# Water Quality Assessment of Six Water Bodies of River Godavari using WAWQI and NSFWQI

**G. Sri Bala, G.V.R. Srinivasa Rao, P.A.R.K. Raju, M. Jagapathi Raju**

***Abstract- Water bodies such as rivers, lakes and ponds act like big reservoirs for water supply and at the same time they act as dumping pools for waste discharges. The key step for the supervision of water systems is to obtain information on the changes of quality data with respect to time and place. Water Quality Index (WQI) is a statistical precise tool that converts large water quality data into a distinct and unique number that is easily understood by the public. In the present study, commonly used WQI's say Weighted Average Water Quality Index (WAWQI) and National Sanitation Foundation Water Quality Index (NSFWQI) were calculated for six streams of River Godavari. The values of WQI calculated for six streams in three seasons were relatively poor and require well-organized treatment before the water from these bodies is used for any purpose.***

***Keywords: Water quality, WAWQI, NSFWQI, Seasonal variations***

## I. INTRODUCTION

Water is the prime natural resource. This precious resource is falling due to rise in population and the other human related activities. Various citizens of the globe accomplish their water demand from ground and surface waters through municipality. Some people also depend on hidden boreholes. Periodic monitoring of the quality is needed for public wellbeing (Poonam et al., 2013).

The composition and features of any particular source can be assessed by physic-chemical and biological attributes. These augments are risky if they exceed their permissible limits in water (Tyagi et al., 2013). Water bodies are exposed to large amounts of household wastewater, industrial effluents, agricultural runoff, mine wastes, urban waste water, radioactive minerals, pesticides and other various contaminants ( Noorbakhsh et al., 2014).

**Revised Manuscript Received on December 22, 2018.**

**G. Sri Bala**, Research Scholar, Assistant Professor, Department of Civil Engineering, SRKR Engineering College, Bhimavaram, Andhra Pradesh, India

**G.V.R. Srinivasa Rao**, Professor & Head, Department of Civil Engineering, College of Engineering (A), Andhra University, Visakhapatnam, Andhra Pradesh, India

**P.A.R.K. Raju**, Professor, Department of Civil Engineering, SRKR Engineering College, Bhimavaram, Andhra Pradesh, India

**M. Jagapathi Raju**, Professor & Head, Department of Civil Engineering, SRKR Engineering College, Bhimavaram, Andhra Pradesh, India

Water Quality Index is a widely used tool that renovates complex data of water into simplified version. WQI is also a simple indicator for the description of quality (0-100 scale). This indicator is quite popular and is widely used in many places across the globe. It is an effective problem solving principle that takes care of issues of water management (Giriyappanavar et al., 2013). USEPA, 2009 states that facilitating the WQI includes three main steps:

1. Measure the constraints of water as per the standard procedures
2. Convert values of the measured parameters to sub-index values
3. At last, originate the overall WQI by summing sub-indices.

WQI is divided into two main indices such as relative and absolute. Relative indices are based on ecosystem criteria whereas absolute indices are as per water quality criteria (Horton, 1965). The study stresses on absolute indices such as WAWQI and NSFWQI. Both these indices were calculated for the study because of their simplicity and availability of the required parameters. The functions and their effects that build the mathematical structure of the indexes affect the parameters and finally represent index like a solo number (Liu et al., 2012).

## II. MATERIALS AND METHODS

### *Details of Study Area*

The study area is situated between 16°19'05.02" and 16°56'08.37" N latitudes and 80°58'16.10" and 81°51'26.10" E longitudes and is situated in the southern part of West Godavari District. Irrigation in West Godavari is carried on through a network of six streams, namely the Eluru canal, the Kakaraparru canal, the Narasapur canal, the Attili canal, the Venkayya Vayyeru canal, and the Gostani canal that serves as a main source of water for residents of the area. Both point and non-point waste sources fiercely affect the particular area under concern.

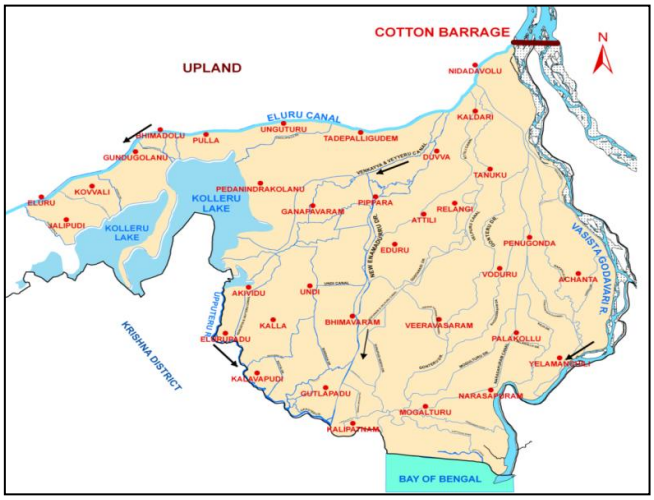


Fig 1: Study area showing six streams of River Godavari

The water samples were collected as per the procedures of APHA 2005 from different sampling stations of the above said streams of Godavari River. Almost 107 surface water sampling stations were selected from six streams. Water samples from 19 sampling stations along Venkayya Veyyeru canal, 9 from Attili canal, 16 from Kakaraparru canal, 18 from Eluru canal, 12 from Gostani canal and 33 from Narsapur canal respectively were collected. The samples were tested for the physico-chemical water quality attributes like pH, electrical conductivity, total dissolved solids, total alkalinity, total hardness, calcium, magnesium, chlorides, nitrates, dissolved oxygen and biological oxygen demand, turbidity and biological parameter like most probable number (MPN) during summer, winter and rainy seasons as per standard methods of Drinking water specification, BIS 2012 using appropriate chemicals and distilled water. The average values of all the attributes measured in all the six streams were used for WQI calculations.

**Fundamental System for Building WQI**

The characteristics of water are measured and are converted to sub-indices. Finally they are aggregated to originate WQI.

***Weighted Arithmetic WQI Technique***

This method categorized water taking measured variables into account as described (Chauhan et al., 2010).

Rating was worked out using the following expression.

$$q_n = 100[V_n - V_{io}]/[S_n - V_{io}]$$

where $q_n$ = quality rating for the $n^{th}$ water quality parameter

$S_n$ permissible limit for the measure parameter

$V_{io}$ = ideal value of nth parameter in pure water, (i.e., 0 for all other parameters except the parameters pH and DO 7.0 and 14.6 mg/L respectively)

Unit weight was nothing but the inverse of permissible value. At last, the index value was calculated as an aggregation of rating and unit weight linearly. The standards and unit weights of ICMR and BIS were considered in Table1.

$$WQI = \sum q_n w_n / \sum w_n$$

**Table1. Standard permissible limits and unit weights (All values except pH and Electrical Conductivity are in mg/L)**

| SNO | Parameters | Criteria limits | Unit Weight |
|---|---|---|---|
| 1 | pH | 6.5 - 8.5 | 0.219 |
| 2 | Electrical Conductivity | 300 | 0.371 |
| 3 | Total Dissolved Solids | 500 | 0.0037 |
| 4 | Total Alkalinity | 120 | 0.0155 |
| 5 | Total Hardness | 300 | 0.0062 |
| 6 | Calcium | 75 | 0.025 |
| 7 | Magnesium | 30 | 0.061 |
| 8 | Chlorides | 250 | 0.0074 |
| 9 | Nitrate | 45 | 0.0412 |
| 10 | Dissolved Oxygen | 5 | 0.3723 |
| 11 | Biological Oxygen Demand | 5 | 0.3723 |

**Table2. Status and Index levels (Chatterji and Raziuddin 2002)**

| WQI Level | Status |
|---|---|
| 0-25 | Excellent |
| 26-50 | Good |
| 51-75 | Poor |
| 76-100 | Very Poor |
| >100 | Unsuitable |

**NSFWQI technique**

NSFWQI is one of the public indices that pay no attention to the kind of water utilization. Brown et al. (1970) developed a WQI based on

Delphi's method. This endeavour was sustained by NSF and hence the name is NSFWQI. The elaborated work was discussed in various works by Landwehr & Deininger, 1976. Various ideas of professional experts were considered and rating curves were developed (Fernandez et al., 2011). Rating scale of values were developed from Vr =100 to Vr = 0 which implies that the extreme value is most desirable and vice versa.

NSFWQI is evaluated by using limits of Indian Council for Medical Research (ICMR) and Central Public Health Environmental Engineering Organization (CPHEEO).

**Table3. Standard permissible limits and unit weights**

| SNO | Water attributes | Standards(Vi) | Unit Weight(Wi) |
|---|---|---|---|
| 1 | pH | 7.0-8.5 | 0.18 |
| 2 | TDS | <1500 | 0.001 |
| 3 | Hardness | <600 | 0.002 |
| 4 | Total Alkalinity | <120 | 0.012 |
| 5 | Dissolved Oxygen | >5 | 0.307 |
| 6 | Turbidity | <25 | 0.307 |
| 7 | Chlorides | 250-1000 | 0.006 |
| 8 | Nitrates | <50 | 0.031 |
| 9 | MPN,coliforms/100 ml | <10 | 0.154 |

**Table4. Modified Rating Scale for calculating WQI (Tiwari & Mishra, 1985)**

| Parameter | Range of value | | | | |
|---|---|---|---|---|---|
| pH | 7.0-8.5 | 8.6-8.7 | 8.8-8.9 | 9.0-9.2 | >9.2 |
| TDS | 0-375 | 375.1-750 | 750.1-1125 | 1125.1-1500 | >1500 |
| Hardness | 0-150 | 150.1-300 | 300.1-450 | 450.1-600 | >600 |
| Total Alkalinity | 21-50 | 50.1-70 | 70.1-90 | 90.1-120 | >120 |
| Dissolved Oxygen | >7.0 | 5.1-7.0 | 4.1-5.0 | 3.1-4.0 | <3.0 |
| Turbidity | <5.0 | 5.0-10.0 | 10-17.5 | 17.6-25 | >25 |
| Chlorides | 0-50 | 51-100 | 101-150 | 151-250 | >250 |
| Nitrates | 0-13 | 14-26 | 27-39 | 40-50 | >50 |
| MPN,coliforms/100 ml | <=1 | 2.0-4.0 | 5.0-7.0 | 8.0-10.0 | >10 |
| Vr | 100 | 80 | 60 | 40 | 0 |
| Status | Clean | Slight | Moderate | Excess | Severe |

**Table5. Status and Index level of water quality (Tiwari & Mishra, 1985)**

| WQI Level | Rating |
|---|---|
| 91-100 | Excellent |
| 71-90 | Good |
| 51-70 | Medium |
| 26-50 | Bad |
| 0-25 | Very bad |

## III. RESULTS AND DISCUSSION

The average results of all the sampling stations in six streams for all three seasons were presented in the Table 6, Table 7 and Table 8.

**Table6. Results of physicochemical and biological characteristics of six streams (Pre-Monsoon)**
**(All values except pH and EC are in mg/L).**

| SNO | Parameters/ Stream | Venkayya Vayyeru | Attili | Kakaraparru | Eluru | Gostani | Narsapur |
|---|---|---|---|---|---|---|---|
| 1 | pH | 8.20 | 7.80 | 7.68 | 8.64 | 8.64 | 8.70 |
| 2 | EC | 545.00 | 2000.00 | 1420.00 | 250.00 | 250.00 | 305.00 |
| 3 | TDS | 384.60 | 1412.00 | 1004.30 | 183.33 | 183.33 | 217.00 |
| 4 | Alkalinity | 150.20 | 403.00 | 475.70 | 111.91 | 111.91 | 128.00 |
| 5 | Hardness | 152.50 | 462.00 | 382.80 | 105.83 | 105.83 | 123.30 |
| 6 | Calcium | 44.10 | 120.40 | 98.20 | 27.20 | 27.20 | 31.80 |
| 7 | Magnesium | 10.20 | 24.10 | 13.40 | 10.50 | 10.50 | 12.40 |
| 8 | Chlorides | 127.40 | 305.50 | 371.60 | 31.90 | 31.90 | 55.30 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 9 | Nitrate | 7.82 | 36.30 | 18.90 | 3.89 | 3.89 | 9.20 |
| 10 | DO | 4.84 | 5.46 | 5.07 | 4.35 | 4.35 | 5.10 |
| 11 | BOD | 4.20 | 4.90 | 3.60 | 4.12 | 4.12 | 3.54 |
| 12 | Turbidity | 5.90 | 2.84 | 3.05 | 7.55 | 5.80 | 3.60 |
| 13 | MPN | ≥2400 | ≥2400 | ≥2400 | ≥2400 | ≥2400 | ≥2400 |

**Table7. Results of physicochemical and biological characteristics of six streams (Monsoon) (All values except pH and EC are in mg/L).**

| SNO | Parameter/ Stream | Venkayya Vayyeru | Attili | Kakaraparru | Eluru | Gostani | Narsapur |
|---|---|---|---|---|---|---|---|
| 1 | pH | 8.23 | 9.06 | 7.92 | 8.50 | 8.19 | 8.54 |
| 2 | EC | 265.10 | 224.50 | 210.00 | 172.14 | 185.80 | 171.50 |
| 3 | TDS | 190.00 | 157.20 | 150.00 | 120.50 | 130.10 | 120.10 |
| 4 | Alkalinity | 94.00 | 62.22 | 100.00 | 100.00 | 97.00 | 91.00 |
| 5 | Hardness | 105.00 | 116.40 | 110.00 | 97.10 | 100.00 | 87.00 |
| 6 | Calcium | 23.10 | 25.70 | 25.00 | 22.10 | 27.10 | 18.36 |
| 7 | Magnesium | 11.90 | 10.50 | 9.80 | 8.18 | 8.64 | 9.04 |
| 8 | Chlorides | 73.10 | 77.00 | 50.50 | 30.80 | 35.80 | 35.30 |
| 9 | Nitrate | 8.13 | 5.84 | 10.10 | 6.70 | 4.88 | 10.30 |
| 10 | DO | 4.90 | 4.80 | 4.60 | 4.80 | 4.91 | 5.10 |
| 11 | BOD | 4.60 | 3.80 | 3.12 | 4.54 | 3.02 | 3.16 |
| 12 | Turbidity | 5.10 | 4.70 | 5.00 | 4.17 | 5.12 | 2.10 |
| 13 | MPN | ≥2400 | ≥2400 | ≥2400 | ≥2400 | ≥2400 | ≥2400 |

**Table8. Results of physicochemical and biological characteristics of six streams (Post-Monsoon) (All values except pH and EC are in mg/L).**

| SNO | Parameters/ Stream | Venkayya Vayyeru | Attili | Kakaraparru | Eluru | Gostani | Narsapur |
|---|---|---|---|---|---|---|---|
| 1 | pH | 8.30 | 8.17 | 8.38 | 8.60 | 8.18 | 8.40 |
| 2 | EC | 424.00 | 175.00 | 175.00 | 200.00 | 242.00 | 192.00 |
| 3 | TDS | 298.00 | 126.00 | 124.00 | 154.00 | 171.00 | 137.00 |
| 4 | Alkalinity | 117.00 | 90.00 | 84.00 | 105.00 | 107.00 | 86.00 |
| 5 | Hardness | 100.00 | 76.00 | 91.00 | 85.00 | 100.00 | 85.00 |
| 6 | Calcium | 25.10 | 23.20 | 21.20 | 20.90 | 25.30 | 20.30 |
| 7 | Magnesium | 17.50 | 9.12 | 8.14 | 7.12 | 17.40 | 9.65 |
| 8 | Chlorides | 120.60 | 23.50 | 100.20 | 30.25 | 40.26 | 35.77 |
| 9 | Nitrate | 9.40 | 4.40 | 13.00 | 9.30 | 5.77 | 13.20 |
| 10 | DO | 4.50 | 4.60 | 4.60 | 4.80 | 5.00 | 5.20 |
| 11 | BOD | 4.50 | 5.20 | 4.80 | 4.40 | 5.10 | 4.80 |
| 12 | Turbidity | 6.80 | 4.30 | 2.80 | 3.04 | 6.10 | 0.73 |
| 13 | MPN | ≥2400 | ≥2400 | ≥2400 | ≥2400 | ≥2400 | ≥2400 |

The results of WAWQI and NSFWQI of six streams in the study were presented in Table 9 and Table 10.

**Table9. WAWQI of six streams in three seasons**

| SNO | Stream | Pre-Monsoon | | Monsoon | | Post-Monsoon | |
|---|---|---|---|---|---|---|---|
| | | WQI | Status | WQI | Status | WQI | Status |
| 1 | Venkayya Vayyeru | 107.87 | Unsuitable | 85.86 | very poor | 101.46 | Unsuitable |
| 2 | Attili | 235.04 | Unsuitable | 86.34 | very poor | 80.78 | very poor |
| 3 | Kakaraparru | 177.84 | Unsuitable | 71.55 | poor | 91.31 | very poor |
| 4 | Eluru | 87.37 | very poor | 80.08 | very poor | 82.69 | very poor |
| 5 | Gostani | 87.37 | very poor | 70.38 | poor | 86.38 | very poor |
| 6 | Narsapur | 88.58 | very poor | 72.93 | poor | 81.44 | very poor |

**Table10. NSFWQI of six streams in three seasons**

| SNO | Stream | Pre-Monsoon | | Monsoon | | Post-Monsoon | |
|---|---|---|---|---|---|---|---|
| | | WQI | Status | WQI | Status | WQI | Status |
| 1 | Venkayya Vayyeru | 64.68 | Medium | 65.34 | Medium | 65.22 | Medium |
| 2 | Attili | 62.96 | Medium | 59.92 | Medium | 65.70 | Medium |
| 3 | Kakaraparru | 69.78 | Medium | 65.34 | Medium | 71.60 | Good |
| 4 | Eluru | 61.86 | Bad | 71.60 | Good | 68.00 | Medium |
| 5 | Gostani | 66.78 | Bad | 65.46 | Medium | 65.46 | Medium |
| 6 | Narsapur | 77.14 | Very bad | 74.14 | Good | 77.98 | Good |

The observed range of WAWQI in the six streams is found to vary from 70.38 to 235.04 by the arithmetic mean method. The water quality in all the streams was found poor, very poor and unsuitable. So, stringent regulations in water treatment are required if the water from these sampling stations of all the streams is selected as a source for drinking purpose.

According to NSFWQI, the value of the index was found to vary from 59.92 to 77.98.Only a small difference was there between two systems to classify water. It was also clear from Table 9, Table 10 that the water quality was bad in summer compared to other two seasons.

One point is evident that according to WAWQI by Brown et al., ranges from 51 to 75 has been classified as poor whereas according to NSFWQI, this range has been considered as medium. So, it is better to consider the border permissible limit between 0-50 for Brown's method and 75 – 100 range for NSF method.

## IV. CONCLUSIONS

WQI has some constraints and it does not convey all the picture of water. Despite of having such problems with WQI, it is widely used as an indicator by public. The study is very important because all the residents of Western Delta depend on these six streams for domestic purpose on West Godavari District, Andhra Pradesh. The water bodies were found ailing for drinking. So, if proper treatment is done, all the six streams in the study with its 107 sampling stations can be effective utilized. Thus the NSFWQI, WAWQI are very useful to the public for the judgment of surface water status and can be effectively used for formulating the purification water systems.

## Acknowledgement

The study is a part of project work sponsored by Technology Mission: War for Water, Department of Science and Technology, NEW DELHI.

## REFERENCES

1. APHA 2005, Standard Methods for the examination of Water and Wastewater, 20th edition, American Public Health Association, Washington D.C.
2. BIS 2012. Bureau of Indian Standards, IS : 10500, Manak Bhavan, New Delhi, India.
3. Chaterjee C. and Raziuddin M., "Determination of water quality index (WQI) of a degraded river in Asanol Industrial area, Raniganj, Burdwan, West Bengal, Nature", *Environment and pollution Technology*., 1(2), 181 – 189(2002).
4. Chauhan, A. And Singh, S., "Evaluation of Ganga water for drinking purpose by water quality index at Rishikesh, Uttarakhand, India", Report Opinion, 2(9), 53 – 61. 2010.
5. CPHEEO (Central Public Health Environmental Engineering Organization), 1991. Manual of water supply and treatment, Ministry of Urban Development, New Delhi.
6. Giriyappanavar B.S., Patil R.R, 2013. "Water Quality Assessment of Gullava Reservoir of Belgaum District Using NSF – WQI", *International Journal of Scientific Research*, Vol.2(4), ISSN NO 2277 – 8179.
7. Horton, R.K. (1965). "An Index – Number System for rating water quality", *Journal of the water pollution Control Federation*, 37(3) : 300 – 305.

8. Landwehr, J.M. and R.A.Deininger (1976). " A comparison of several water quality indices." *Journal of the water pollution control federation*, 48(5) : 954 – 958.
9. Liu, Z., Sun, G., Huang, S., Sun, W., Guo, J. (2012). Water Quality Index as a simple indicator of drinking water source in the Dongjiang River, China, *International Journal of Environmental Protection*, 2(5), pp : 16 – 21.
10. Noorbakhsh J., Seyedmahalleh E.S., Darvishi G., Golbabaeikootenasi F., Mehrdadi N., 2014. " An Evaluation of Water Quality from Siahrod River, Haraz Rivr and Babolrood River by NSFWQI index", *Current World Environment*, Vol.9(1), 59 – 64
11. Poonam T., Tanushree B., Sukalyan C., (2013). "Water quality indices – important tools for water quality assessment: A Review", *International Journal of Advances in Chemistry* (IJAC) Vol.1, No.1, pp: 15 – 28.
12. Tiwari, T.N. and Mishra, M., 1985. A preliminary assignment of water quality index to major rivers. *Ind J Environ Protect.* 5 : 276.
13. Tyagi S., Sharma B., Singh P., Dobhal R., (2013). "Water Quality Assessment in Terms of Water Quality Index", *American Journal of Water Resources*, Vol. 1, No. 3, pp 34-38.
14. USEPA (2009). Environmental Impact and benefits Assessment for Final Effluent Guidelines and Standards for the construction and Development Category. Office of Water. Washington DC. EPA – 821 – R – 09 – 012.