** |
| 19 | Lead (Pb) | 0.05mg/l** |

* Water Quality Standards for Coastal Waters Marine Outfalls. SW-II Standard. Central Pollution Control Board, New Delhi. Source : EPA, 1986 [GSR 7], dated Dec. 22, 1998.

** South African Water Quality Guidelines for Coastal Marine Waters, 1996. International Target Values for the Natural Marine Environment, Vol.1, pp B-1-B-3. and Chap. 4.2. pp 31.

However, it does not readily give an overall view of the spatial and temporal trends in the water quality [4]. Water Quality Indices are established from important physico-chemical parameters for different months to understand the coastal water quality better for the general public using 'Weighted Arithmetic Water Quality Index'.

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$$WQI = \frac{\sum QiWi}{\sum Wi}$$

Where, Qi = Quality rating
 Wi = Relative weight

Water quality grads can be classified by as excellent, good, poor, very poor and unsuitable with reference to the grads provide in Table 3. [4],[5].

Table 3: Grads of Water Quality Index (WQI) and status of Water Quality Rating.

| WQI | Category of Water Quality |
|---------|---------------------------|
| <50 | Excellent |
| 50-100 | Good |
| 100-200 | Poor |
| 200-300 | Very Poor |
| >300 | Unsuitable |

III. RESULTS AND DISCUSSION

Investigations on water quality revealed appreciable differences between the coastal environment subject to pollution and the unaffected open sea location. Statistical descriptions such as mean, standard deviation, maximum and minimum values of analytical results of Physico-chemical parameters at different field station at Visakhapatnam coast are given in Table 4.

Table 4: Statistical description of various parameters at different sampling stations of Visakhapatnam coastline.

| Parameters | Statistics | S1 | S2 | S3 | S4 | S5 | S6 | S7 | S8 | S9 | S10 |
|--------------------------------------|----------------|-------|------|------|------|------|-------|-------|------|------|------|
| <i>Temperature (degrees Celsius)</i> | Minimum | 26.6 | 26.6 | 26.2 | 32.8 | 26.1 | 26.4 | 26.1 | 26.3 | 26 | 26.8 |
| | Maximum | 29.7 | 29.1 | 29.1 | 33.6 | 29 | 29.6 | 29.4 | 29.1 | 29 | 29.2 |
| | Mean | 27.85 | 27.8 | 27.5 | 33.2 | 27.6 | 28.05 | 27.83 | 27.8 | 27.6 | 27.9 |
| | Std. Deviation | 1.215 | 1 | 0.99 | 0.29 | 0.98 | 1.116 | 1.197 | 0.96 | 1.08 | 0.99 |
| <i>pH</i> | Minimum | 7.9 | 7.7 | 7.6 | 7.8 | 7.6 | 7.9 | 7.8 | 7.8 | 7.6 | 7.8 |
| | Maximum | 8.3 | 8.1 | 8.1 | 8.7 | 8 | 8.4 | 8.3 | 8.2 | 8 | 8.2 |
| | Mean | 8.125 | 8 | 7.88 | 8.36 | 7.75 | 8.036 | 7.961 | 8.08 | 7.76 | 7.88 |
| | Std. Deviation | 0.128 | 0.14 | 0.17 | 0.29 | 0.15 | 0.16 | 0.15 | 0.13 | 0.15 | 0.14 |
| <i>Conductivity (mS/cm)</i> | Minimum | 41.27 | 30 | 25.1 | 65.3 | 25.8 | 30.02 | 29.98 | 27.3 | 25.5 | 27.7 |
| | Maximum | 44.68 | 48.9 | 36.8 | 79.3 | 38.9 | 43.14 | 44.58 | 41.4 | 34.7 | 42.3 |
| | Mean | 42.94 | 33.6 | 28.2 | 68.2 | 28 | 33.18 | 32.72 | 30.5 | 27.4 | 30.2 |
| | Std. Deviation | 1.016 | 6.25 | 3.62 | 4.61 | 4.42 | 4.204 | 4.904 | 4.5 | 2.98 | 4.93 |
| <i>Turbidity (NTU)</i> | Minimum | 34.06 | 27.3 | 20 | 36.2 | 21 | 28.01 | 27.57 | 26.4 | 24.3 | 28 |
| | Maximum | 45.6 | 40.4 | 34.2 | 47.5 | 37.8 | 42.5 | 41.57 | 39.7 | 38.6 | 40.9 |
| | Mean | 36.41 | 30.5 | 23.3 | 39.1 | 25.2 | 32.86 | 32.2 | 30.7 | 27.8 | 32 |
| | Std. Deviation | 3.891 | 4.11 | 4.65 | 4.01 | 5.75 | 5.123 | 5.261 | 5 | 4.89 | 4.67 |
| <i>Salinity (ppt)</i> | Minimum | 18.34 | 21.8 | 19.8 | 20.5 | 21.2 | 18.6 | 20.1 | 21.5 | 21.3 | 20 |
| | Maximum | 24.2 | 28.3 | 24.3 | 26.9 | 27.2 | 27.2 | 27.26 | 27.6 | 28.6 | 27.6 |
| | Mean | 21.63 | 26.1 | 23 | 23.8 | 25.7 | 25.02 | 25.62 | 25.8 | 26.4 | 25.4 |
| | Std. Deviation | 2.086 | 2.37 | 1.64 | 2.56 | 2.1 | 3.169 | 2.572 | 2.13 | 2.7 | 2.65 |
| <i>Total Suspended Solids (mg/l)</i> | Minimum | 34.14 | 34.8 | 21.4 | 39.7 | 21.1 | 28.26 | 29.08 | 32.5 | 20.8 | 22.3 |
| | Maximum | 47.07 | 42.8 | 30.7 | 53.1 | 31.1 | 40.9 | 42.87 | 41.7 | 28.2 | 38.4 |
| | Mean | 37.05 | 37 | 23.8 | 43.2 | 24.4 | 32.08 | 32.64 | 35.9 | 22.8 | 26.3 |
| | Std. Deviation | 4.486 | 2.82 | 3.63 | 4.63 | 3.63 | 4.85 | 4.824 | 3.63 | 2.88 | 5.86 |
| <i>Dissolved Oxygen (mg/l)</i> | Minimum | 0.8 | 3.1 | 4.3 | 2.26 | 4 | 3.16 | 3.86 | 3.8 | 4 | 3.6 |
| | Maximum | 5.2 | 5.9 | 7.2 | 3.8 | 7 | 6.8 | 6.9 | 6.7 | 7.3 | 6.7 |
| | Mean | 3.725 | 4.83 | 5.81 | 2.85 | 5.69 | 5.62 | 5.658 | 5.64 | 5.88 | 5.44 |
| | Std. Deviation | 1.312 | 0.93 | 0.79 | 0.47 | 0.81 | 1.056 | 0.849 | 0.83 | 0.91 | 0.86 |

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|---|----------------|-------|------|------|------|------|-------|-------|------|------|------|
| <i>Biochemical Oxygen Demand (mg/l)</i> | Minimum | 3.3 | 2.4 | 0.7 | 0.2 | 0.5 | 2.3 | 2 | 1.8 | 0.9 | 1.3 |
| | Maximum | 6.8 | 5.7 | 2.4 | 1.7 | 3.2 | 5.8 | 6.6 | 4.7 | 2.9 | 3.8 |
| | Mean | 3.975 | 2.89 | 1.09 | 0.54 | 1.15 | 3.013 | 2.775 | 2.28 | 1.28 | 1.8 |
| | Std. Deviation | 1.16 | 1.14 | 0.55 | 0.49 | 0.87 | 1.143 | 1.554 | 0.99 | 0.66 | 0.82 |
| <i>Ammonical Nitrogen (mg/l)</i> | Minimum | 0.017 | 0.01 | 0.01 | 0 | 0.01 | 0.01 | 0.01 | 0.01 | 0 | 0.01 |
| | Maximum | 0.056 | 0.03 | 0.02 | 0.02 | 0.03 | 0.036 | 0.031 | 0.03 | 0.03 | 0.03 |
| | Mean | 0.027 | 0.02 | 0.01 | 0 | 0.01 | 0.018 | 0.019 | 0.01 | 0.01 | 0.02 |
| | Std. Deviation | 0.013 | 0 | 0.01 | 0.01 | 0.01 | 0.008 | 0.008 | 0.01 | 0.01 | 0.01 |
| <i>Nitrates (mg/l)</i> | Minimum | 0.03 | 0.01 | 0.01 | 0 | 0.01 | 0.011 | 0.023 | 0.02 | 0.01 | 0.02 |
| | Maximum | 0.073 | 0.03 | 0.04 | 0.03 | 0.04 | 0.054 | 0.063 | 0.05 | 0.04 | 0.24 |
| | Mean | 0.039 | 0.02 | 0.02 | 0.01 | 0.02 | 0.026 | 0.03 | 0.03 | 0.02 | 0.05 |
| | Std. Deviation | 0.014 | 0.01 | 0.01 | 0.01 | 0.01 | 0.013 | 0.014 | 0.01 | 0.01 | 0.08 |
| <i>Nitrites (mg/l)</i> | Minimum | 0.005 | 0 | 0 | 0 | 0 | 0.003 | 0.002 | 0 | 0 | 0 |
| | Maximum | 0.014 | 0.01 | 0.01 | 0.01 | 0.01 | 0.021 | 0.018 | 0.01 | 0.01 | 0.02 |
| | Mean | 0.008 | 0 | 0 | 0 | 0 | 0.006 | 0.005 | 0 | 0 | 0.01 |
| | Std. Deviation | 0.003 | 0 | 0 | 0 | 0 | 0.006 | 0.006 | 0 | 0 | 0.01 |
| <i>Phosphates (mg/l)</i> | Minimum | 0.019 | 0.01 | 0 | 0 | 0 | 0.006 | 0.005 | 0.01 | 0 | 0.01 |
| | Maximum | 0.036 | 0.02 | 0.01 | 0.01 | 0.02 | 0.03 | 0.024 | 0.02 | 0.01 | 0.02 |
| | Mean | 0.025 | 0.01 | 0.01 | 0 | 0.01 | 0.017 | 0.014 | 0.02 | 0.01 | 0.01 |
| | Std. Deviation | 0.006 | 0 | 0 | 0 | 0 | 0.007 | 0.006 | 0 | 0 | 0 |
| <i>Silicates (mg/l)</i> | Minimum | 0.085 | 0.08 | 0.08 | 0.1 | 0.07 | 0.081 | 0.086 | 0.09 | 0.07 | 0.08 |
| | Maximum | 0.124 | 0.1 | 0.1 | 0.17 | 0.1 | 0.113 | 0.127 | 0.13 | 0.1 | 0.11 |
| | Mean | 0.098 | 0.09 | 0.09 | 0.14 | 0.08 | 0.092 | 0.1 | 0.11 | 0.08 | 0.09 |
| | Std. Deviation | 0.015 | 0.01 | 0.01 | 0.03 | 0.01 | 0.013 | 0.016 | 0.01 | 0.01 | 0.01 |
| <i>Iron (mg/l)</i> | Minimum | 1.3 | 2 | 0.8 | 3.9 | 2.1 | 2.6 | 2.2 | 1.7 | 1 | 2.1 |
| | Maximum | 2.8 | 3.1 | 2.1 | 5.2 | 2.9 | 3.3 | 3 | 2.4 | 2 | 2.8 |
| | Mean | 1.738 | 2.38 | 1.3 | 4.63 | 2.6 | 2.95 | 2.488 | 2.08 | 1.35 | 2.41 |
| | Std. Deviation | 0.573 | 0.4 | 0.45 | 0.44 | 0.26 | 0.256 | 0.253 | 0.21 | 0.33 | 0.21 |
| <i>Copper (mg/l)</i> | Minimum | 0.011 | 0.02 | 0.01 | 0.05 | 0.01 | 0.027 | 0.011 | 0.01 | 0.01 | 0.01 |
| | Maximum | 0.017 | 0.03 | 0.02 | 0.09 | 0.02 | 0.04 | 0.025 | 0.02 | 0.02 | 0.02 |
| | Mean | 0.014 | 0.02 | 0.01 | 0.07 | 0.02 | 0.033 | 0.017 | 0.02 | 0.01 | 0.02 |
| | Std. Deviation | 0.002 | 0 | 0 | 0.02 | 0 | 0.004 | 0.005 | 0 | 0 | 0 |
| <i>Chromium (mg/l)</i> | Minimum | 0.019 | 0.03 | 0.03 | 0.1 | 0.02 | 0.031 | 0.028 | 0.03 | 0.01 | 0.01 |
| | Maximum | 0.024 | 0.04 | 0.04 | 0.16 | 0.03 | 0.062 | 0.043 | 0.04 | 0.03 | 0.04 |
| | Mean | 0.021 | 0.03 | 0.03 | 0.12 | 0.03 | 0.05 | 0.038 | 0.04 | 0.02 | 0.03 |
| | Std. Deviation | 0.002 | 0 | 0 | 0.02 | 0 | 0.013 | 0.006 | 0.01 | 0.01 | 0.01 |
| <i>Zinc (mg/l)</i> | Minimum | 0.055 | 0.05 | 0.04 | 0.1 | 0.04 | 0.011 | 0.054 | 0.04 | 0.05 | 0.05 |
| | Maximum | 0.071 | 0.06 | 0.05 | 0.15 | 0.07 | 0.106 | 0.091 | 0.07 | 0.06 | 0.06 |
| | Mean | 0.065 | 0.06 | 0.05 | 0.13 | 0.06 | 0.088 | 0.073 | 0.06 | 0.05 | 0.06 |
| | Std. Deviation | 0.007 | 0 | 0 | 0.02 | 0.01 | 0.031 | 0.016 | 0.01 | 0.01 | 0 |
| <i>Cadmium (mg/l)</i> | Minimum | 9E-04 | 0 | 0 | 0.02 | 0 | 0.007 | 0.004 | 0 | 0 | 0 |
| | Maximum | 0.002 | 0 | 0 | 0.04 | 0.01 | 0.014 | 0.01 | 0.01 | 0 | 0.01 |
| | Mean | 0.001 | 0 | 0 | 0.03 | 0 | 0.01 | 0.006 | 0.01 | 0 | 0 |
| | Std. Deviation | 2E-04 | 0 | 0 | 0.01 | 0 | 0.003 | 0.002 | 0 | 0 | 0 |
| <i>Lead (mg/l)</i> | Minimum | 0.001 | 0 | 0 | 0.04 | 0 | 0.01 | 0.004 | 0 | 0 | 0 |
| | Maximum | 0.002 | 0 | 0 | 0.06 | 0.01 | 0.026 | 0.014 | 0.01 | 0 | 0.01 |
| | Mean | 0.001 | 0 | 0 | 0.05 | 0 | 0.018 | 0.01 | 0.01 | 0 | 0.01 |
| | Std. Deviation | 4E-04 | 0 | 0 | 0.01 | 0 | 0.006 | 0.004 | 0 | 0 | 0 |

S1-Bangarampalem; S2-Rambilli; S3-Pudimadaka; S4-Appikonda; S5-Yarada; S6-RK Beach; S7-Tenneti Park;
S8-Rushikonda; S9-Thotlakonda; S10-Bheemunipatnam.

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The sampling station, Appikonda, where the effects of pollution are relatively high, the waters are distinctly characterized by an overall range of (median values) high temperature (32.8^oC – 33.6^oC), pH (7.8-8.7), high turbidity (36.2-47.5 NTU); low dissolved oxygen (2.26-3.8 mg/l), low nutrients and high trace metals. These results can be attributed to the release of industrial effluents discharge at the sampling point. High nutrient concentrations such as ammonical nitrogen (0.027mg/l), Nitrates (0.039 mg/l), Nitrites (0.08 mg/l), Phosphates (0.025 mg/l) and silicates (0.098 mg/l) inputs were observed in the Bangarammapalem sampling station due to the inflow of Sarada River, which carries high loads of nutrients during rainy seasons.

During the study, the values of water quality parameters at other field station (Rambili, Pudimadaka, Yarada, R.K Beach, Tenneti Park, Rushikonda, Thotlakonda and Bheemunipatnam) are within the range of recommended standards (Table 2).

Application of WQI is a useful method in assessing the suitability of water for various beneficial uses. The WQI values of the present investigation from different sampling stations are given in Table 5.

Table 5: Water Quality Indices calculated from different sampling stations in all seasons at Visakhapatnam Coastline.

| Year | Season | S1 | S2 | S3 | S4 | S5 | S6 | S7 | S8 | S9 | S10 |
|------|---------|--------|-------|-------|--------|-------|--------|--------|--------|-------|-------|
| 2013 | APR-JUN | 76.73 | 50.90 | 26.18 | 279.82 | 48.03 | 149.84 | 87.49 | 100.65 | 36.81 | 79.59 |
| | JUL-SEP | 81.92 | 52.45 | 25.84 | 235.33 | 49.32 | 124.31 | 78.06 | 99.58 | 34.29 | 81.99 |
| | OCT-DEC | 108.23 | 66.70 | 35.18 | 161.78 | 52.19 | 118.23 | 85.87 | 77.35 | 40.43 | 71.56 |
| 2014 | JAN-MAR | 90.93 | 59.86 | 29.58 | 183.03 | 49.88 | 113.28 | 67.96 | 71.73 | 36.84 | 71.46 |
| | APR-JUN | 85.92 | 52.05 | 25.29 | 179.8 | 53.03 | 150.49 | 82.96 | 111.65 | 35.88 | 87.56 |
| | JUL-SEP | 73.74 | 63.42 | 32.60 | 285.45 | 39.0 | 100.87 | 89.02 | 86.32 | 38.40 | 79.57 |
| 2015 | OCT-DEC | 153.0 | 91.43 | 68.08 | 313.89 | 86.79 | 200.59 | 153.72 | 115.42 | 76.98 | 136.3 |
| | JAN-MAR | 106.8 | 73.82 | 38.81 | 164.69 | 70.52 | 161.90 | 132.94 | 109.34 | 36.63 | 98.49 |

S1-Bangarammapalem; S2-Rambilli; S3-Pudimadaka; S4-Appikonda; S5-Yarada; S6-RK Beach; S7-Tenneti Park; S8-Rushikonda; S9-Thotlakonda; S10-Bheemunipatnam.

Water Quality Indices are established from important physico-chemical parameters for different months to understand the coastal water quality better for the general public. A lower value of WQI would indicate a better quality of water whereas high values indicate poor quality of water.

The calculated values of WQI for the studied parameters in this investigation were less than 50 for the sampling stations of Pudimadaka, Thotlakonda which indicate excellent water quality, where minimal human intervention was observed. In sampling stations such as Rambili, Yarada, Tenneti Park, Rushikonda and Bheemunipatnam recorded WQI values in between 50-100, indicating good quality of water. Human interventions like fishing, surfing and recreation activities are observed in these areas.

The WQI values for sampling stations (Bangarammapalem, Appikonda and RK Beach) were enumerated above 100, because of high amounts of pollutants discharges such as sewage and industrial effluents. The WQI values of RK beach are in poor range (100.87-200.89), which shows the possible vulnerability of water quality at the field station. Further, increase in human activities at this area can degrade the water quality making it unfit for public use.

During the study, it was found that the coastal waters of present study area are subject to considerable seasonal changes. Relatively high values were observed in October month of 2014, this can be the result of cyclone 'Hud-Hud', which carried waste laden run-off from land to sea. This result can be attributed to the study findings of [7], which recorded high water parameter readings post 'Hud-Hud', than before the cyclone. Significant high values of WQI were recorded in (October-December) part of the monsoon season, compared to other seasons. The present study findings are

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supported by earlier observations in seasonal variations of Physico-chemical parameters of coastal waters in Visakhapatnam [7], [8].

IV. SUMMARY AND CONCLUSION

On the basis of the examined parameters in this investigation, it can be concluded that the coastal water quality at all sampling stations, except in Bangarammapalem and Appikonda of Visakhapatnam area was good in general and was within coastal water standards in particular. The same results can be attributed from WQI values calculated from selected water quality parameters. Thus, the 'Weighted Arithmetic Water Quality Index' proved to be a useful measure for the analysis and categorization of the quality of coastal waters of Visakhapatnam region.

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