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Assessment of Water Quality Index of River Godavari at Rajahmundry

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Abstract:

Assembling different water quality parameters into one single number leads an easy interpretation of an index, thus providing an important tool for management and decision making purposes. Water Quality Index exhibits the overall water quality at a specific location and specific time based on several water quality parameters. The purpose of an index is to transform the complex water quality data into information that is easily understandable and useable by the general public. As a part of research work, eight important water viz., pH, Dissolved Oxygen, Electrical Conductivity, Total Dissolved solids, Total Alkalinity, Total Hardness, Calcium and Magnesium were used to evaluate WQI of River Godavari at Rajahmundry water quality monitoring station. In this paper, the seasonal variations of WQI during the study period (2009-2012) and future period (2012-2015) are discussed. The results revealed that the developed model performance was significant with MAE=4.97, RMSE=7.31 and MAPE=5.15% respectively. According to the classification criteria standards based on NSF WQI, the WQI values varied from 99.28 in June 2012 to 98.36 in May 2015; indicating the water is excellent to good quality. The water quality index followed a linear trend pattern the fluctuations in the dissolved oxygen levels affected the WQI.

Keywords: River Godavari, Rajahmundry, WQI

1.0 Introduction:

Water is the most important natural resource; it is the most basic human need and a valuable national asset. Efficient development and optimum utilization of water resources, therefore is of great significance to the overall development of country. Water resource management in India is going to be vitally important to sustain the needs of one billion population of India. The management of water resources is an item of high priority for the existing conditions which can be achieved only through efficient development and management. Water management is a heterogeneous area with linkages to different sectors of Indian economy. Since water is a shared and community resource, it has often led to disputes between different states and also with the neighboring countries and that adds to the problems of water resource management in India. The quality and quantity of available water resources play an important key role for the development of a nation. Hence various technologies and policies, to ensure the safety of this valuable resource, is the need of the hour for a developing country like India.

Water quality index is a means to summarize large amounts of water quality data into simple terms for reporting to management and the public in a consistent manner. Similar to the ultra violet (UV) index or an air quality index, it tells us whether the overall quality of water bodies poses a potential threat to various uses of water. WQI is a set of standards used to measure changes in water quality in a particular river reach over time and make comparisons from different reaches of a river. A WQI also allows for comparisons to be made between different rivers. This index allows for a general analysis of water quality on many levels that affect a stream's ability to host life.

The WQI was first developed by Horton in the early 1970s, is basically a mathematical means of calculating a single value from multiple test results. The index result represents the level of water quality

in a given water basin, such as lake, river or stream. After Horton a number of workers all over the world developed WQI based on rating of different water quality parameters. Basically a WQI attempts to provide a mechanism for presenting a cumulatively derived, numerical expression defining a certain level of water quality (Miller *et al.,* 1986). The different statistical approaches were followed for analyzing water quality data based on rank order of observations and factor analysis (Shoji *et al.,* 1966,). For the evaluation of water quality, WQI was applied to river water (Ashwani Kumar *et al.,* 2009, Rita.N.Kumar et al., 2009, N. Singkran . et al, 2010).

The objectives of the present study are (1) To investigate water quality of River Godavari at Rajahmundry station, Andhra Pradesh State, India (2) To determine the present and future situations of water quality index using the standards of Central Public Health Environmental Engineering Organization (CPHEEO), 1991 & Indian Council of Medical Research (ICMR), 1975 and (3) To categorize the conditions of water quality as per the classification criteria standards based on National Sanitation Foundation Water Quality Index.

2.0 Materials and Methods:

2.1 Study Area:

Godavari is the third largest river in India and a major waterway in central India, originating in the Western Ghats and flowing eastwardly across the Deccan Plateau between the states of Maharashtra and Andhra Pradesh. The river enters Andhra Pradesh state near Bhadrachalam and flows along Godhavarikhani, Rajahmundry, Kovvur, Tallapudi and Narsapur in a southeast direction until it empties into the Bay of Bengal through two mouths. The upper waters of the Godavari are scarcely utilized for irrigation, but the entire delta has turned into a garden of perennial crops by means of the anicut at Dowlaiswaram, constructed by Sir Arthur Cotton 145 years ago.

Rajahmundry is located at 16.98°N 81.78°E with an average elevation of 14 meters (45 feet). It is the fourth largest city in Andhra Pradesh, on the banks of the River Godavari, well known as the Cultural Capital of Andhra Pradesh. The Rajahmundry, part of the Deccan Traps, are located on the Godavari River and are of particular interest to geologists. The city's origins can be traced back to the rule of the Chalukya king RajarajaNarendra who reigned around 1022 A.D after whom it is named Rajamahendri or Rajamahendravaram. Later renamed as Rajahmundry during the rule of the British, for whom the city was the headquarters of the Godavari district. When the district was split into East and West, subsequently, Kakinada -a well-known port city became the headquarters of East Godavari.

Rajahmundry is also one of the Hindu pilgrimage sites, with a number of temples like the Kotilingalu (10 million Sivalingas) temple on the bank of Godavari. It hosts holy congregations called Pushkarams held once every 12 years and considered auspicious to take sin-ridding holy dips with the last in August 2003, when around 34 million are said to have taken the bath. This festival lasts for 12 days and people offer prayers and makes offerings to their departed family members.

Rajahmundry also hosts few corporates and multinationals as part of its industrial development, such as: ITC Limited, ILTD Division, The Horlicks Factory (GlaxoSmithKline Ltd), The Coastal Paper Mills (P) limited, The Kadiyam Paper Mills etc., The Central Tobacco Research Institute, Oil and Natural Gas Corporation (Headquarters of ONGC's Krishna Godavari basin), Gas Authority of India Ltd (GAIL), GVK Power Plant- Jegurupadu, Multiple gas based Power Plants by GMR Group, The A.P.Gas Power Corporation Ltd etc., in and around Rajahmundry. Hence the present research work has been taken up to assess the seasonal water quality variation and to forecast the fate of River Godavari due to various developmental activities taking place in and around Rajahmundry.

2.2 Methods:

Water samples were collected once in every month from the water quality monitoring station Rajahmundry and samples were collected from the surface waters of the River. The water samples were analyzed at “Water Quality Level –II Laboratory”, Dowlaiswaram, Hydrology Project, Irrigation & CAD Department, Government of Andhra Pradesh, India; as per the APHA standard methods of Practice. The water quality data of various parameters were studied during the period Jan 2009 to May 2012 and historic data (Jan 2004 to Dec 2008) obtained from the Hydrology Department, Govt of Andhra Pradesh, were used in the analysis. The values of the parameters obtained were used for the calculation of the WQI values of Time series model (09-12). The

analysis of the water quality data for estimation of quality parameters and WQI values was made based on season wise. The WQI obtained by the actual measured model and Time series (09-12) were compared using the statistical criterion for performance. (Mean Absolute Error, Root Mean Square Error and Mean Absolute Prediction Error). Using the overall data available till date, the water quality parameters for the future years June 2012 to May 2015 were estimated and used for the prediction of WQI of Time series (2012-2015).

Water quality index was calculated for each and every month for assessing the quality of water. It was done by considering eight important physico-chemical properties using Central Public Health Environmental Engineering Organisation (CPHEEO), 1991 & Indian Council of Medical Research (ICMR), 1975 standards. In order to calculate WQI eight important parameters, pH, dissolved oxygen (DO), total dissolved solids (TDS), electrical conductivity (EC), Total Alkalinity (Alk), Total hardness (Har-T), calcium (Ca) and magnesium (Mg) were used . These parameters maximum contribute for the quality of river. The steps for WQI are:

2.3 Weightage:

Factors which have higher permissible limits are less harmful because they can harm quality of river water when they are present in very high quantity. So weightage of factor has an inverse relationship with its permissible limits.

Therefore Wi α1/ XiOr Wi = k/Xi

Where, k = constant of proportionality

Wi = unit weight of factor

Xi = maximum permissible limits as recommended by Indian Council of Medical Research / Public Health Environmental Engineering Organization

Values of k were calculated as:

$$k = \frac{1}{\sum_{i=1}^{8} \left(\frac{1}{Xi}\right)}.$$

Where

$$\sum_{i=1}^{8} \left(\frac{1}{Xi}\right) = \frac{1}{Xi\,(pH)} + \frac{1}{Xi\,(DO)} + \frac{1}{Xi(EC)} + \frac{1}{Xi(TDS)} + \frac{1}{Xi(Alk)} + \frac{1}{Xi(Har-t)} + \frac{1}{Xi(Ca)} + \frac{1}{Xi(Mg)}$$

The weightage of all the factors were calculated on the basis of the above equation.

Table: 1 Water Quality factors: the ICMR / CPHEEO standards assigned unit Weights

Water quality Factors	ICMR / CPHEEO Standards (Xi)	Unit Weight (Wi)
pH	7.0 – 8.5 **	0.322
Dissolved Oxygen	>5*	0.548
Electrical Conductivity	<300*	0.009
Total Dissolved solids	< 1500**	0.002
Total Alkalinity	<120*	0.023
Total Hardness	<600**	0.005
Calcium	<75*	0.037
Magnesium	<50*	0.055

*ICMR Standards (1975) **CPHEEO Standards (1991)

2.4 Rating Scale:

Rating scale (Table 3) was prepared for range of values of each parameter. The rating varies from 0 to 100 and is divided into five intervals. The rating Xr = 0 implies that the parameter present in water exceeds the standard maximum permissible limits and water is severely polluted. On the other hand Xr= 100 implies that the parameter present in water has the most desirable value. The other ratings fall between these two extremes and are Xr = 40, Xr = 60 and Xr = 80 standing for excessively polluted, moderately polluted and slightly less polluted respectively. This scale is modified version of rating scale given by Tiwari and Mishra (1985).

Table 2: Rating Scale for Calculating WQI

Water Quality Parameter	Ranges				
pH	7.0–8.5	8.6 - 8.7 6.8 – 6.9	8.8 – 8.9 6.7 – 6.8	9.0 – 9.2 6.5 – 6.7	>9.2 < 6.5
Dissolved Oxygen	> 7.0	5.1 - 7.0	4.1 – 5.0	3.1 – 4.0	<3.0
Electrical Conductivity	0 – 75	75.1–150	150.1 –225	225.1 - 300	>300
Total Dissolved Solids	0 -375	375.1–750	750.1-1125	1125.1–1500	>1500
Total Alkalinity	21-50	50.1- 70 15.1 - 20	70.1 – 90 10.1 – 15	90.1 – 120 6 – 10	>120 <6
Total Hardness	0 -150	150.1 – 300	300.1– 450	450.1 – 600	>600
Calcium	0 – 20	20.1 – 40.0	40.1 – 60.0	60.1 – 75.0	>75
Magnesium	0 – 12.5	12.6 – 25.0	25.1 – 37.5	37.6 -50	>50
Xr	100	80	60	40	0
Extent of Pollution	Clean	Slight pollution	Moderate Pollution	Excess Pollution	Severe Pollution

Table3: Rating Scale for Quality of water

Value of WQI	Quality of Water
90 – 100	Excellent
70 – 90	Good
50 – 70	Medium
25 - 50	Bad
0 - 25	Very Bad

2.5 Water Quality Index Calculation:

Essentially, a WQI is a compilation of a number of parameters that can be used to determine the overall quality of a river. WQI is calculated for each month and is given in Table 4. The parameters involved in the WQI are dissolved oxygen, pH, Dissolved Oxygen, Electrical Conductivity, Total Dissolved solids, Total alkalinity, Total Hardness, Calcium and Magnesium. The numerical value is then multiplied by a weighting factor that is relative to the significance of the test to water quality. The sum of the resulting values is added together to arrive at an overall water quality index.

WQI = Wi x Xr

i.e. Water Quality Index is equal to the product of rating (Xr) and unit weight (Wi) of all the factors.

Wi x Xr = Wi(pH) x Xr(pH) + Wi(DO) x Xr(DO) + Wi(EC) + Xr (EC)
+ Wi(TDS) x Xr(TDS) + Wi(Total Alkalinity) x Xr(Total Alkalinity)
+ Wi(Hardness) x Xr(Hardness) + Wi(Ca) x Xr(Ca) + Wi(Mg) x Xr(Mg)

The values of Xi, Wi and Xr are given in Tables 2 and 3. Hence by multiplying Wi and Xr we can get the value of WQI. The WQI result represent the level of water quality in a given water basin such as lake, river or stream. Similar WQI was given by Mariappan*et al.* (1998) by using nine important water quality parameters.

Basic statistical analysis was done for each parameter.

3.0 Results and Discussion:

The values of the parameters obtained for the Time series (09-12) model were used for the calculation of the WQI values of Time series model (09-12). The analysis of the water quality data for estimation of quality parameters and WQI values was made based on season wise. The WQI obtained by the actual measured model and Time series (09-12) were compared using the statistical criterion for performance. The descriptive statistics of the three developed models viz., Actual Measured WQI model, Time Series (09-12) model and Time Series (12-15) model are tabulated above. Significant correlation was found for the Time series model (09-12) and Actual measured model, which is attributed to the consistency in the estimation of the forecasted water quality parameters. The trend patterns of WQI for both the present study period models were significantly identical. The values of the WQI for both the model matched well during the southwest monsoon season (June to Sept) and northeast monsoon period (Oct to Dec). Variations occurred for a few months during winter (Jan to Feb) and summer season (Mar to May) due to the fluctuations in the Dissolved Oxygen levels in water. The

availability of dissolved oxygen plays an important role in the health of River, hence higher weightage factor was given to dissolved oxygen. As such any slight change may alter the rating factor, and WQI obtained by the product of weigthage factor and rating factor will be significantly altered, thereby affecting the pattern of the WQI.

The forecasted water quality index values for June 2012 to May 2015 are shown in table:5. The higher values of WQI indicated that the water is very much clear and free of any impurities, and the water is in good condition to support the biotic communities. High values of WQI were obtained throughout the year 2012-2013 indicating the quality of water is of excellent grade. Identical values of WQI were obtained for the winter season (Jan to Feb) and summer season (Mar to May) for all the future three years. The WQI value ranged from 88.32 in June 2013 to 88.689 in Dec 2014 during the southwest monsoon season (June to Sep) and northeast monsoon period (Oct to Dec).(Mean Absolute Error, Root Mean Square Error and Mean Absolute Prediction Error). The results of the various proposed models are tabulated below;

Table4: Descriptive Statistics of Water Quality Index of Rajahmundry station:

Time Period	Minimum	Maximum	Mean	Std. Dev	Variance
Actual Measured	88.04	99.46	96.53	4.74	22.51
Time Series (09-12)	87.68	99.28	93.98	5.68	32.22
Time Series (12-15)	88.32	99.46	95.07	5.17	26.72

Table5: Water Quality Index values for Future three years

Month	2012-13	2013-14	2014-15
June	99.28	88.32	88.32
July	99.28	88.32	88.32
Aug	99.28	88.32	88.32
Sep	99.28	88.32	88.78
Oct	99.28	99.46	88.50
Nov	99.28	88.5	88.68
Dec	99.28	88.5	88.68
Jan	99.28	99.28	99.28
Feb	99.28	99.28	99.28
Mar	99.10	98.36	98.36
Apr	99.10	98.36	98.36
May	99.10	98.36	98.36

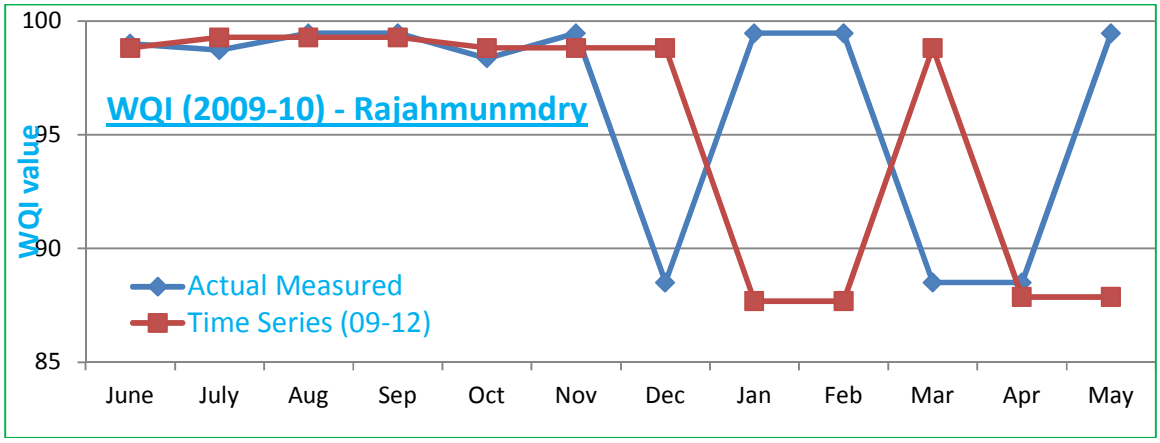

Figure 1(a) : The Monthly Variations of WQI during 2009-2010

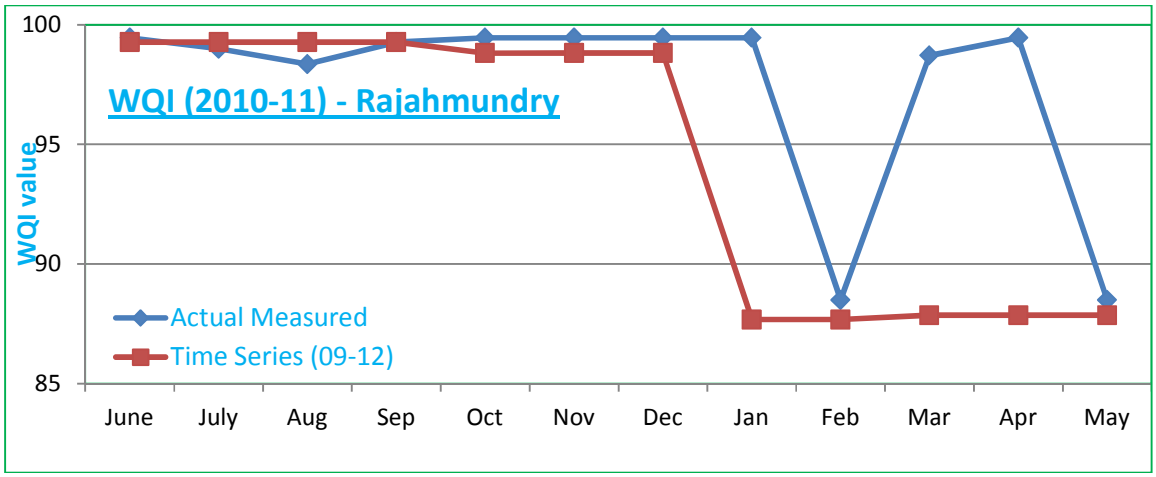

Figure 1(b): The Monthly Variations of WQI during 2010-2011

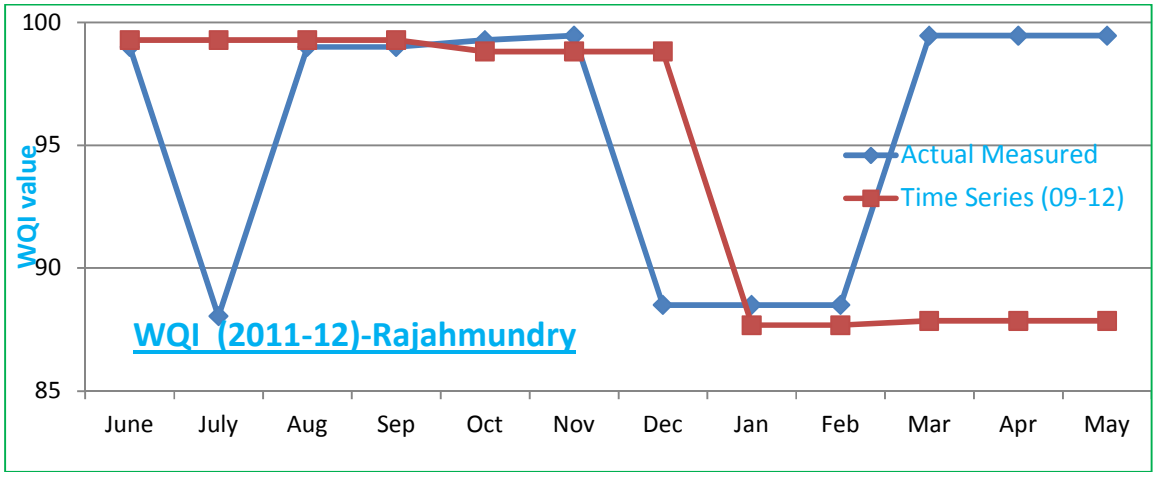

Figure 1(c): The Monthly Variations of WQI during 2011-2012

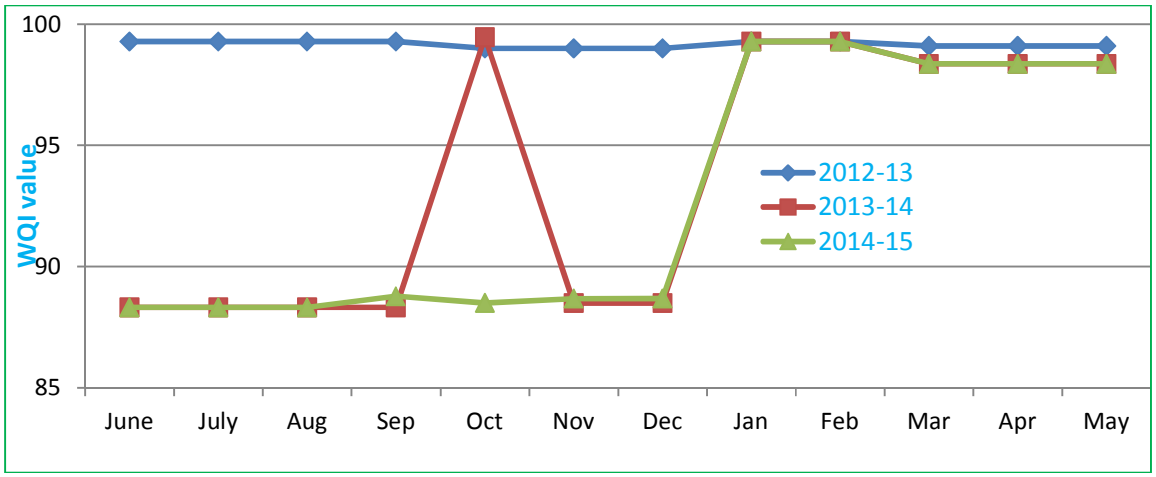

Figure 1(d): The Monthly Variations of WQI for the Future 3Years

4.0 Conclusion:

The results of the limited study indicate that the performance of the Actual Measured model and the Time Series (09-12) model were significant. The statistical criterion revealed the MAE=4.97, RMSE=7.31 and MAPE=5.15% respectively, which indicated that the developed models were performing well. The dissolved oxygen level is mostly responsible for the variations occurring in the WQI values. Fluctuations in the dissolved oxygen levels (beyond 7.0 and b/w 7.0 – 5.1) altered the rating factor (from 100 to 80) which had a direct implication on the WQI values. The water quality of River Godavari at Rajahmundry station varied from excellent to good. High values of WQI for the future three years (June 2012 to May 2015) indicate that the water quality of River Godavari is good. However, WQI may be used as a tool to convey the information regarding the quality of water and to take up necessary measures so as to maintain the quality and life of the mighty River. Further the water quality index of river Godavari for future years can be predicted using the present developed model.

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