Application of Water Quality Index for Assessment of Surface Water Quality Status in Goa

GURDEEP SINGH[1] and RAKESH KANT KAMAL[2]*

[1]Vinoba Bhave University, Hazaribagh-825301, Jharkhand, India.
[2]Centre of Mining Environment, Department of Environmental Science & Engineering,
Indian School of Mines, Dhanbad-826004, Jharkhand, India.

ABSTRACT

Water quality index (WQI) is valuable and unique rating to depict the overall water quality status in a single term that is helpful for the selection of appropriate treatment technique to meet the concerned issues. Thirty Six surface water samples were collected from in and around mining talukas of Goa (India). The quality of surface water were evaluated by testing various physico-chemical parameters such as pH, Total Dissolved Solid (TDS), Total Hardness (TH), Total Suspended Solid (TSS), Calcium, Magnesium, Chloride, Nitrate, Sulphate, Dissolved Oxygen and Biochemical Oxygen Demand (BOD) . The WQI for all samples were found in the range of 34 to 107. The highest value of WQI was observed during the monsoon season while the lowest value was during the post monsoon season. Most of the water samples within study area were found within Good to moderate categories.

Key word: Goa, Seasonal variation, Surface water, Water quality index.

INTRODUCTION

Water is addressed as a necessary resource and life preservative. It is required for most human activities like – drinking, cooking bathing, washing, agriculture, industry, recreation, navigation and fisheries etc. About 75% of the world's surface area is covered with water. Out of which 97% of the earth's water is in the ocean, not fit for human use due to its high salt content. Remaining 2% is locked in polar ice caps and only 1% is available as fresh water in rivers, lakes, streams reservoirs and ground water, suitable for human consumption. Now-a-day, water quality issues have become a significant concern due to the growth of population, urban expansion and technological development. Water can be easily contaminated in different ways through unregulated or regulated but not well designed and monitored disposal practices. In India's case, the future is a bit more-worse, since we have only 2.45% of the word's landmass supporting 16% of the world's population and our freshwater resource does not exceeding 4% of the global water resources (Kumar 2005). Apart from availability, continuous water pollution due to disposal of sewage, industrial and mining wastes also threatens to reduce the available quantity of usable water and more and more of our ground and surface water resources including lakes, ponds and rivers are being categorized as polluted (Subramanian *et al.* 2000; Mohan *et al* 2000; Kumaresan *et al.* 2006; Singh *et al.* 2007; Singh *et al.* 2013). Access to safe drinking water remains an urgent necessity, as 30 % of urban and 90 % of the rural Indian population still depends completely on untreated surface or groundwater resources (Kumar *et al.* 2005).Access to drinking water in India has increased over the past few decades with the tremendous adverse impact of unsafe water for health (Singh *et al.* 2013).Scarcity of clean and potable drinking water has emerged in recent years as one of the most serious developmental issues in many parts of West Bengal, Jharkhand, Orissa, Western Uttar Pradesh, Andhra Pradesh, Rajasthan and Punjab (Tiwari and Singh 2014).

Water quality index (WQI) is defined as a technique of rating that provides the composite influence of individual water quality parameter on the overall quality of water (Singh *et al.* 2013). Water Quality Index, a technique of rating water quality, is an effective tool to assess quality and ensure sustainable safe use of water for drinking (Tiwari *et al.* 2014). Water quality index is one of the most effective tools to communicate information on the quality of any water body (Rizwan and Gurdeep 2010).WQI is an a superior way to the understanding of water quality issues by integrating complex data and generating a score, which ultimately describes the water quality status (Tiwari *et al.* 1985; Singh, D. F. 1992; Rao, S.N; 1997; Mishra *et al.* 2001). One of the major advantages of WQI is that, it incorporates data from multiple water quality parameters into a mathematical equation that rates the health of water quality with number (Yogedra and Puttaiah 2008).

Mining is one of the major activities causing water pollution and threatens the quality surface water. Water pollution in mining areas is mainly due to overburden (OB) dumps, surface impoundments, mine water, industrial effluents, acid mine drainage, tailing ponds etc. (Singh *et al.* 2013). River and other streams are not far from the mining industries and it contaminate continuously from point as well as non-point source. Waste generation due to the operation and expansion of mining and industrial activity in Goa is going to be a serious negative impact on the water resource in near future. The problems of water quality degradation and its adverse impacts on availability of potable and irrigation water, soil quality and agricultural productivity, and biodiversity in the area have been attracting increasing attention of people. The aim of this study is to assess the quality of surface water for the suitability of drinking and domestic purpose in Goa mining region.

Study area

Goa is the 25th State of India, attaining statehood in May 1987.It lies between the latitudes 14°53'54" N & 15°40'00" N and longitudes 73°40'33" E & 74°20'13" E with geographical area of 3,702 km² and coastline of 105 km. The study area comprises of 5 mining Talukas namely Bicholim, Sattari, Dharbandora, Quepem and Sanguem encompassing an area of 1513 km². Study area entails all the areas wherein mining activities of Goa are encompassed along with a belt of five km from the lease boundary (Fig 1).

MATERIALS AND METHODS

The water samples were collected from thirty six (36) different locations in all two seasons, Pre-monsoon post-monsoon season. Sampling locations were selected on the basis of different land use pattern (agricultural, mining, residential and barren etc.). Care was taken to collect subsequent samples from same location in all season. The Samples were taken from 10 to 15cm below the water surface using acid washed plastic container to avoid unpredictable changes in characteristic as per standard procedures (APHA, 2005). Details of sampling locations along with their latitude and longitude are illustrated in (table 4).

Water Quality Index

WQI's aim at giving a single value to the Water quality of a source reducing great amount of parameters into a simpler expression and enabling easy interpretation of monitoring data (Singh *et al.* 2013).Water Quality Index (WQI) is a technique of rating that provides the composite influence
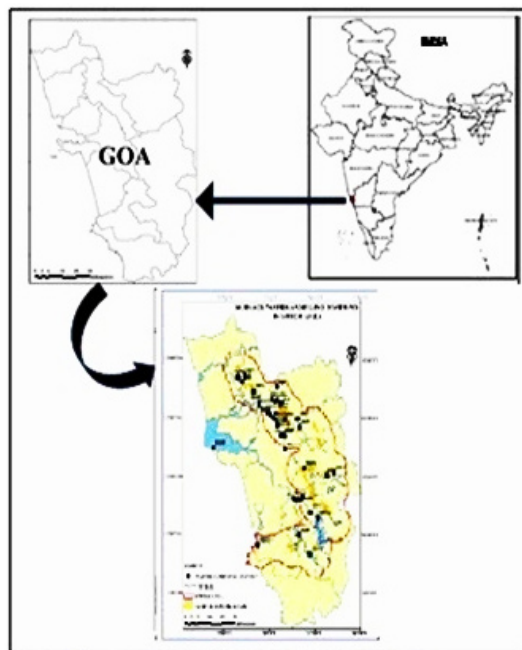

Fig. 1: Sampling location map of the Goa Mining

of individual parameter on the overall quality of water. WQI a well known method as well as one of the most effective tools to express water quality that offers a simple, stable, reproducible unit of measure and communicate information about water quality to the policy makers and concerned citizens (Singh *et al*. 2013). The weights for various water quality parameters are assumed to be inversely proportional to the recommended standards for the corresponding parameters. One of the major advantages of WQI is that, it incorporates data from multiple water quality parameters into a mathematical equation that rates the health of water quality with number (Brown *et al*. 1970). In this study for the calculation of water quality index, twelve important parameters were chosen. The WQI has been calculated by using the standards of drinking water quality recommended by the World Health Organization (WHO), Bureau of Indian Standards (BIS), and Indian Council for Medical Research (ICMR).The weighted Arithmetic index method has been used for the calculation of WQI of the

water body. Further quality rating or sub index was calculated using the following expression

$$q_n = 100(V_n - V_{io})/(S_n - V_{io}) \quad ...(1)$$

(Let there be *n* water parameter and quality rating or sub index (q_n) corresponding to n^{th} parameter is a number reflecting the relative value of this parameter in the polluted water with respect to its standard permissible value)

q_n= Quality rating for the nth water quality parameter

V_n= Estimated value of the nth parameter at a given sampling station

S_n= Standard permissible value of the nth parameter

V_{io}= Ideal value of nth parameter in pure water. (i.e., 0 for all other parameter except the parameter pH and Dissolved oxygen (7.0 and 14.6 mg/l respectively)

Unit weight was calculated by a value inversely proportional to the recommended standard value S_n of the corresponding parameter.

$$W_n = K/S_n \quad ..(2)$$

where W_n = Unit weight for the nth parameters, S_n = Standard value for n^{th} parameters, K = Constant for proportionality.

Table. 1: Descriptive category of WQI values

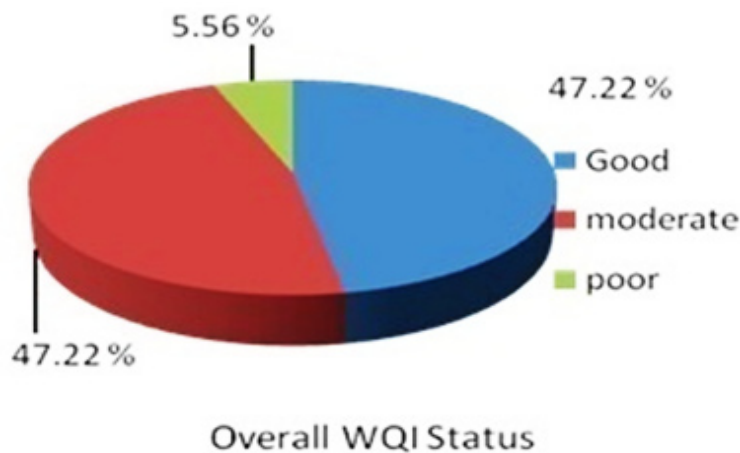| Water Quality Index Level	Water Quality Status
0-25	Excellent Water Quality
26-50	Good Water Quality
51-75	Moderate Water Quality
76-100	Poor Water Quality
>100	Unsuitable for Drinking

Fig. 2: WQI Categories of Samples (%) in all the seasons

The overall water quality index was calculated by aggregating the quality rating with the unit weight linearly:

$$\text{WQI} = \sum q_n\, W_n / \sum W_n \qquad ...(3)$$

Different levels of water quality index and their respective water quality status were given in Table-1. Various parameters and their unit weight were calculated and summarized in Table -2 with their standards and recommended agencies.

RESULTS AND DISCUSSION

The World Health Organization (WHO), Bureau of Indian Standards (BIS), and Indian Council for Medical Research (ICMR) for the drinking water together with its corresponding status categories of WQI are given in Tables 1, Table 2, Table 3 and Table 4, respectively. The WQI of water samples were found in the range of 34 to 83 in post monsoon, 28 to 81 in winter, 34 to 86 in summer and 23 to 107 in monsoon season. The WQI for all samples were found in the range of 34 to 107. Almost 94% of the total water samples were found in range of good and medium except SW2 and SW35 which were found to be in poor categories. Out of 36 water samples only two (6%) were found within poor category, it is due to transportation of iron ore and mining activities. Huge overburden dumps are piled in and around mining areas were suffered during monsoon seasons due to leaching. Among all the of the water samples, the percentage (%) of WQI categories Good (47.22%), Moderate (47.22) and Poor (5.56%) were observed in all four the seasons (Fig. 2).

CONCLUSION

On the basis of the above discussions, it may be concluded that the WQI for all samples were found in the range of 34 to 107 in the four seasons.

**Table. 2: Drinking water standards recommending agencies and unit weights
(All values are in mg/L, except pH and Electrical conductivity)**

S. No.	Parameter	Standard	Recommended Agency	Unit Weight
1	pH	6.5-8.5	ICMR/BIS	0.219
2	Electrical Conductivity	300	ICMR	0.371
3	Total Dissolved Solids	500	ICMR/BIS	0.0037
4	Total Hardness	300	ICMR/BIS	0.0062
5	Total Suspended Solid	500	WHO	0.0037
6	Calcium	75	ICMR/BIS	0.025
7	Magnesium	30	ICMR/BIS	0.061
8	Chloride	250	ICMR	0.0074
9	Nitrate	45	ICMR/BIS	0.0412
10	Sulphate	150	ICMR/BIS	0.01236
11	Dissolved Oxygen	5	ICMR/BIS	0.3723
12	BOD	5	ICMR	0.3723

Table. 3: Season wise statistical variation in WQI values

Seasons	Minimum	Maximum	Mean	Std. Deviation
Post monsoon	34	83	50.14	12.08
Winter	28	81	50.94	12.7
Summer	34	86	53.56	12.45
Monsoon	23	107	59.92	23.61

Table. 4: Details of sampling locations and status of surface water quality

S. No	Sample Code	Location	Type of water	Latitude (N)	Longitude (E)	Status
1	SW 1	Assonora River in Bardez Taluka	River	73°54'19.2"	15°37'11.9"	Good
2	SW 2	Tributary of Moide River in Shrigao, of Bicholim Taluka	River	73°53'43.3"	15°36'23.4"	Poor
3	SW3	Valvanti River in Pariye of Sattari Taluka	River	74°03'01"	15°35'17.8"	Good
4	SW4	Mandovi River near Amona Jetty in Bicholim Taluka	Nallah	73°58'2.9"	15°31'49.1"	Moderate
5	SW5	Tributary of mandovi, Surla nallah in Bicholoim Taluka	River	74°03'15"	15°29'41.8"	Good
6	SW6	Mandovi River in Khnodguinum Bicholim Taluka	River	74°02'20.8"	15°30'42"	Good
7	SW7	Kudnem River Shonshi nallah Sattari Taluka	River	74°02'23.7"	15°32'37"	Good
8	SW8	Advai nallah in Sattari Taluka	Nallah	74.5°05'20"	15°30'40.4"	Moderate
9	SW9	Cudnem river in arvalem Bicholim Taluka	River	74°01'36.5"	15°33'2.1"	Good
10	SW10	Cudnem river of cudnem in bicholim Taluka	River	74°00'50.8"	15°32'45.3"	Good
11	SW11	Cudnem river in gauthan of Bicholim Taluka	River	74°00'17.7"	15°33'8.2"	Moderate
12	SW 12	Ragda river in guleli of Sattari Taluka	River	74°06'25.2"	15°28'22.6"	Moderate
13	SW 13	Mandovi river in Usgao of Dharbandora Taluka	River	74°06'8.4"	15°26'38.1"	Good
14	SW14	Khandepar river in codli village of Dharbandora Taluka	River	74°07'37"	15°21'29.8"	Moderate
15	SW15	Sigao in Khandepar of Dharbandora Taluka	River	74°00'45.2"	15°29'57.1"	Moderate
16	SW16	Khandepar river in collem village of Dharbandora Taluka	River	74°14'9.7"	15°20'43.8"	Good
17	SW17	Sanvordem nallah in Sanguem Taluka	Nallah	74°07'37"	15°16'37.9"	Good
18	SW18	Selalulim Dam in Sanguem Taluka	Reservoir	74°10'39.2"	15°12'50.4"	Good
19	SW19	Sanguem river in Sanguem Taluka	River	74°08'58.7"	15°13'57.2"	Good
20	SW20	Kushavati river in kevona village of Quepem Taluka	River	74°07'55.0"	15°08'10.7"	Good
21	SW21	Kushavati river in Sulcorna village of Quepem Taluka	River	74°07'38.6"	15°30'8.0"	Good
22	SW21	Sal river in Betul village of Quepem Taluka	River	73°57'12.1"	15°8'17.44"N	Moderate
23	SW23	Zuari river in Sanvordem of Quepem Taluka	River	74°6'43.9"	15°15'57.6"	Moderate
24	SW24	Mayem lake in Bicholim taluka	Lake	73°56'21.7"	15°34'31.71"	Good

Table 4. Continues...

25	SW25	Mandovi near cottombi jetty Bicholim Taluka	Jetty	74°01'32.9"	15°28'52.4"	Good
26	SW26	Mandovi river sarmanas jetty in Bicholim taluka	Jetty	73°57'34.39"	15°32'41.20"	Moderate
27	SW27	Moide river in sirsaim jetty in Bardez Taluka	Jetty	73°52'53.65"	15°36'53.161"	Moderate
28	SW28	Mandovi river in Naveli jetty in Bicholim Taluka	Jetty	74°0'42.68"	15°29'58.884"	Moderate
29	SW29	Mandovi river nera Rumda jetty in Bicholim Taluka	Jetty	74°02'40"	15°26'.56"	Moderate
30	SW30	Mandovi river in mayni jetty in bicholim Taluka	Jetty	73°59'58.96"	15°30'34.671"	Good
31	SW31	Zuari river Capxem jetties in Quepem Taluka	Jetty	74°5'47.583"	15°16'8.688"	Moderate
32	SW32	Zuari river nera shelvaaana jetty in quepem Taluka	Jetty	74°5'22.277"	15°16'12.97"	Moderate
33	SW33	Khandepar river in Opa village of Ponda Taluka	Jetty	74°5'47.583"	15°16'8.688"	Moderate
34	SW34	Mandovi river near cumbharjua canal in Ponda Taluka	pond	73°57'30.36"	15°32'1.632"	Moderate
35	SW35	Zuari river near Marmugao port in Marmugao Taluka	Harbour	73°47'27.2"	15°24'48.4"	Poor
36	SW36	Mandovi river nera Surla jetty in Bicholim Taluka	Jetty	74°01'44.0"	15°28'.51.4"	Moderate

The highest value of WQI was observed during the monsoon season while the lowest value was during the post monsoon season. The water quality analysis shows that the 47.22 % surface water samples were found as Good category and 47.22 % moderate category can be use for direct consumption while 5.56 % belongs to poor category shows that the water is not suitable for direct consumption in Goa mining region. After treatment of that water samples can be used for drinking purposes in the study area.

ACKNOWLEDGEMENT

REFERENCES

1. APHA., Standard methods for examination of water and waste water, 20th Edn., Washington, DC (2005).
2. Brown R. M., McClelland N. I., Deininger R. A. and Tozer R.G., Water quality index-do we dare, *Water Sewage Works*, **117**(10):339-343, (1970).
3. Bureau of Indian Standards., BIS 10500, Manak Bhavan, New Delhi, India (2003).
4. I.C.M.R., Manuals of standards of quality for drinking water supplies. I.C.M.R. New Delhi, (1975).
5. Kumar R., Singh R.D. and Sharma K.D., Water resources of India, *Curr Sci.,* **89**, 794–81, (2005).
6. Kumaresan M. and Riyazddin P., Major ion chemistry of environmental samples around sub-urban of Chenai city, *Current Science,*

9:1668-1677, (2006).

7. Mishra P. C. and Patel R. K., Study of the pollution load in the drinking water of Rairangpur, a small tribal dominated town of North Orissa, *Indian J. Environment and Ecoplanning*, **5**(2): 293-298, (2001).

8. Mohan R., Singh A. K., Tripathi J. K. and Chaudhary G. C., Hydrochemistry and quality assessment of groundwater in Naini industrial area, District Allahabad, Uttar Pradesh, *Journal Geological Society India,* **55:**77-89, (2000)

9. Rao N.S. Studies on Water Quality Index in Hard rock Terrain of Guntur District, Andhra Pradesh, India, National Seminar on Hydrogeology of Precambrian Terrains and Hard Rocks Areas, Dharwad, 129-134, (1997).

10. Rizwan R. and Gurdeep S., Assessment of Ground Water Quality Status by Using Water Quality Index Method in Orissa, India, *World Applied Sciences Journal*, **9**(12):1392-1397, (2010).

11. Singh A. K., Mondal G.C., Singh S., Singh P. K., Singh T. B., Tewary B. K. and Sinha A., Aquatic Geochemistry of Dhanbad District, Coal City of India: Source Evaluation and Quality Assessment, *Journal Geological Society India,* **69**:1088- 1102 (2007).

12. Singh A. K., Raj Beenu., Tiwari A. K. and Mahato M. K., Evaluation of hydrogeochemical processes and groundwater quality in the Jhansi district of Bundelkhand region, India, *Environmental Earth Science*, **70**(3): 1225-1247, (2013).

13. Singh D.F., Studies on the water quality index of some major rivers of Pune, Maharashtra *Proceedings of the Academy of Environmental Biol.*, **1**(1), 61-66, (1992).

14. Singh P. K., Tiwari A. K. and Mahato M. K., Qualitative Assessment of Surface Water of West Bokaro Coalfield, Jharkhand by Using Water Quality Index Method *International Journal of ChemTech Research,* **5**(5), (2013).

15. Singh P. K., Tiwari A. K., Panigarhy B. P. and Mahato M. K., Water quality indices used for water resources vulnerability assessment using GIS technique: a review, *International Journal Earth Science and Engineering,* **6**(6-1):1594-1600, (2013).

16. Subramanian V., Water: quantity-quality perspectives in South Asia, Kingston International Publishers Limited Surrey, (2000), UK.

17. Tiwari A. K. and Singh A. K., Hydrogeochemical investigation and groundwater quality assessment of Pratapgarh district, Uttar Pradesh, *Journal of the Geological Society of India,* **83**(3): 329-343, (2014).

18. Tiwari A. K., Singh P. K. and Mahato M. K., GIS-Based Evaluation of Water Quality Index of Groundwater Resources in west Bokaro Coalfield, India, *Current World Environment,* **9**(3), (2014).

19. Tiwari T. N., and Mishra M. A., A preliminary assignment of water quality index of major Indian rivers, *Indian J. Environmental Protection*, **5**: 276-279, (1985).

20. WHO., Guidelines for drinking water quality. Recommendations, Geneva: World Health Organization. 2nd Edn., **1**, 188 (1993).

21. Yogedra K. and Puttaiah E.T., Determination of Water Quality Index and Suitability of an Urban Waterbody in Shimga town, Karnatka.Sengupta,M and Dalwani,R (Eds.).Proceedings of Taal2007,The World Lake Conference, 342-346 (2008)