Chapter 15
Strategic Evaluation of Water Quality Monitoring Network Using GIS-AHP Model in a Large River System

Preeti Rajput, Manish Kumar Sinha, and Gaurav Kant Nigam

Abstract Mahanadi River and its tributaries are passes through the various important cities of Chhattisgarh and Odisha state in India. It serves as the valuable source of water for its domestic, agricultural and industrial need. To monitor river water quality, analytical hierarchy process-based water quality index (WQI) has been adopted to reveal the general status of water quality spatio-temporally. Along the length of the river variation of quality is modelled by interpolation in GIS platform. It is found that the 13.11% of observed stations located nearby major cities of Chhattisgarh and Odisha are extremely bad in general status. The water is of these locations cannot be used as drinking source even after the conventional treatment and disinfection. 4.91% of location lie under very bad status with controlled waste disposal. 22.95% of location identify as bad status of its quality. 54.09% falls for the medium status and the remaining 4.91% stations are having good class of general status that can be used as drinking source after conventional treatment. This study results the overall WQI in Mahanadi River basin and also gives a strategic evaluation of various water quality monitoring network in a large river system.

Keywords Analytical hierarchy process · Cluster analysis · Mahanadi River system · Sustainable use · Water quality index · Water quality parameters

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15.1 Introduction

The pollution of water depends on its sources as it board water into the water body. Mukherjee (2017) says that pollution creates due to unmanaged activity in system. Urban evolution changes regional conditions of environment and effectually alters local settings and in specifically the relative flow of toxic waste into streams, thereby resentfully changing the status of water body. Duan (2016) highlights the issues of surface water contamination due to wastewater disposal is an intense problem in developing countries, where unplanned small and medium industry and densely populated localities with unsewered areas exist. This is created by high rates of migration into cities due to urbanization. Mattos (2012) does the study of rainfall and the resulting surface runoff transport. There are different types of materials of chemical and biological root to the adjacent collecting water body. This results in that the water body is essentially altered from its innate state. These operations do not permit the system itself to be modelled by simple mathematical modelling approach. As the effect of which spread over the other sectors, consequently makes system unsustainable by increase in vulnerability. Apart from its impact on environment, the footprint goes to the economy also. According to Karamouz (2008), the most ruinous economic aftermath from water pollution is the expense of water treatment for human use for different purpose, loss of commercial fish husbandry and lessening the value of real estate properties. Hou (2014) focusses on the effect of urban runoff, which will outturn both short-term and long-term transformation in collecting waters noted to habitat vulnerability and chemical toxicity. This in trend will consequently bring transformation to aquatic communities such as increased fatality of biota and destructive revision to breeds assortment and profusion. Therefore, though stormwater runoff events are episodic, what is of serious concern is the shock pollutant load on collecting waters resulting from an urban stormwater runoff event. The study of Mirrasooli (2017) reveals that the good quality of river water indicates the sustainable use of water resources. It is highly important to maintain the good quality of river water because it affects the ecosystem further. The river stretches nearby urban area is vulnerable to pollution due to untreated effluents being dumped in the river, and consequently, quality of river water has deteriorated significantly. According to Sutadian (2015), the quality of water judged by the large number of variables belongs from its chemical, physical and biological property which represent the status of water body. These large number of parameters with their different scale of measurement makes it tough to understand the status report by the public. To overcome this problem, Klimas (1996) suggests water quality indexing approach which has been used worldwide for evaluating river water quality reasonably. WQI is a single number which is the cumulative effects of properties, extracted from the parameters with the different scale of measurements by bring them into a single platform. The first WQI proposed in 1965 and since then it has been identified as one of the most efficient ways to know the water quality status. The study of Wu (2015) gives the idea about various indices that have been developed in the past by many agencies and researcher with the objective to refine the existing indices. However, there is no WQI till date accepted globally for defining the water quality status. And also, WQI is not capable to report the water quality for all uses nor capable to provide the complete information, it only express general status of water body. Therefore, it takes the continuous attention to develop WQI that is congenial to local and regional area. In Reda et al. (2015) and Ning and Chang (2002), they have done their work for different river basin using analytical hierarchy process (AHP)-based modelling for evaluation of water quality monitoring system. Based on the literature review, this study is an attempt to develop WQI for Mahanadi River basin with the application of AHP.

According to Sutadian (2017), quality of water reflects the health of river. Water quality degradation is a big challenge for decision makers. Because it is difficult to quantify the overall quality due to large number of parameters. This concern has been solved by WQI approach. WQI consolidates the complexity of factors affecting water quality in a single number.

Shoba and Shobha (2014) prove the fact that due to industrial revolution and urbanization vulnerability of rivers has increased. The waste generated from the industry and urban area dumped into the river either directly or indirectly. The study of Zi (2010) reveals that the design of WQI depends on the intended use of water body and the data availability. Apart from that the redundancy of parameters, the selected set of parameters involves the regress subjective judgement. To conclude the status, the set of selected parameters has to standardize either by linear interpolation rescaling, categorical scaling or comparison with the permissible limits. And, aggregated according to the relative importance. There are many WQI developed with time and requirements as CCMEWQI (Khan et al. 2004) developed by the Canadian Council of Ministers of the Environment as a tool to assess and report water quality information to both management institutions and the public. The CCMEWQI gives the liberty to choose the water quality parameters, which helps the index users to modify and adopt the index according to local water quality issues. It provides a simple mathematical concept for the computation of final index value. The NSFWQI (Brown 1977) is one of the earliest WQIs, which was developed during the early 1970s. The Bascarón index (House and Newsome 1989) was developed specifically for Spain.

The fundamental concept for the assessment of river water quality is the compliance of water quality objectives (Hunsaker and Levine 1995). This concept is applied for all the considered water quality parameter. But, this type of analysis fails to give sufficient information on the general status of water quality. In Sutadian et al. (2015), it shows the statistical analysis between considered parameters. This type of assessment provides the information about the water quality even though there is a smaller number of parameters to be monitored. The management of river water quality is one of the important environmental challenges in front of the users. The objective of this study is to develop a concept based on multi-criteria analysis (MCA).

15.2 Study Area

This study has been done on Mahanadi River system in India. The area of interest for this study circumscribed within 80° 30′ E–86° 50′ E longitudes and 19° 20′ N–23° 35′ N latitudes. The total catchment area of the basin is 141,600 km^2 with maximum elevation of 877 m and minimum of 193 m (Sinha and Rajput 2020). The tributaries of Mahanadi roam around Chhattisgarh and Orissa and in some parts of neighbouring state. Dadhwal et al. (2010). The total length of the river is about 851 km. In this study, 66 measuring station locations (observed by Central Pollution Control Board, India) were selected shown in Fig. 15.1 for water quality sampling. Selected locations are surrounded by the urban area influenced by industrial activities which makes these locations vulnerable to the river water pollution. According to Panda (2006), Mahanadi provides housing for various large industries along with aluminium and thermal plants. All the industrial waste and sewage dump to Mahanadi daily. Also, there are practice that the entire town's sewage is discharged directly into the river which consists of faecal sludge, grey water from toilets, kitchen waste and several other contaminated forms of liquid waste.

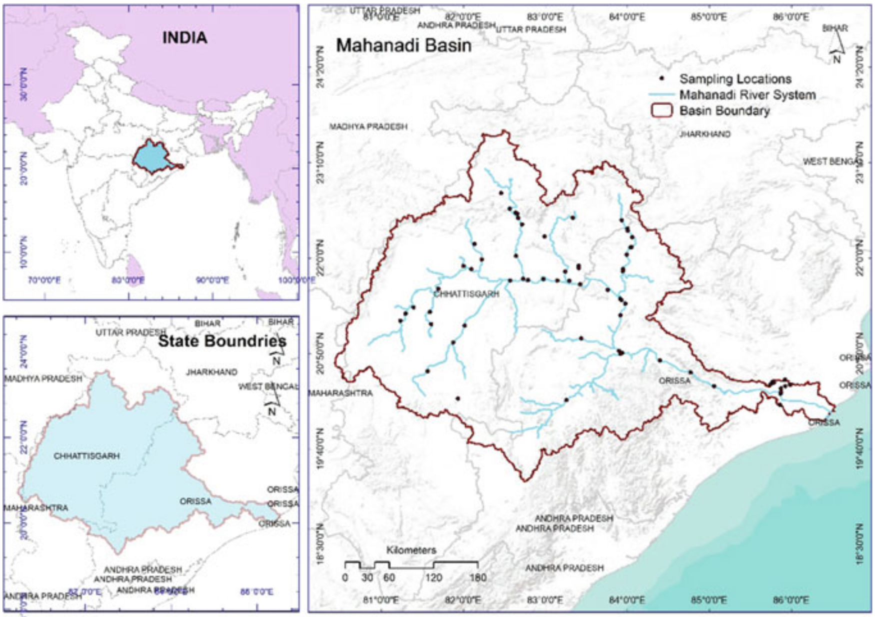

Fig. 15.1 Location map of the Mahanadi River system indicating sampling points in the basin

15.3 Material and Methods

The computation of WQI and its representation is a tedious work as it involves the users need and the extent of use. The methodology used in this work is depicted in Fig. 15.2. WQI converts the specifically shortlist parameters of water property into a unique index value that represent the quality of river water at any location. To develop the WQI as per Sutadian (2017), four steps can be followed, which are the selection of variables for representing the water property, converting them to a common single scale and obtain sub-index value, assigning weight to each parameter according to the relative importance and addition of sub-indices to generate the unique index value.

15.3.1 Water Quality Parameter Characterization

The selection of variables is crucial step in the computation of WQI. Stehling (1988) gives the suggestion that the water quality parameters were selected to identify the

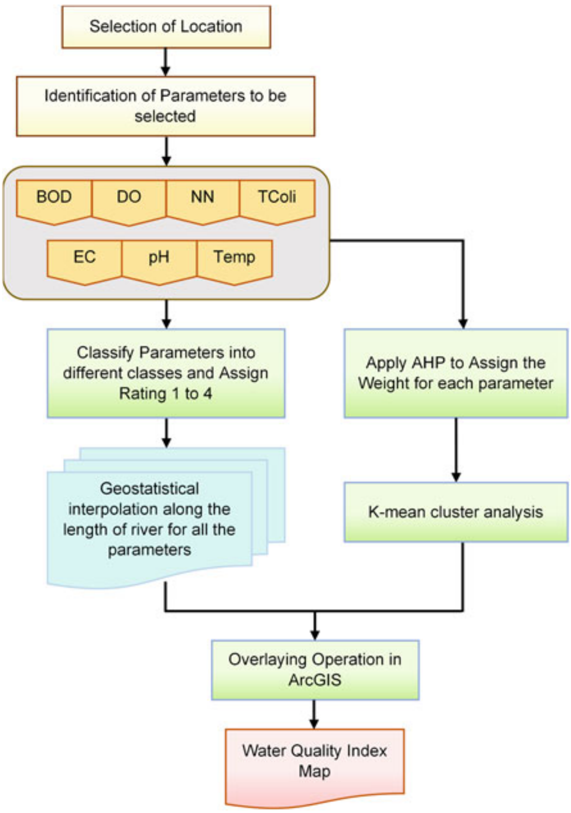

Fig. 15.2 Flow chart of the methodology adopted to compute WQI

most affected parameter due to pollution load on the water body. These parameters were selected on the basis of their pollution intimation property for the different types of uses of water body. And on the basis of the data values, which show anomalies as compared to expected values. The general status of water quality in river has been identified by considering the complexity of different factors affecting the water quality. To take into account, the following variables of water properties, namely temperature (temp), dissolve oxygen (DO), biological oxygen demand (BOD), pH, nitrite + nitrate (NN), conductivity (EC) and total coliform (Tcoli), have been selected to consider all the three physical, chemical and biological properties in this study to describe the status of the River of Mahanadi basin.

The temperature is the parameters which affect the solubility of oxygen in water and control the decay and growth rates. The rate of reactions in the water body between the chemicals and biological activities is affected by temperature in a considerable scale (Miles and Water 2012).

Every process is set to make at a certain temperature level in nature. Any biological and chemical change have some process that has positive or negative impact on the environment. The deviation of temperature from normal scale is triggered by anthropogenic activities. Effluents that are released from industry and urban land feed and the water body spreads thermal pollution (Weber et al. 2006). Dissolved oxygen represents the status of water body. Its concentration represents pollution load on the system. Its permissible limit is 6 mg/l or more. DO changes drastically over a day therefore it should be checked at frequent interval of day and night time with the specific consideration of its minimum level. Also, the dilution of oxygen in water will depends on the temperature of water body, as higher the temperature lowers the DO level, at high altitude DO is low. For the estimation of chemical and biological action as adsorption rate of heavy metals in the river, pH is taken into account for the computation of WQI. The value of pH should lie in between 6.5 and 8.5. pH measures the acidic or basic nature of solution. For any biological function in a system, pH is a critical determinant. For biological integrity, it is necessary to maintain the pH as the deviation from normal condition may interfere the metabolic process.

Drastic changes in pH value may have potential calamitous influence on river ecosystems. During photosynthesis, carbon dioxide consumes and consequently increases pH. During respiration carbon dioxide release, thus decreasing pH. Potential sources of pH change at the basin are effluents from wastewater plants, industries, mine drainage and effluents from informal settlements. Nitrate + nitrite is used as WQI indicator to check the immediate discharge of organic waste to the river. If NN goes beyond 1.2 mg/l, it will be objectionable to use that water. The biological oxygen demand concentration effectively affects the dissolve oxygen concentration, therefore it is considered as representative of river status according to aquatic life. BOD is an indicator of the existence of organics that are susceptible to biooxidation. When surplus biodegradable organic substance comes into aquatic ecosystems and encounters bacterial putrefaction, huge amounts of DO absorb creating an imbalance which leads to caustic deterioration to the ecosystem. Biological oxygen demand should be 2 mg/l or less in five days at 20 degree centigrade. Conductivity is the capacity of water to regulate electric current. It depends on the salt concentration of water. Salts in the water body come from the industrial discharge or release of illegal effluent into the body. The sudden change in conductivity provides fair indication of the change in water quality. Fluctuations in conductivity values in a catchment may be experienced seasonally due to rainfall influences also. To know the domestic point load and agricultural non-point load, total coliform has been considered in this study. Total coliform has the permissible limit of 50 or less MPN/100 ml (Junior et al. 2014).

15.3.2 WQI Computation

To convert the parameters into a representative unit which reveals the comprehensive quality of water for different uses, it needs to bring the parameters of different scale into a common scale. To standardize the parameters of different scale, rescaling is done by assigning the rate value to the parameters according to the permissible limits for the general water quality standard provided by the Central Pollution Control Board (CPCB), GOI. Parameters are divided into various classes and rating of one to four is provided as listed in Table 15.1. Rating of one is used to represent most departed range of water quality parameter value and four is used for the most ideal range. On this reasoning, actual parameter values are converted into a value having common scale for all parameters. Then, weighted overlay method applied. In this study, weights are allotted to the parameters by employing the AHP. The weights are computed through pair-wise comparison matrices of water quality parameters by comparing several choices.

15.3.3 Application of AHP Method

The paired comparison of parameters with their relative importance is depicted in Table 15.2. The intensity of importance is assigned from 1 to 9. Where 1 is assigned for representing the equally important, 3 moderately important, 5 strongly important, 7 very strongly important and 9 extremely important. The values 2, 4, 6, 8 are the intermediate scale between two judgement. The judgement is the then checked by

Table 15.1 Rating of individual parameters according to class

S. No.	Parameters	Weight (%)	Range	Rating
1	Biological oxygen demand mg/l	38.18	< 2.0	4
			2.0–2.5	3
			2.5–3.0	2
			> 3.0	1
2	Dissolve oxygen mg/l	22.35	< 6.0	1
			6.0–7.0	2
			7.0–8.0	3
			> 8.0	4
3	pH	14.11	6.5–7.5	4
			7.5–8.5	3
			8.5–9.5	2
			9.5–10	1
4	Nitrate + nitrite mg/l	10.11	< 1.2	4
			1.2–2.1	3
			2.1–3.0	2
			> 3.0	1
5	Temperature	6.97	24.5–26.5	4
			26.5–28.5	3
			28.5–30.5	2
			30.5–32.5	1
6	Total coliform MPN/100 ml	4.94	< 50	4
			50–500	3
			500–5000	2
			> 5000	1
7	Conductivity micromhos/cm	3.34	< 2000	4
			2000–2250	3
			> 2250	1

computing the consistency of paired matrix. The comparison matrix is then normalized, and the priority vectors have been computed. These priority vectors represent the weight of parameters respective to their relative importance. To check the consistency of paired matrix, principal eigenvector is computed (Harker and Vargas 1987). Saaty (1980) gives the equation to measure the consistency, called degree of consistency. The ratio of degree of consistency and random consistency index is called consistency ratio (CR). The random consistency index is based on the size of the matrix formed by the selected parameters. The maximum size of the matrix could be ten. Its values vary according to the size and it may lie between 0 and 1.49. If CR is less than or equal to 10%, inconsistency is tolerable. If CR is greater than 10%, it needs

Table 15.2 Comparison matrix and relative weight of WQI parameters

Para.	BOD	DO	pH	NN	Temp	Tcoli	EC	Weight(%)
BOD	1	2	3	4	6	7	9	38.18
DO	1/2	1	2	2	3	5	7	22.35
pH	1/3	1/2	1	2	2	3	4	14.11
NN	1/4	1/2	1/2	1	2	2	3	10.11
Temp	1/6	1/3	1/2	1/2	1	2	2	6.97
Tcoli	1/7	1/5	1/3	1/2	1/2	1	2	4.94
EC	1/9	1/7	1/4	1/3	1/2	1/2	1	3.34

to amend the tendentious judgement. The WQI is then computed by aggregating the sub-index value. The maximum value of WQI could be 4.0 and the minimum value 1.0. Therefore, to classify the status of water body, WQI values are divided into four equal parts by normal distribution as 1.0–1.75 very bad (water source conditions are departed natural or desirable level) status, 1.75–2.50 bad (water source can be used for industrial cooling and controlled waste disposal) status, 2.50–3.25 medium (water source can be used for promulgation of aquatic life) status, 3.25–4.00 good (water source can be used for drinking water after traditional method of purification) status.

15.3.4 Water Quality Mapping Using GIS Application

To represent the river water quality situation and its variation along the length of the river, these computations are performed in ArcGIS platform. The individual parameter maps are prepared by converting point valued quality data into spatially varying water quality with the help of interpolation. Interpolation is the technique of estimation of pixel values of unsampled point based on known pixel value of surrounding sampled point. In GIS, interpolation is done in two ways as the geostatistical and the deterministic way. Geostatistical interpolation is based on the statistical behaviour of known sampled data series. Mathematically, sound technique to interpolate parameters changing under environmental process. The deterministic interpolation works on the concept of degree of similarity. In this type of interpolation, a smooth surface is created by using surrounding points and mathematical function to assign values to the unknown point. In present work, geostatistical interpolation technique has been used to identify the spatial variation of water quality parameters along the river stretch. This technique helps to understand the pluming behaviour of pollutants, which suggest the overall water quality of river.

After getting the interpolated maps of all the seven parameters, reclassification is done according to the range of parameters into four different classes and assigns new values from 1 to 4. Then, weighted overlaying is performed by stacking the maps with its associated weight determined by AHP technique. The resultant map is representing the WQI map of Mahanadi River.

15.3.5 Application of K-Mean Clustering

To support the AHP analysis, K-mean clustering technique is used in this study. K-mean clustering technique is the algorithm of unsupervised learning. With this algorithm, the monitoring sites are grouped in four clusters. All the four clusters represent four classes of very bad, bad, medium and good status of WQI as identified in AHP analysis. These clusters are formed on the basis of water quality parameters observed in different locations. Each cluster having the locations of water quality monitoring station of similar water quality characteristics.

15.4 Results and Discussion

The sustainable development is the need of this hour. Management of good water quality status is one of the crucial domains of development. The objective of which is to optimally utilize the available water resources and maintaining its quality with social and economic development. The objective was to establish the WQI for the determination of general water quality status of the Rivers of Mahanadi basin. This was accomplished by the application of AHP with GIS to the water quality parameters.

15.4.1 Data Analysis and Mapping of Water Quality Parameters

The statistical analysis of water quality parameters and its variation along the length of the river gives the overview on the general character of the river. The individual parameters stats were listed in Table 15.3. The graphical variation of water quality parameters along the river in selected 66 locations is depicted in Fig. 15.3.

Biological Oxygen Demand (BOD): BOD is the parameter that gives the idea about the immediate discharge of organic waste to the river system. This parameter is departed from its normal standard range which affects the DO level and they are by aquatic life. Biological oxygen demand has its lowest value 1.2 mg/l and highest

Table 15.3 Statistical characterization parameters used in the computation of WQI

Parameters	Min.	Max.	Mean	SD	CV
BOD	1.2	8.0	2.4	1.4	57.1
DO	3.1	7.4	5.8	0.9	15.4
Temp.	27.0	44.0	37.6	4.8	12.9
EC	163.0	50,910.0	2808.0	9804.6	349.16
pH	7.5	10.0	8.3	0.3	4.2
Tcoli	300.0	160,000.0	39,846.9	55,125.9	138.3
NN	0.8	29.0	3.8	4.2	107.2

value 8.0 mg/l which are beyond the permissible range when tested for five days at 20 degree centigrade.

Dissolve Oxygen (DO): To estimate the pollutant load on the river system, DO is considered as it affects the aquatic life. Dissolved oxygen stabilizes the biodegradable substances with the help of living organisms. In this study, DO varies with minimum value of 3.1 mg/l to maximum value of 7.4 mg/l in selected locations along the length of Mahanadi River but ideally DO should be more than 6 mg/l.

Temperature (Temp.): It is considered for the knowledge of decay and growth rates in river system. Therefore, it is one of the important parameters for river water quality simulation. Temperature is the parameter which affects the acceptability of inorganic and chemical contaminants in water body. In this study, its value varies from 27 to 44°. Temperature will alter the odour, colour and taste of water.

pH: The strength of acidity or alkalinity of any solution sample is represented by the pH. There is no health-based guideline for the pH value. It is required for evaluation of chemical and biological processes such as adsorption rate of heavy metals in river. It has range of 7.5 to 10 along the Mahanadi River stretch.

Electrical Conductivity (EC): It is directly related to total dissolved solids (TDS). Concentrations of TDS in water depend on different geological regions due to the differences in the solubility of minerals. For domestic use, it is recommended that water should have TDS less than 500 mg/l. If it founds more than 1000 mg/l, it imparts unpleasant taste and makes inadequate for other uses. In Mahanadi River, EC value varies with minimum of 163 mhos/cm to maximum of 50,910 mhos/cm along the length. For the Mahanadi River system, this parameter is well within the permissible limit.

Nitrate Nitrogen (NN): Naturally, the nitrate concentration is low in water bodies but due to the humans, it appears in the water body in considerable amount. Nitrate reaches the water body by leaching or runoff from agricultural land or contamination from human or animal wastes as a consequence of the oxidation of ammonia. As per WHO standard for drinking water, it should not more than 10 mg/l. In this study, nitrate varies from 0.8 to 29 mg/l.

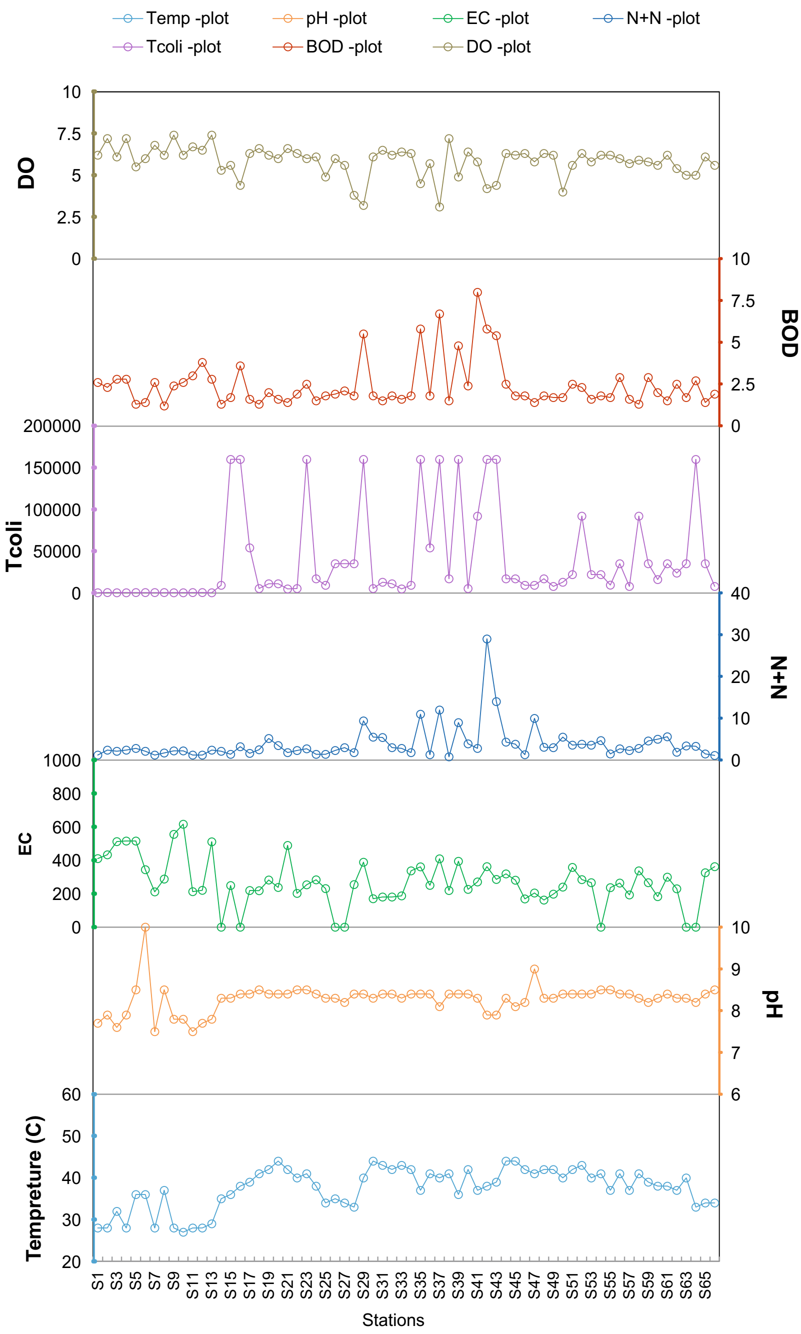

Fig. 15.3 Station-wise water quality parameters distribution in 66 sites

Total Coliform (Tcoli): The values of this variable depart from river water quality standards in the study area. For the determination of agriculture pollution load and domestic point and non-point loads, total and faecal coliform used to identify location. As per the standards of CPCB, the permissible value of total coliform is 50 or less MPN/100 ml but the resultant map has the minimum value of 300 MPN/100 ml and maximum value of 160,000 MPN/100 ml. This map indicates the situation that would not be acceptable to have for sustainable use of river system.

15.4.2 Result of AHP Application on Spatial Distribution of River Water Quality

The percentage influence amongst the parameters is computed and it was found according to the relative significance of the parameters. The computation suggests that BOD has the maximum weight of 38.18%. The DO, pH, NN, Temp, Tcoli and EC have weights of 22.35%, 14.11%, 10.11%, 6.97%, 4.94% and 3.34%, respectively. The resultant maps of selected water qualities are depicting the variation along the length of the river in Figs. 15.4, 15.5, 15.6, 15.7, 15.8, 15.9 and 15.10 obtained from spatial interpolation. These maps are overplayed with its weight obtained from AHP

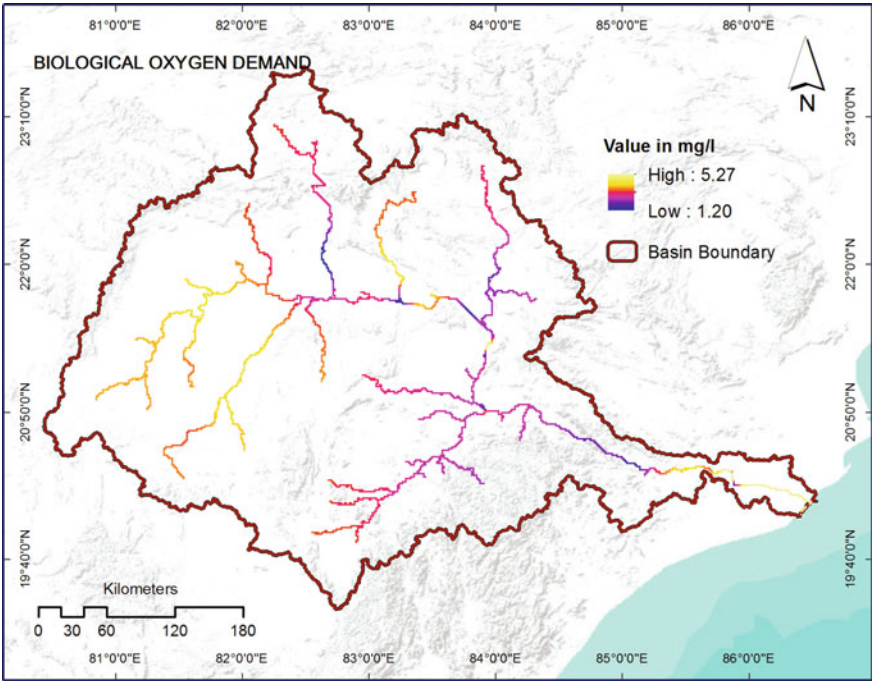

Fig. 15.4 Spatial variation of biological oxygen demand in Mahanadi River

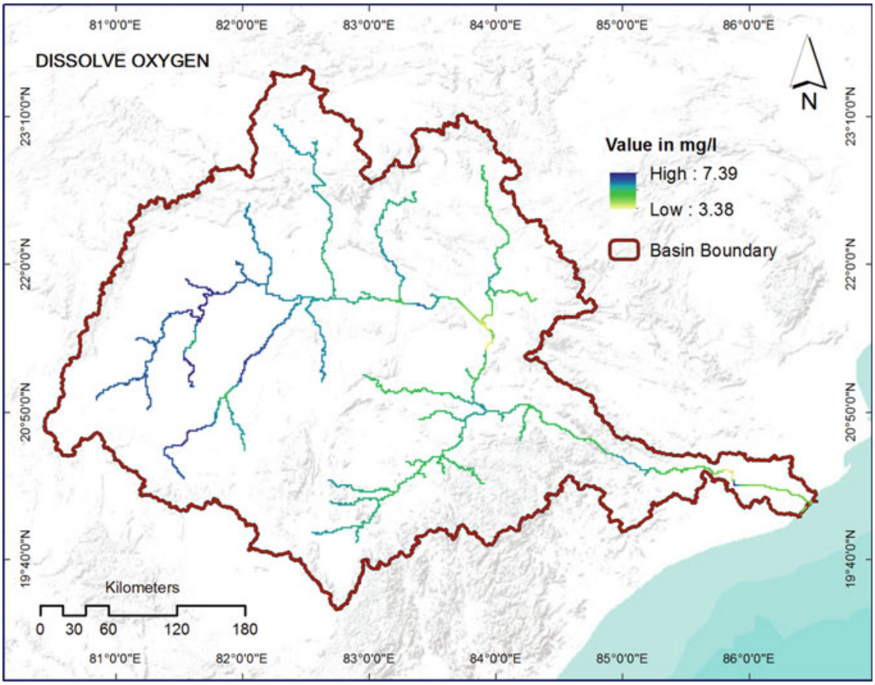

Fig. 15.5 Spatial variation of dissolved oxygen in Mahanadi River

analysis. The resultant map is showing the variation of WQI along the river length in Fig. 15.11. On the detail observation of WQI Map, the total length of river is classified according to the good, medium, bad and very bad status with respect to WQI value as listed in Table 15.4.

15.4.3 Results of K-Mean Cluster Analysis

To check the consistency of methodology adopted in this study, K-mean cluster analysis was done. The result of cluster analysis shows that all the four clusters have same members as the members in WQI category with the error of 18.16%, obtained from the AHP analysis. The statistical properties of water quality parameters for each cluster are listed in Table 15.5. These stats reveal the limiting values of parameters for the four designated water quality standards as per obtained by AHP-WQI.

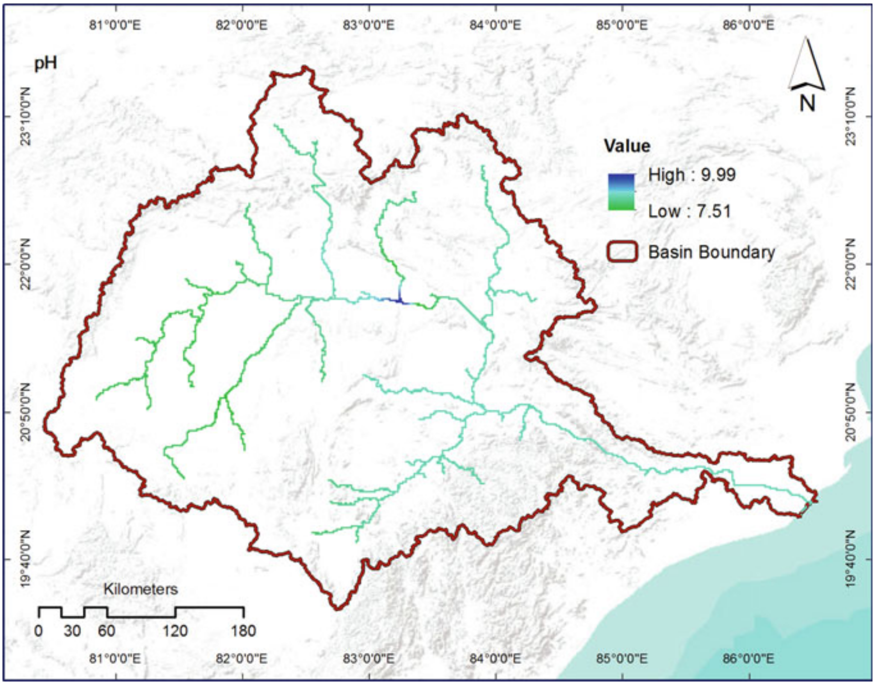

Fig. 15.6 Spatial variation of pH value in Mahanadi River

These clusters reveal the location of water quality measuring site with respective water quality status. The resultant map is shown in Fig. 15.12. Figure shows the clusters of measuring sites along the length of river. The lowest value calculated is 1.38, which belongs to very bad situation and the highest value of 3.27 which suggests the good condition. On the analysis of result, it was found that 21.21% of the location is in very bad situation, 27.27% bad, 48.51% medium and 3.03% is in good situation.

On the investigation, it was found that the greatest threat to the Mahanadi comes from coal mines, industry, thermal power station and urban local bodies. The chemical compounds in industrial waste and sewage are poisonous and toxic, and it is having long-term effect on rivers ecological balance. And the problem intensifies when people continue to use this water for daily purpose which contaminates land as well. The measuring stations located at Kharun River upstream side of the Raipur city is of medium status whereas downstream side of it has bad status. From this observation, it can be conclude that the Kharun River water gets deteriorated after passing the Raipur city. This result represents that the water of Kharun River is not in good practice of sustainable use. Also, it can be seen that the Kelo River passes nearby

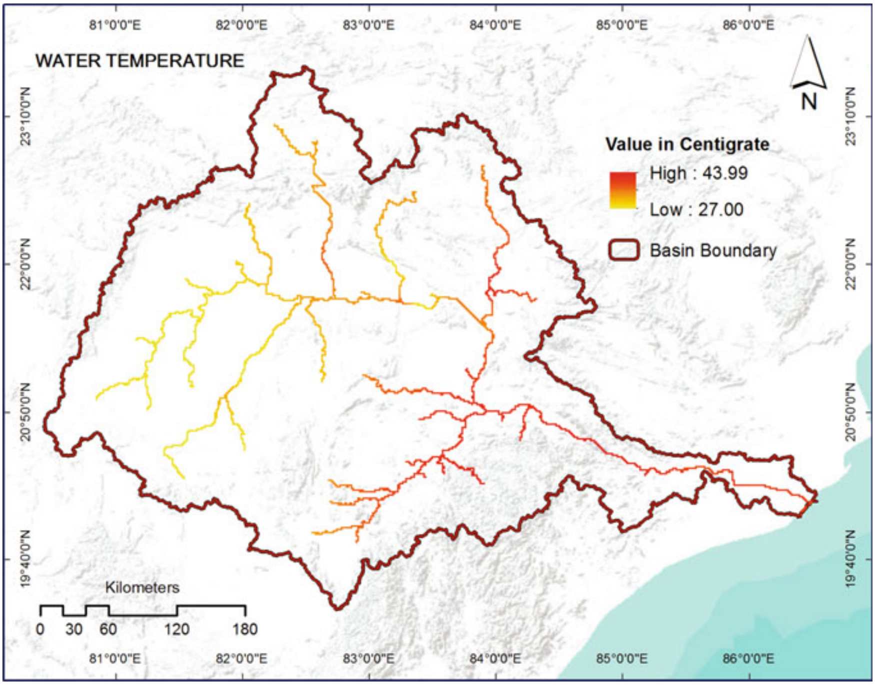

Fig. 15.7 Spatial variation of maximum temperature in Mahanadi River

Raigarh city has its general water quality in bad status. This may be due to the dense industrial Sproule in this area. Similarly, the Seonath River at Sigma, Mahanadi at Rajim and at interstate boundary have its general quality in bad status. Hence, the resultant map can be used as the base information map for the implementation of management measuring strategy.

15.5 Conclusion

Water is one of the fundamental lives supporting element for all living organisms on the earth and for them the quality of water is a consistent matter of concern for the perpetual transformation. Conservation of quantity, quality and authenticity of water resources is the primary responsibility of humans for sustainable development. It is

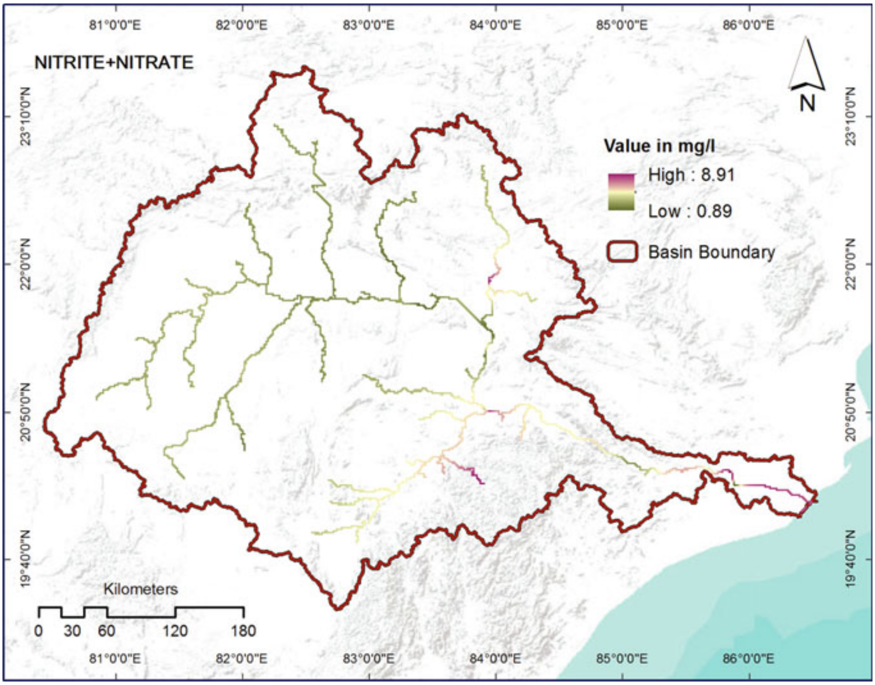

Fig. 15.8 Spatial variation of nitrate + nitrite in Mahanadi River

suggested from this study that the maintenance of water quality should be the responsibility of users. And the management of water resources should be the responsibility of government authorities. Availability of fresh water for humans, animals and plants should not be compromised at any cost as it is a basic need. Although water quality problems have been addressed and action plans proposed in the national legislature, most of these plans have not been fully implemented for various reasons. Illegal dumping of waste, effluent discharge into rivers, direct discharge of storm water and releases of polluted mine drainage are common in the Mahanadi River basin. Most of industries were built without comprehensive analyzes of long-term impact on the catchments and without consultation with the affected surrounding communities. At some location, it is concluded that there are point sources of contamination which claim their standard of effluent discharge is as per norms. Therefore, it is suggested bring a body who legally monitor the water quality at regular interval. Making policy for setting the standard to regulate usage could be the possible step towards control-

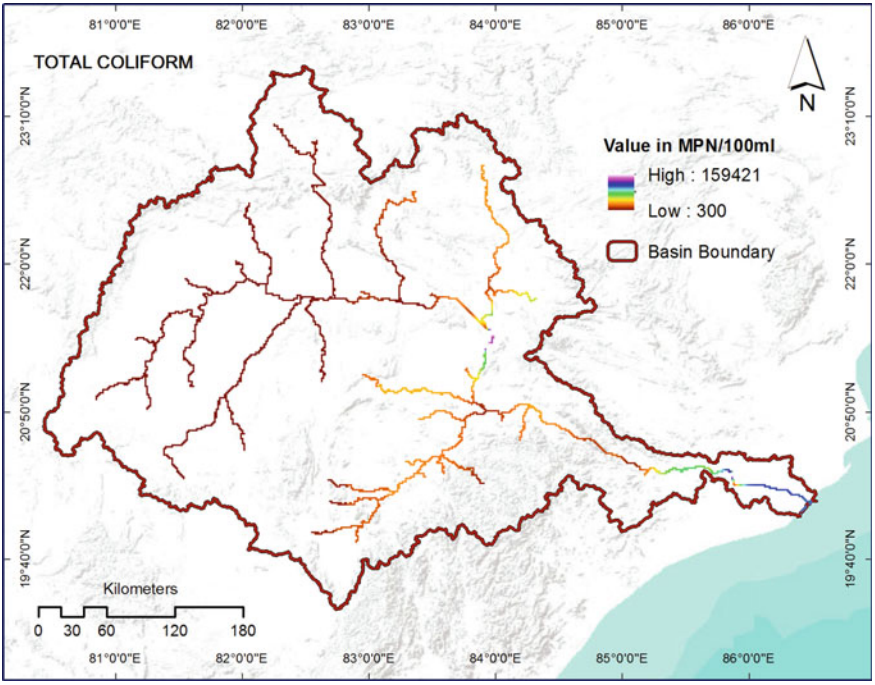

Fig. 15.9 Spatial variation of total coliform in Mahanadi River

ling damage by pollution. The rollback centres for recycling of resultant waste water from small industry and urban activity should be activated under the pollution prevention policy. Formulating strategy for the provision of good sanitation in the area of informal settlements. Applying the use of modern forming practices in which reprocess the manure and produce biofuels can cut short some amount of pollution load. It is concluded that because the location specific factors are influencing water quality, its quantification is extremely difficult. Chemical processes exert a strong influence on water quality characteristics. This study was an attempt to assess the sustainability of the Rivers of Mahanadi basin. To monitor the quality index-based approach, it has been applied so that the different locations can be compared in same scale of general status. The AHP provides a system in this study to integrate the individual parameters defining different properties of water resulted from environmental pollution .

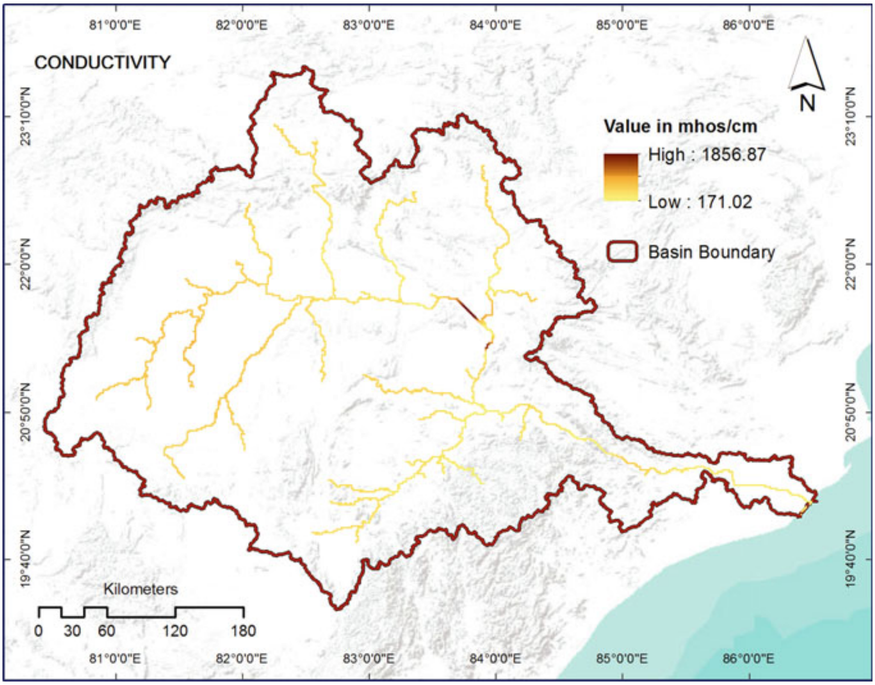

Fig. 15.10 Spatial variation of conductivity in Mahanadi River

AHP helps in representing and quantifying problem parameter by giving percentage influence. For the Mahanadi basin, it was the biological oxygen demand which was departed from its desirable limits in most of the station followed by dissolved oxygen and nitrite + nitrate. These three parameters are representing heavy organic pollution load. So, it is necessary to monitor the disposal of waste water at river site. The outcome of this study can be useful for interpretation of footprint of regional developmental activity due to pro industry policy. And the spatial variation of water quality index value along the river suggests the location of possible sites of water treatment plant.

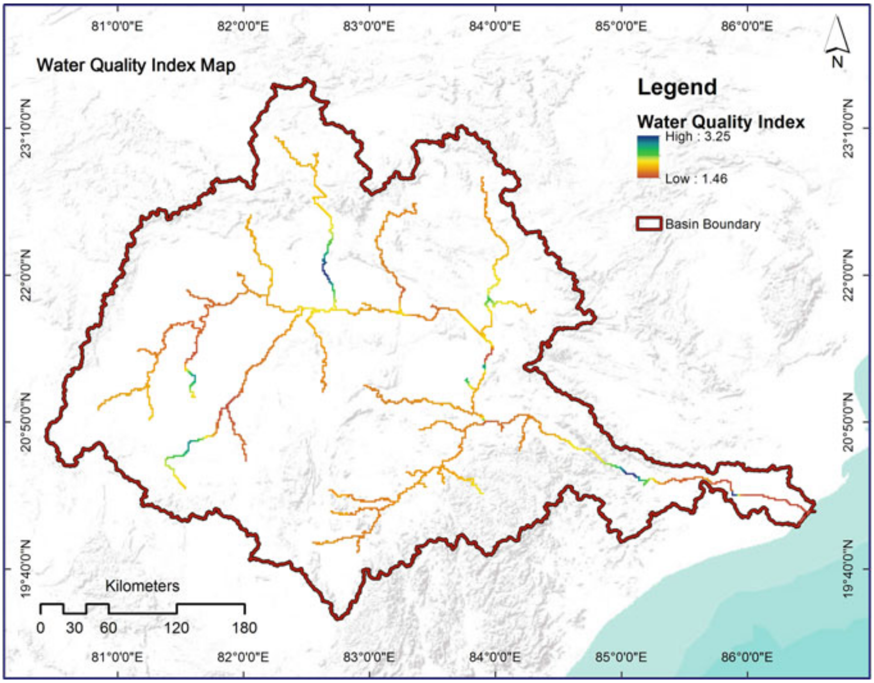

Fig. 15.11 Spatial variation of resulting WQI map for Mahanadi River

Table 15.4 Statistical characterization of Mahanadi River length based on WQI

S. No.	Class name	Range	Length of river (in km)	Length of river (in %) (%)
1	Very bad	1.00–1.75	230	7
2	Bad	1.75–2.50	523	17
3	Medium	2.50–3.25	1713	55
4	Good	3.25–4.00	647	21

Table 15.5 Statistical result of K-Mean cluster analysis

Parameters	Cluster 1	Cluster 2	Cluster 3	Cluster 4	Over all
BOD	2.6–3.8 (2.9 ± 0.5)	2.3–2.4 (2.4 ± 0.1)	1.2–8 (2.4 ± 1.5)	2.8–2.8 (2.8 ± 0)	1.2–8 (2.4 ± 1.4)
DO	6.2–6.8 (6.48 ± 0.3)	7.2–7.4 (7.3 ± 0.1)	3.1–7.2 (5.68 ± 0.8)	7.2–7.4 (7.3 ± 0.1)	3.1–7.4 (5.84 ± 0.9)
Temp.	27–28 (27.8 ± 0.45)	28–28 (28 ± 0.01)	32–44 (39.1 ± 3.23)	28–29 (28.5 ± 0.7)	27–44 (37.6 ± 4.87)
Cond	212–616 (334.6 ± 178.7)	434–556 (495 ± 86.3)	163–50,910 (3186 ± 10,512)	511–516 (513.5 ± 3.53)	163–50,910 (2808 ± 9804)
pH	7.5–7.8 (7.64 ± 0.13)	7.8–7.9 (7.85 ± 0.07)	7.6–10 (8.37 ± 0.28)	7.8–7.9 (7.85 ± 0.07)	7.5–10 (8.28 ± 0.35)
Tcoli	300–460 (406 ± 76.02)	300–500 (400 ± 141.4)	350–160,000 (46,078 ± 56,898)	300–300 (300 ± 0)	300–160,000 (39,847 ± 55,125)
N + N	1.2–2.2 (1.4 ± 0.45)	2.2–2.4 (2.3 ± 0.14)	0.8–29 (4.19 ± 4.2)	2.4–2.4 (2.4 ± 0)	0.8–29 (3.87 ± 4.14)

Note Minimum–Maximum
(Mean ± Standard Deviation)

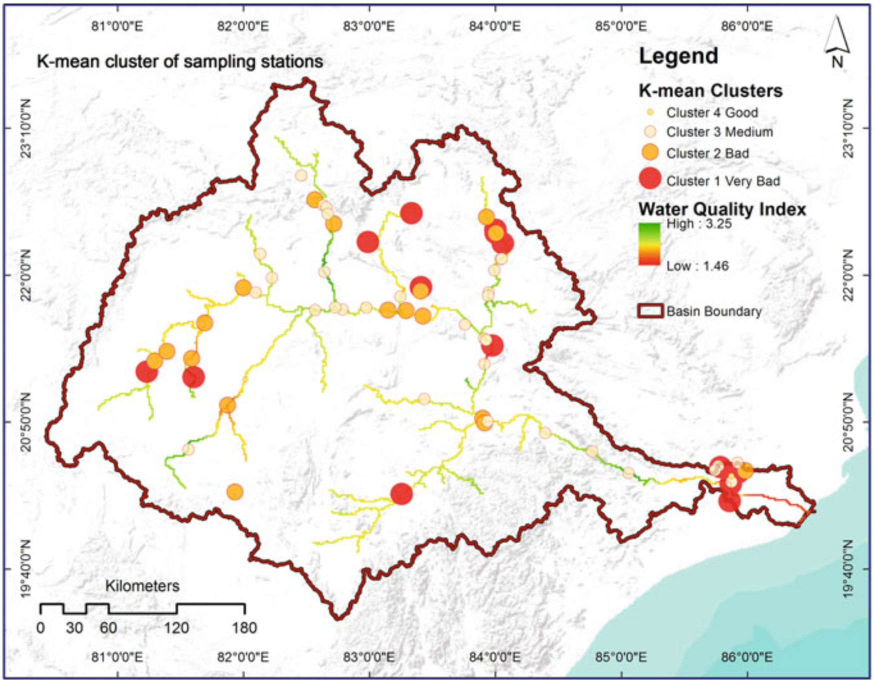

Fig. 15.12 Location of K-mean cluster members for Mahanadi River system

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