IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE)
e-ISSN: 2278-1684,p-ISSN: 2320-334X, Volume 18, Issue 3 Ser. III (May – June 2019), PP 39-55
www.iosrjournals.org

Water Quality Monitoring and Its Assessment on Mahanadi Basin

Abhijeet Das[a], Dr. Bhagirathi Tripathy[b]
[a] *Guest Faculty, Civil Engineering Department, Odisha.*
[b] *Assistant Professor, Civil Engineering Department, IGIT, Sarang, Odisha.*

Abstract
Mahanadi River is said to be the lifeline of the state Odisha, as the people use the water extensively, without sufficient and reliable information about water qualities and pollution status. The purpose of this study is to evaluate the water quality of the river and to analyze the suitability for drinking, agricultural and industrial uses. Most of the agriculture, industry and all-round developments are due to rich water resource potential of this river. This is why this study on the Mahanadi River is extremely important for the region. For this study, samples from 21 sampling stations over a period of 14 years were collected during low flow periods (between June – August) and high flow periods (between November – January) and multivariate techniques like factor analysis, Pearson correlation analysis and cluster analysis is being applied to surface water quality data sets obtained during two different hydrological periods. Results shows during low flow conditions, water quality was strongly affected by agricultural and irrigation uses. So, the major pollutant source changed from urban land uses to agricultural uses during the low flow period. The main reason for this was the negative effect of runoff to surface water quality because of the storage ability, the buffering capacity of roads and buildings to rain or storm water in urban areas, had been drastically weakened. Thus, major pollution threats in low and high flow periods were urban and agricultural land uses which are defined as non-point pollution sources. Therefore, priority should be given to minimization of these sources to improve water quality in the basin. This approach is believed to assist decision makers in identifying priorities to improve water quality that has deteriorated due to various land uses.
Keywords: *Pearson Correlation, Factor analysis, Cluster analysis, Runoff, Buffering capacity, Water quality.*

Date of Submission: 06-12-2018 Date of Acceptance: 25-06-2019

I. Introduction

Water, a prime natural resource and precious nationalasset which formsthechiefconstituentofecosystem. Sustainable management of water resources is an essential requirement for the growth of the state's economy and well-being of the population. It is an essential requirement for human and industrial developments which promotes sustenance of human civilization and it is the most delicate part of theenvironment. Water quality deals with the physical,chemical and biological characteristics in relation to allother hydrological properties. The water quality from the rivers has a considerable importance for the reason that these water resources are generally used for multiple matters such as drinking, domestic and residential water supplies, agriculture (irrigation), hydroelectric power plants, transportation and infrastructure, tourism, recreation, and other human or economic ways to use water.

Watersourcesmaybemainlyintheformofrivers,lakes,glaciers, rain water, ground water etc. Besides the need ofwater for drinking, water resources play a vital role invarious sectors of economy such as agriculture, livestockproduction,forestry,industrialactivities,hydropowergeneration,fisheriesandothercreativeactivities.Theav ailability and quality of water either surface or ground,have been deteriorated due to some important factors likeincreasingpopulation,industrialization,urbanizationetc. Water quality of any specific area or specific source can be assessed using physical, chemical and biological parameters. The values of these parameters are harmful for human health if they occurred more than defined limits.

For a given river, the water quality is the result of several interrelated parameters with a local and temporal variation which are influenced by the water flow rate during the year. In the context of sustainable water management, many hydrological studies have been published around the world, which highlights the ecological role of water from the rivers. Moreover, there have been more researches based upon water quality evaluation. This category of studies is related to the quality of water courses which generally use many statistical and mathematical models.Water quality monitoring has one of the highest priorities in environmental protection policy. The main objective is to control and minimize the incidence of pollutant-oriented problems and to provide water of appropriate quality to serve various purposes such as drinking water supply, irrigation water. The quality of water is defined in terms of its physical, chemical and biological parameters.

Multivariate statistical techniques, such as cluster analysis (CA), principal component analysis (PCA) and factor analysis (FA) helps in the interpretation of complex data matrices to better understand the water quality and ecological status of the studied system, allows the identification of possible factors that influences water environment system, and offers a valuable tool for reliable management of water resources. These have been used successfully in hydrochemistry for many years. It allows deriving hidden information from the data set about the possible influences of the environment on water quality.

One of the multivariate methods named factoranalysisattemptstoexplainthecorrelationsbetween theobservationsintermsoftheunderlyingfactors,whicharenot directly observable. There are three stagesin factoranalysis i.e., acorrelationmatrixwill be generated for all the variables, factors are extracted from the correlation matrix based onthecorrelationcoefficients ofthevariables and thefactors arerotated to maximize the relationship between some of the factorsandvariables.

The primary step is to determination of the parameter correlationmatrix. It is used to account for the degree of mutually sharedvariability between individual pairs of water quality variables.Then, eigenvalues and factor loadings for the correlation matrixaredetermined.EigenvaluescorrespondtoanEigen factorwhich identifies the groups of variables that are highly correlatedamongthem.Lowereigenvaluesmaycontributelittletothe explanatory ability of the data. Only the first few factors areneeded to account for much of the parameter variability. Oncethe correlation matrix and eigenvalues are obtained, factor loadings are used to measure the correlation between the variablesandfactors.Factorrotationis usedtofacilitateinterpretationby providing a simpler factor structure.

In this context, it is beingevaluatedthepossibilitythatasmallergroupof water quality parameters/ locations might provide sufficientinformation for water quality assessment. Factor analysis wasapplied to a surface water quality data set collected from Mahanadi River Basin, Odisha over a period of 2000-2014.

Waterqualitymonitoring was conducted at 21 stations in the study area during low- and high-flow periods. The selected parameters for theestimation of surface water quality characteristics were: electrical conductivity (EC), total dissolved solids (TDS), sodium(Na^+), potassium (K^+), calcium (Ca^{2+}), magnesium (Mg^{2+}), sulphate(SO^{2-}),nitrate-nitrogen(NO_3-N),KjeldahlNitrogen,bio chemical oxygen demand (BOD) and chemical oxygen demand(COD). COD measurements were performed using the potassium dichromate method. This statistical method applied in this study can be used to assess the relationship between variable and possible pattern in distribution of measured data. In this study we mainly used factor analysis to group water body into several zones with different water quality and to find the most important factor that describe the natural and anthropogenic influences.

II. Review Of Literature

Water is vital for any life process and there can be no substitute for it. Water is also used for transportation, is a source of power and serves many other useful purposes for domestic consumption, agriculture and industry. The main important source of water in any area is rain and it has a dramatic effect on agriculture. Plants get their water supply from natural sources and through irrigation. The yields of crops particularly in rain fed areas depends on the rainfall pattern, which makes it important to predict the probability of occurrence of rainfall from the past records of hydrological data using statistical analysis. The water quality from the rivers has a considerable importance for the reason that these water resources are generally used for multiple matters such as drinking domestic and residential water supplies, agriculture/irrigation, hydroelectric power plants, transportation and infrastructure, tourism, recreation and other human or economic ways to use water. For a given river the water quality is the result of several interrelated parameters with a local and temporal variation which are influenced by the water flow rate during the year. In the context of sustainable water management, many hydrological studies have been published around the world, which highlights the ecological role of water from the rivers. Moreover, there have been more researches based upon water quality evaluation. This category of studies is related to the quality of water courses which generally use many statistical and mathematical models.The extensive literature review was carried out by referring standard journals, reference books and conference proceedings. The major work carried out by different researchers is summarized below:

P. J. Puri, M. K. N. Yenkie, et al have studied water quality index (WQI) has been calculated for different surface water resources especially lakes, in Nagpur city, Maharashtra (India), for the session January to December 2008; comprising of three seasons, summer, winter and rainy season. Sampling points were selected on the basis of their importance. Water quality index was calculated using water quality index calculator given by National Sanitation Foundation (NSF) information system. **B. N. Tandel, Dr. J. Macwan, C. K. Soni** have studied, the water quality index is a single number that expresses the quality of water by integrating the water quality variables. Its purpose is to provide a simple and concise method for expressing the water quality for different usage. The present work deals with the monitoring of variation of seasonal water quality index of some strategically selected surface water bodies. The index improves the comprehension of general water quality issues, communicates water quality status and illustrates the need for and the effectiveness of protective practices. **S. Chandra, A. Singh and P. K. Tomar** have described, lake water is a source of drinking and domestic use water for rural and urban population of India. The main goal of the present study was to assess drinking water quality of various lakes i.e., Porur lake Chennai, Hussain Sager Hydrabad Vihar lake Mumbai in India. For this, lakes water samples were collected from six different sites and composite sample prepared were analyzed for pH, turbidity, electrical conductivity (EC), total dissolved solids (TDS), total alkalinity (TA), total hardness (TH)and calcium hardness (Ca-H), chemical oxygen demand(COD), biochemical oxygen demand (BOD), dissolved oxygen (D.O.), sulphate (as SO4 2-), nitrate (as NO3) and chloride (Cl-) levels .Some heavy metals like Iron, Zinc, Cadmium, Mercury, Nickel and Chromium were also analyzed in these samples. **Wu-Seng Lung, A. M. Asce** has studied, a two-layer time-variable model is developed to quantify seasonal variations of pH and alkalinity levels in acidic lakes. The model incorporates the CO2/ HCOJ/ CO5 equilibria with internal sources and sinks of alkalinity and acidity in the water column. External alkalinity and C02 acidity loadings are also incorporated. The modeling framework is applied to the Bickford Reservoir in Massachusetts and to Woods Lake and Panther Lake in Adirondack Park, New York. **V. Pradhan, M. Mohsin, B. H. Gaikwad** have studied, water quality of Chilika Lake was determined during the month of January 2012. It was observed that all the parameters are above permissible limit except at the sample site S2. The results are discussed in the light of findings of other workers.**Dr. M. K. Mahesh, B. R. Sushmitha, H. R. Uma** have explained, a water quality index (WQI) developed by the Canadian Council of Ministers of the Environment (CCME) was applied to Hebbal lake of Mysore, Karnataka State, India, to study its impact on aquatic life, livestock and to know whether it is suitable for recreation, irrigation and drinking. The index of the lake is rated as poor with respect to drinking, recreation and livestock, marginal with respect to Aquatic life and excellent for irrigation purpose. The overall water quality is rated as poor. The water quality is almost always endangered or deteriorated and the conditions often deviate from natural levels. Anabaena and Microcystis aeruginosa form blooms, Phacus pleuronectes is also recorded and the lake water is unsuitable to protect aquatic life. Incidence of Fish kill occurred in 2011 due to contamination of water.**M. S. Islam, B. S. Ismail, et al** have studied, the purpose of this study was to assess the hydrological properties and water quality characteristics of Chini Lake in Pahang, Malaysia. A total of seven sampling stations were established at the main Feeder Rivers of Chini Lake for measurement of stream flow. A total of 10 monitoring stations covering the study area were selected for water sampling. Fourteen water quality parameters were analyzed based on in-situ and ex-situ analysis for two seasons and laboratory analyses were carried out according to the HACH and APHA methods. Stream flow from the seven Feeder Rivers into the Chini Lake was relatively slow, ranging from 0.001 to 1.31 m/s 3 or an average of 0.21 m /s. **V. B. Y. Sheikh, P. R. Bhosale, B. N. Nagargoje** has explained, Physical, chemical, ionic, biological studies were conducted at (Maharashtra State, India). It is positioned on south east corner of Maharashtra. Nagzari dam is situated at Nagzari village of Kinwat quality of Nagzari dam. Water is to determine the nutrient status of the water with reference to drinking water quality as well as irrigational purpose. Also observe the seasonal variations of selected water parameters and identify the pollution sources dam. The physical and chemical parameters were analyzed as per APHA revealed that there were fewer variations in the physicochemical, ionic, heavy metals analysis of the present water quality parameters undertaken and results received through the entire one year of study showed that the status of water quality is quite normal and within the permissible limit as mentioned with ISI. **S. Hussaina, V. Maneb, et al.** have studied, In the present work we are reported the Physico chemical properties like pH, conductivity, Turbidity, TDS, DO, fluoride, chloride, Sodium, Sulphate, etc. and the values are compared for treated and untreated water samples. The samples were collected from treatment plant of Ahmedpur, Dist Latur. The values change apparently after the treatment of water.**R. W. Gaikwad, V. V. Sasane** has explained, the present work is aimed at assessing the water quality of the groundwater in and around Lonar Lake. Water quality has been determined by collecting groundwater samples and subjecting the samples to a comprehensive physiochemical analysis. For assessing water quality, pH, total hardness, calcium, magnesium, bicarbonate, chloride, nitrate, sulphate, total dissolved solids, iron, manganese and fluorides have been considered. The higher values have been found to be mainly for Iron, Total hardness, chloride, fluoride, calcium and magnesium, many literatures shown that groundwater quality in Lonar Taluka has been badly affected by nitrate contamination. The analysis reveals that the groundwater of the area needs some degree of treatment before consumption, and it also needs to be protected from the perils of contamination.**S. N. Thitame and G. M. Pondhe** have studied, in present investigation an attempt was made for assessment of Seasonal Variation in Physicochemical Characteristics and Quality of Pravara River Water for Irrigation during year 2008. The study reveals that most of the physicochemical parameters of river water at five selected sites show moderate variation in their concentration for all seasons. However, site 3 and 4 stands evidence of discharge of waste water from the city in the river. This intern indicated the quality of water for irrigation in the study area. The Sodium absorption ratio and Residual sodium carbonate values show good water quality for irrigation. **M. Pejaver and M. Gurav** have explained, the two lakes namely Kalwa and Jail Lake of Thane city are eutrophicated and hence the study were done to find the quality of water for the period of

6 months for various physico-chemical parameters to study the pollution status of the lakes. The Jail Lake is found to be relatively more organically polluted and greater degree of eutrophication the Kalwa lake. Among water quality parameters, a positive correlation was found between chlorophyll and temperature, suspended solids, pH, dissolved oxygen (not with chlorophyll c), CO_2 (only with chlorophyll C). A negative correlation was seen between Chlorophyll and light penetration. The Chlorophyll a and b showed negative correlation with CO_2 silicates and Phosphates.**R. M. Khan, M. J. Jadhav, I. R. Ustad** have explained, in order to understand the water quality of Triveni Lake, Physico-chemical parameters were studied and analyzed for the period of one year i.e., December 2010 to November 2011. Various physicochemical parameters, such as water temperature, air temperature, pH, humidity, conductivity, free Co2, total solid, dissolved oxygen, Total alkalinity, Total hardness, caco3, ca++, mg++ were studied. The results revealed that there was significant seasonal variation in some physicochemical parameters and most of the parameters were in normal range and indicated better quality of lake water. It has been found that the water is best for drinking purpose in winter and summer seasons.

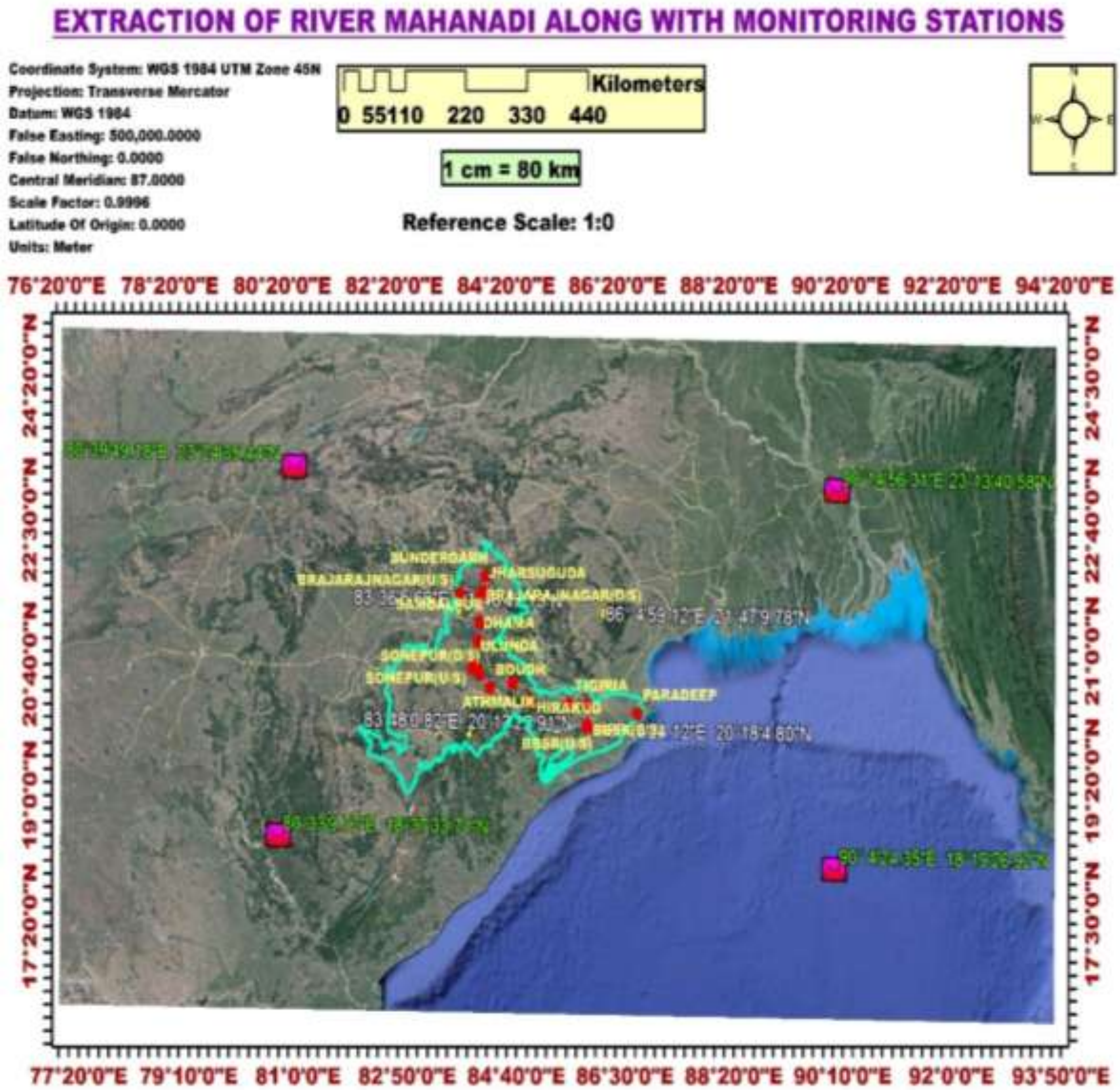
III. Study Area

River Mahanadi rises from a small pool located at about 6 km from Pharsiya village in the Amarkantak hills of Bastar Plateau, which lies to the extreme south east of Raipur district of Chattisgarh State. Out of its total length of 851 km, it covers 494 km in Odisha state. Ib, Ong, Tel, Hariharjore and Jeera are the main tributaries and Kathojodi, Kuakhai , Devi and Birupa are the major distributaries of Mahanadi in Odisha. The multipurpose Hirakud Dam over the Mahanadi at sambalpur is nearly 400 km from the mouth and is located exactly at the midpoint of the trunk stream.

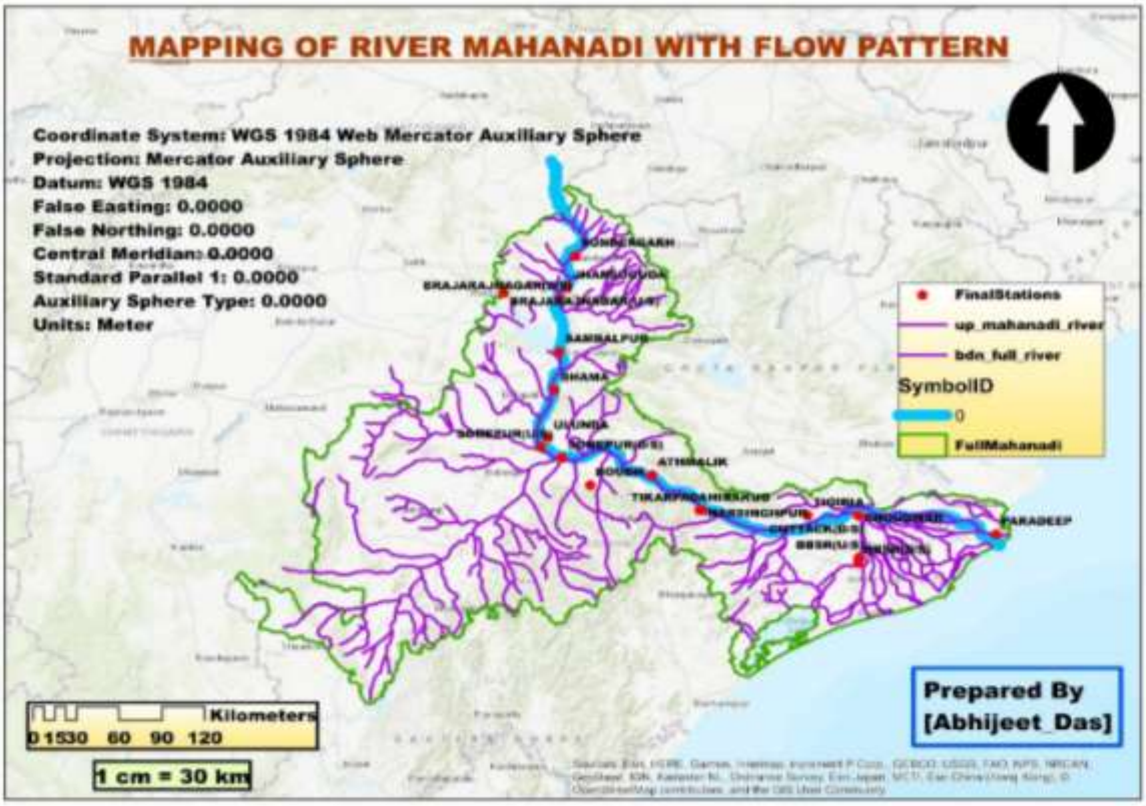
The river Ib joins Mahanadi near Bagra and enters into the Hirakud reservoir from the left. From Sambalpur, the river flows southwards till it joins with Ong and Tel. Tel is the biggest tributary of Mahanadi at sonepur from where again the river flows eastwards to join the Bay of Bengal. Before entering into the coastal plain and forming the delta, the river traverses through the Eastern Ghats cutting across a 60 km long “Satkosia Gorge” overlooked by precipitous hills and lush green tropical forests. Finally, the river emerges out of the Eastern Ghats near Naraj about 10 km to the west of cuttack city. The deltaic action starts near Naraj where the river first divides into two major distributaries i.e., the Mahanadi on the north and the kathojodi on the south. Traversing through the districts of cuttack and puri from west to east through a large no of distributaries, it has developed an extensive delta.

Thepollutionsourcescanbeorganized intothreegroups i.e., pointdischarges, non-pointsourcecontributions and othersources. Point discharges originate from either domestic or industrial polluters. While some of these discharges are made to the river after proper treatment, in many cases no treatment is applied prior tothe discharge. The basic sources of non-point source pollution inthe basin include the diffused transport of contaminants to riverchannelsoriginatingfromagriculturalpractices.Inaddition,there are also other sources of pollution that degrade the qualityof surface waters including transportof eroded land, leachates from mining activities and solid wastedisposal sites.

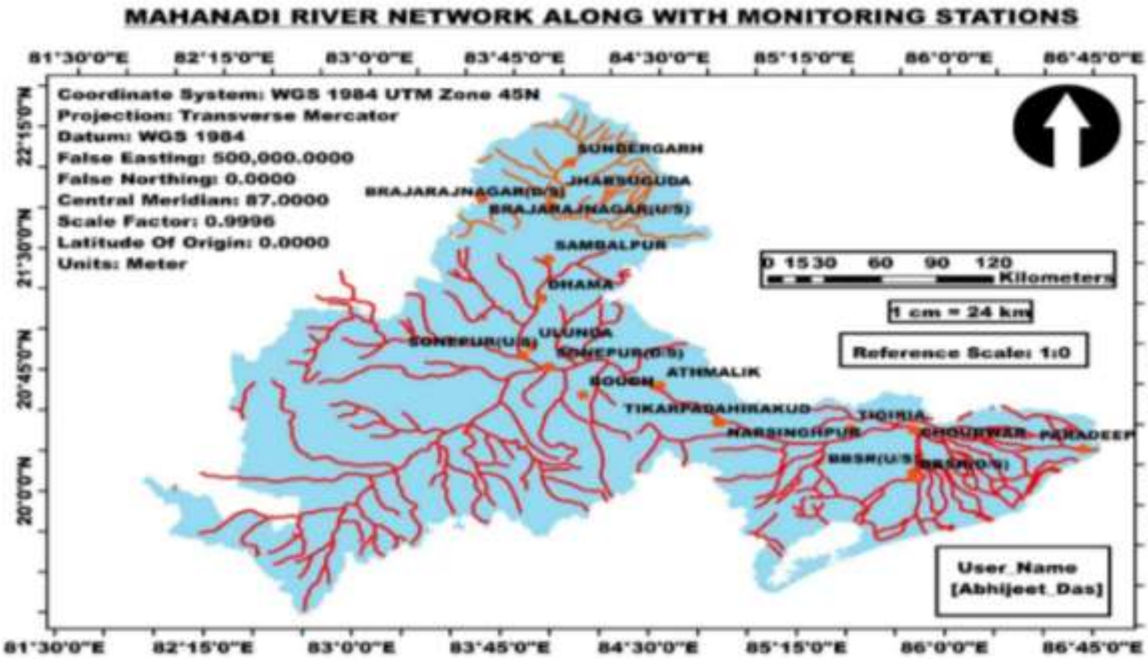
The below (**Figure 1, 2. 3, 4 &5**) showing Extraction, Mapping, Digitization, Plotting of sampling stations, Stream Network Creation and Flow path modelling on Mahanadi basin by the application of GIS Software.



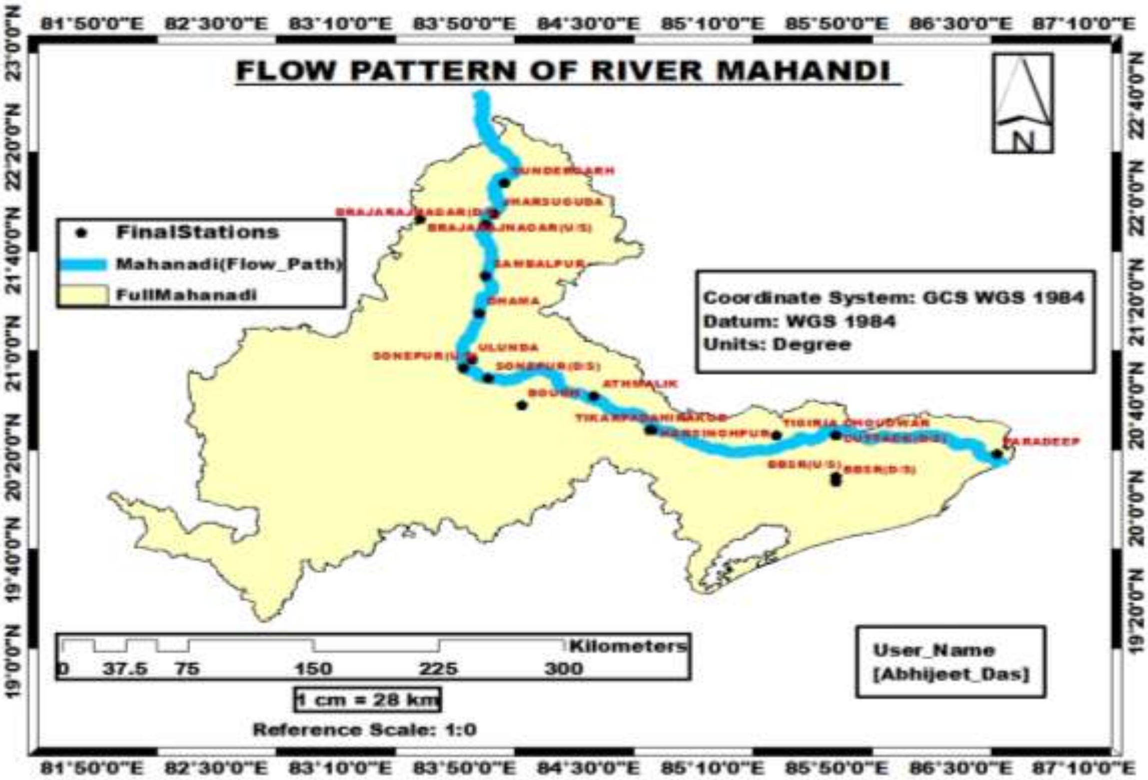
(Figure1. Extraction of Mahanadi Basin from google earth)



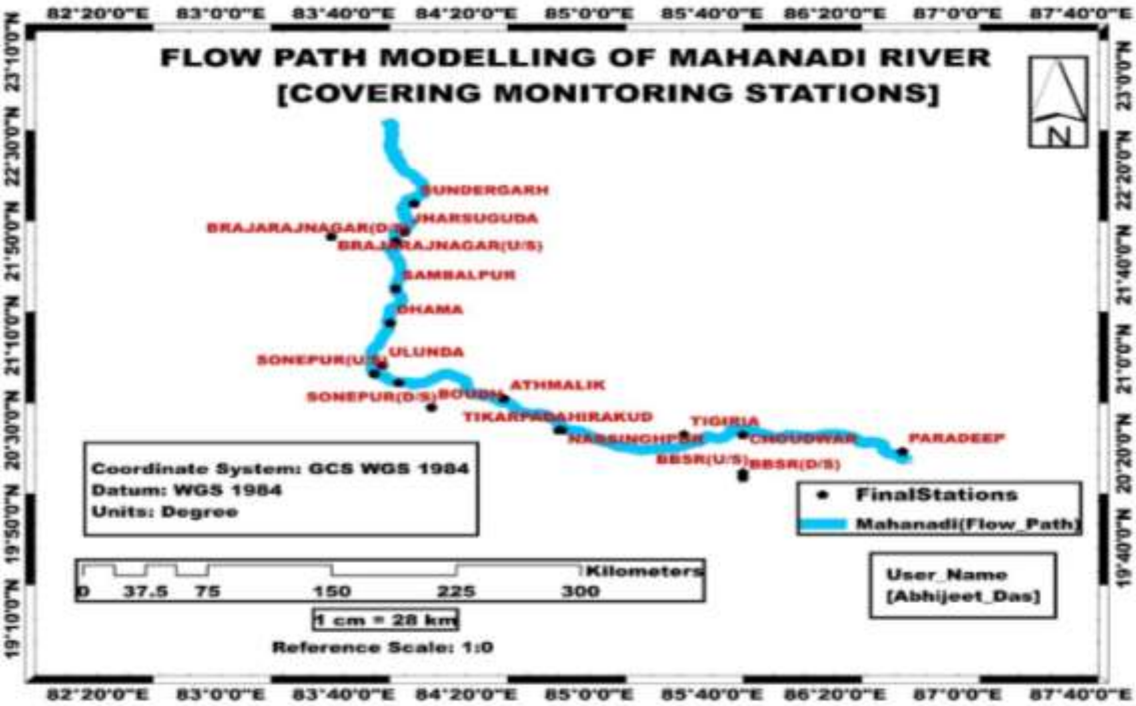
(Figure2. Mapping of monitoring stations of River Mahanadi showing the flow path)



(Figure3. Mahanadi river network covering all sampling stations along the flow path)



(Figure4. Plotting of flow pattern of Mahanadi basin accompanied with sampling stations)



(Figure5. Flow path modelling of River Mahanadi)

IV. Materials And Methods

One of the most fertile soils in the country is found in the Mahanadi River Basin. In this region, the economy is heavily dependent on agricultural production and also the industrial activities. The climate of the region is typically hot and dry in summer and temperature and rainy in winter. So, hydrological conditions of the river during the summer and winter periods are quite different. Thus, assessment of the water quality separated for summer (low flow) and winter (high flow) periods will assist in understanding the main pollutants, their sources and also determining priorities to improve water quality in two different hydrological periods.

SAMPLING AND PARAMETERS

Water samples were collected from 21 stations along the course of theMahanadi River system for a period of 14 years i.e., 2000-2014 in terms of summer (low flow) and winter (high flow) periods in order to assist in understanding the main pollutants, their sources and also determining priorities to improve water quality in two different hydrological periods. The sampling strategy was designed in such a way to cover a wide range of determinants at key sites that accurately represent the water environment quality of the river systems and account for tributary inputs that can have important impacts upon downstream water quality. Various water quality parameters from the monitoring stations were analyzed yearly from 2000 to 2014.

LOW FLOW PERIOD

The descriptive statistics is being carried out of the data sets (Table 1) was taken into consideration for evaluating the pollution load in the water system. The measured parameters include EC, TDS, Na+, K+, $Ca^{2}+$, $Mg^{2}+$, $S0_4\ ^{2-}$, NO_3 -N, TKN, BOD and COD.

Table1.Descriptive statistics of water quality data under low flow conditions (June – August

DESCRIPTIVE STATISTICS OF WATER QUALITY DATA UNDER LOW-FLOW CONDITIONS(JUNE-AUGUST) [2000-2014]								
PARAMETERS	**MEAN**	**NUMBER OF DATA**	**MEDIAN**	**STANDARD DEVIATION**	**VARIANCE**	**COEFFICIENT OF VARIANCE**	**MINIMUM**	**MAXIMUM**
EC	554.9738	21	186.6	1692.756	2865424	3.0501555	144.86	7942.2
TDS	742.4241	21	127.54	2827.384	7994101	3.808314076	86.54	13081.82
Na+	13.31762	21	11.1	8.541365	72.95492	0.641358275	3.7	38.7
K+	1.828571	21	1.7	0.698672	0.488143	0.382086365	0.9	3.75
$Ca^{2}+$	58.48095	21	59.9	10.26205	105.3096	0.175476751	37.3	75.9
$Mg^{2}+$	20.31286	21	18.6	7.236447	52.36617	0.35624961	10.9	37
$S0_4\ ^{2-}$	24.02	21	6.89	78.07425	6095.588	3.250384927	4.83	364.7
NO_3 -N	2.672095	21	2.5	0.951174	0.904731	0.35596547	1.85	6.4
TKN	5.614238	21	5.45	1.835813	3.37021	0.326992406	3.44	11.069
BOD	1.698905	21	1.497	0.569306	0.324109	0.33510181	1.273	3.71
COD	11.54143	21	10.22	4.31729	18.63899	0.374068943	6.63	25.22

Pearson Correlation Matrix is used to evaluate the relationship among the variables. These correlations indicate the waste water from domestic and industrial and its organic load are disposed to the river. The results of the correlation analysis are considered in the subsequent interpretation. A high correlation coefficient (nearly 1 or -1) means a good relationship between two variables and a correlation coefficient around zero means no relationship. Positive values indicate a positive relationship while negative values indicate an inverse relationship. The actual values of the variables (EC, TDS, Na^+, K+, $Ca^{2}+$, $Mg^{2}+$, $S0_4\ ^{2-}$, NO_3 -N, TKN, BOD, COD**)** were taken for statistical analysis (**Table 2**). Correlation matrix analysis represents the strong positive correlations exist between EC- TDS, EC – Sulphate, Sodium – Magnesium, Potassium – BOD, Calcium – Magnesium, NO_3 -N – BOD, TKN – BOD, BOD – CODfor low flow periods.

Table 2. Pearson correlation matrix for low flow period

PEARSON CORRELATION MATRIX FOR LOW FLOW PERIOD											
Variables	**EC**	**TDS**	**Na+**	**K+**	**$Ca^{2}+$**	**$Mg^{2}+$**	**$S0_4\ ^{2-}$**	**NO_3 -N**	**TKN**	**BOD**	**COD**
EC	**1**	1.000	-0.076	0.055	-0.027	-0.015	1.000	0.207	0.681	0.092	0.170
TDS	**1.000**	**1**	-0.074	0.057	-0.026	-0.012	1.000	0.204	0.680	0.088	0.165
Na+	-0.076	-0.074	**1**	-0.001	0.031	0.614	-0.080	-0.013	-0.084	-0.069	-0.104
K+	0.055	0.057	-0.001	**1**	-0.443	0.214	0.061	0.063	0.055	0.446	0.370
$Ca^{2}+$	-0.027	-0.026	0.031	-0.443	**1**	0.175	-0.027	0.153	-0.061	-0.132	-0.056
$Mg^{2}+$	-0.015	-0.012	**0.614**	0.214	**0.175**	**1**	-0.013	-0.166	-0.239	-0.067	-0.101
$S0_4\ ^{2-}$	**1.000**	**1.000**	-0.080	0.061	-0.027	-0.013	**1**	0.211	0.680	0.096	0.176
NO_3 -N	0.207	0.204	-0.013	0.063	**0.153**	-0.166	**0.211**	**1**	0.469	0.813	0.772
TKN	**0.681**	**0.680**	-0.084	0.055	-0.061	-0.239	**0.680**	0.469	**1**	0.363	0.327
BOD	0.092	0.088	-0.069	**0.446**	-0.132	-0.067	0.096	**0.813**	**0.363**	**1**	0.927

COD	0.170	0.165	-0.104	**0.370**	-0.056	-0.101	**0.176**	**0.772**	**0.327**	**0.927**	**1**

Firstly, factor analysis was applied to data sets obtained during the low flow period (between June – August). The correlation matrix of variables was generated and factor are extracted by the centroid method, rotated by Varimax rotation. Calculated eigen values, percent total variance, factor loadings and cumulative variances are illustrated below in (**Table 3, 4, 5**).

Table 3. Factor loading analysis and total variance explained for low flow condition

Principal Component Analysis/ Factor Analysis											
	F1	**F2**	**F3**	**F4**	**F5**	**F6**	**F7**	**F8**	**F9**	**F10**	**F11**
Eigenvalue	4.032	2.472	1.659	1.426	0.678	0.346	0.208	0.142	0.037	0.000	0.000
Variability (%)	36.651	22.474	15.081	12.968	6.160	3.142	1.892	1.292	0.339	0.000	0.000
Cumulative %	36.651	59.125	74.206	87.174	93.334	96.477	98.369	99.661	100.000	100.000	100.000

Table 4. Calculation of Eigen vectors for low flow condition

Eigenvectors					
VARIABLE	**F1**	**F2**	**F3**	**F4**	**F5**
EC	**0.422**	-0.322	0.064	-0.034	-0.083
TDS	**0.421**	-0.324	0.066	-0.036	-0.085
Na+	-0.078	-0.032	**0.625**	0.188	**0.580**
K+	0.118	0.262	**0.309**	-0.539	-0.388
Ca^{2}+	-0.044	-0.090	-0.017	**0.723**	-0.499
Mg^{2}+	-0.081	-0.061	**0.699**	0.112	-0.282
$S0_4^{2-}$	**0.423**	-0.319	0.064	-0.036	-0.091
NO_3 -N	0.309	**0.369**	-0.034	**0.354**	**0.169**
TKN	**0.410**	-0.077	-0.077	0.045	**0.346**
BOD	0.285	**0.506**	0.067	0.038	-0.017
COD	0.302	**0.459**	0.034	0.083	-0.114
Eigenvalue	4.032	2.472	1.659	1.426	0.678
Variability (%)	36.651	22.474	15.081	12.968	6.160
Cumulative %	36.651	59.125	74.206	87.174	93.334

Table 5. Calculation of Factor loadings for low flow condition

Principal Component Analysis (Factor)/Factor loadings/Component loadings					
VARIABLE	**F1**	**F2**	**F3**	**F4**	**F5**
EC	**0.848**	-0.506	0.082	-0.041	-0.068
TDS	**0.846**	-0.509	0.084	-0.042	-0.070
Na+	-0.158	-0.051	**0.805**	**0.224**	**0.478**
K+	0.236	0.411	0.398	-0.643	-0.319
Ca^{2}+	-0.089	-0.142	-0.022	**0.863**	-0.411
Mg^{2}+	-0.163	-0.096	**0.900**	**0.133**	-0.232
$S0_4^{2-}$	**0.850**	-0.501	0.083	-0.043	-0.075
NO_3 -N	0.620	**0.580**	-0.044	**0.423**	0.139
TKN	**0.824**	-0.120	-0.099	0.054	**0.285**
BOD	0.573	**0.795**	0.086	0.046	-0.014
COD	0.606	**0.722**	0.044	0.100	-0.094
Eigenvalue	4.032	2.472	1.659	1.426	0.678
Variability (%)	36.651	22.474	15.081	12.968	6.160
Cumulative %	36.651	59.125	74.206	87.174	93.334

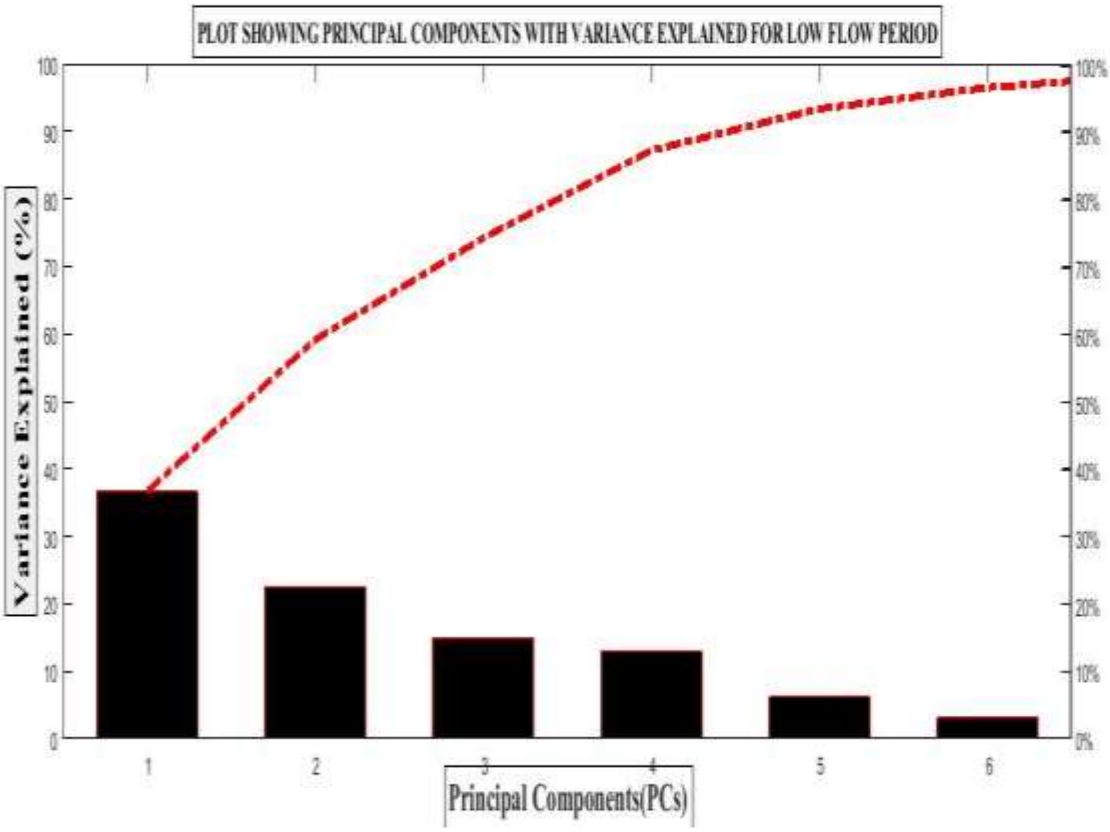
The factor analysis obtained from (**Table 2**) generated major five significant factors which explained 93.334% of the variance in data sets. The following factors were indicated considering the hydro chemical aspects of the water:

a) **Factor 1:**NO_3 -N, BOD, COD, EC, TDS, Sulphate and TKN

b) **Factor 2:** NO_3-N, BOD and COD, TDS and EC.

c) **Factor 3:**Mg^{2+}, Na^+, EC, TDS, potassium ion, sulphate, BOD and COD.

d) **Factor 4:**Sodium, Magnesium, BOD, COD and TKN, Calcium ion and NO_3-N
e) **Factor 5:** Sodium ion and TKN
From the data set, five factors were obtained having eigen value or factor loadings >1 as shown in **figure 6**.

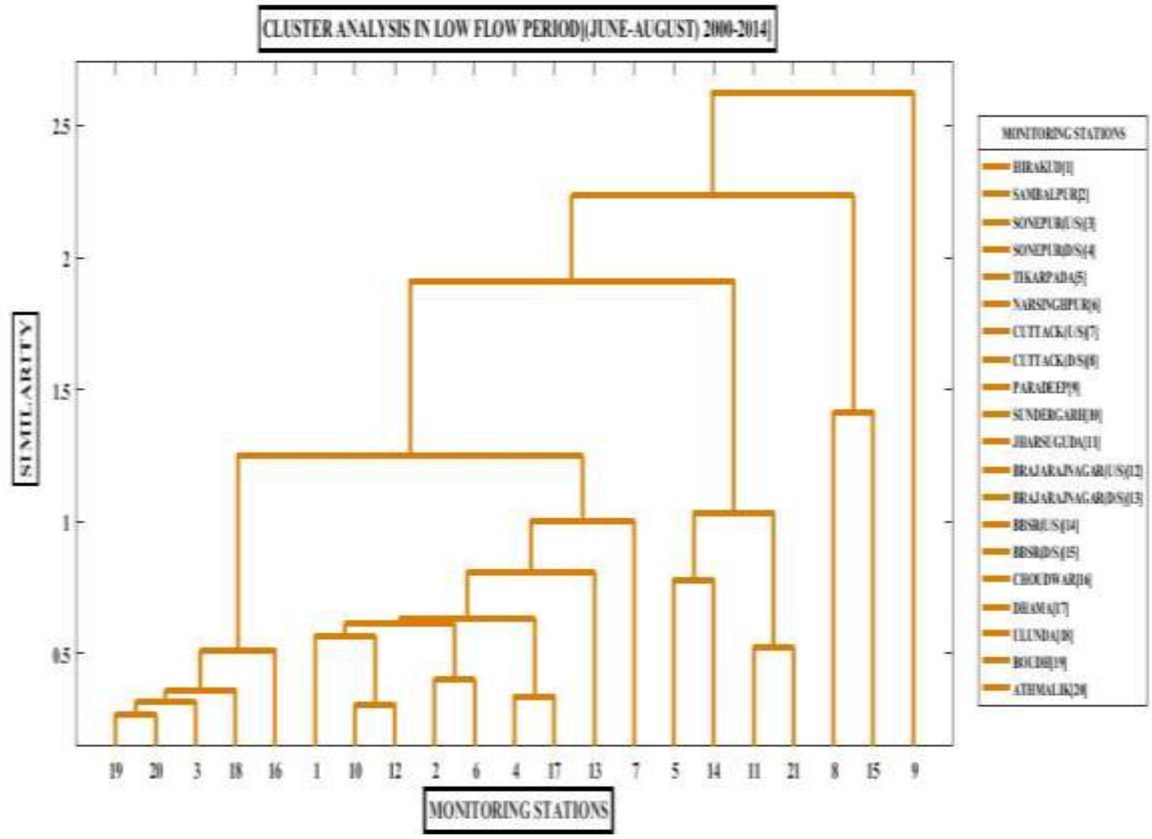


(Figure 6. Scree plot for LP Sites**)**

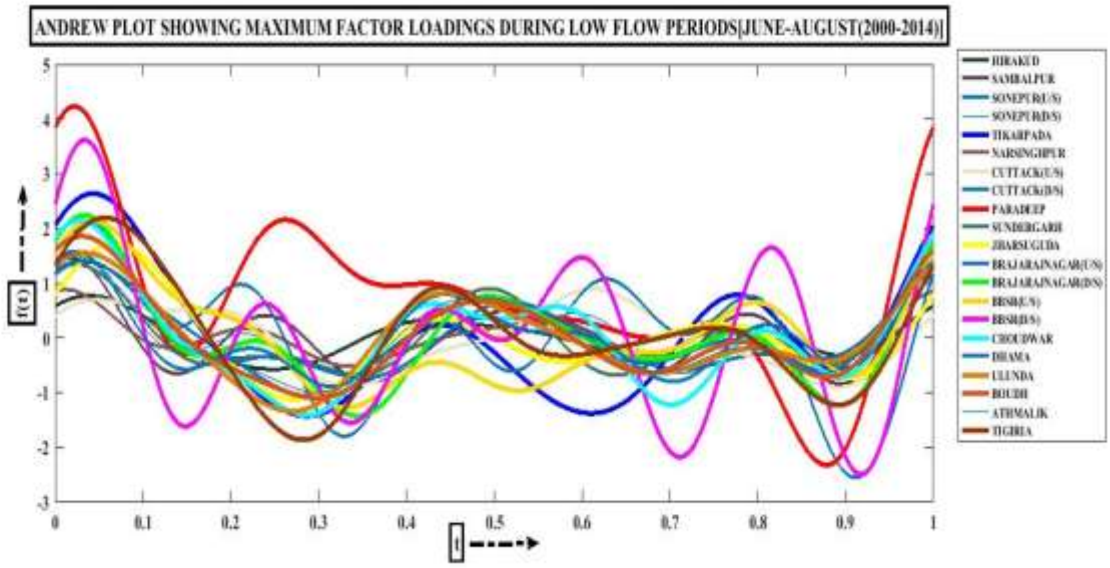
Among five factors (**Table 3 and 4**) and from figure above, it is clearly seen that F1, explaining 36.651% of the total variance, has moderate positive loadings on NO_3 -N, BOD and COD and Strong positive loading on EC, TDS, Sulphate and TKN which is attributed to localized anthropogenic input and also due to deamination of nitrogen containing organic compounds rather than river runoffs. F2, explaining 22.474% of the total variance, moderate positive loadings on NO_3-N and potassium ion and strong positive loadings on BOD and COD and strong negative loading on TDS and EC. F3, explaining 15.081% of the total variance, has strong positive loadings on sodium and magnesium, strong negative loading on TKN, NO_3 - N, calcium and moderate positive loading on EC, TDS, potassium ion, sulphate, BOD and COD. F2 represent organic pollution from domestic waste and non-point source pollution and F3 represents urban land use factor. F4, explaining the lowest variance (12.968%) has moderate loadings on Sodium, Magnesium, BOD, COD and TKN and strong positive loading on Calcium ion and NO_3-N and F5, explaining the very lowest variance (6.160%) has zero moderate loadings and strong positive loading on sodium ion and TKN which both contributes to normal biological degradation products of nitrogenous organic matter.

Urbanization influences the water cycle through changes in flow and water quality. Urban land use (Na^+, K^+, Cl^-) may be differentiated from other land uses such as agriculture (calcium, magnesium), through the use of biogeochemical fingerprints. Salts that are commonly found in subsurface drainage water includes sulphates, chlorides, carbonates and bicarbonates of calcium and magnesium. Tail water also may contain these salts, but generally in much lower concentrations than in drainage water. Based on the results of the factor analysis and typical sources of water pollutants, it is concluded that F1 can be denoted as the “agricultural use” factor with presence of EC, TDS, Sulphate (SO_4^{2-}), TKN. As it was mentioned above, these parameters are mainly found in agricultural drainage water. F2 is strongly correlated with NO_3-N, BOD and COD assigned as the “Organic pollution factor” Magnesium and sodium are strongly corelated with F3 assigned as “Urban land use factor”.

In summary, three factors representing three different processes are Agricultural use factor (F1), Organic pollution factor (F2) and Urban land use factor (F3). Negative factor loadings of NO_3-N having loading (-0.044) explained the disproportion between this parameter and F2. COD, BOD and NO_3-N which were correlated with F2, decreased with increasing NO_3-N concentration which was caused by the nitrification process in water.Therefore, the water quality of the Mahanadi River during the low flow period was mainly controlled by agricultural pollutant sources.



(Figure 7. Dendrogram showing clustering of monitoring sites according to surface water quality characteristics of the Mahanadi River basin)



(**Figure 8.** Andrew plots showing physio-chemical parameters and their loadingson sampling stations of the Mahanadi River basin)

In Clustering approach, sampling sites classification was performed by theuse of cluster analysis. The relationships among the stations (**Figure 7**) were obtained through cluster analyses using Ward's method (linkage between groups), with Euclidian distance as a similarity measure and were synthesized into dendrogram plots. Since we used hierarchical agglomerative cluster analysis, the number of clusters was also decided by water environment quality, which is mainly affected by land use and industrial structure. Considering the different agglomerative hierarchical clusters and its factor loadings on the sampling, it is concluded that:

CLUSTER- I- (1 – 2 – 3 – 4 – 6 – 7 – 10 – 12 – 13 – 16 – 17 – 18 – 19-20): Sampling sites, mainly located in between Hirakud and Athamalik are clustered in this group. Sambalpur is the major urban area (population about 1.5 lakhs, districts and division headquarters) immediately downstream of Hirakud reservoir (about 5 km). Apart from being a source of water supply, Mahanadi at Sambalpur is used for bathing and waste water (untreated) disposal which is responsible for the observed deterioration of water quality at sambalpur D/s.

Factor 1: Low factor scores of F1 (agricultural use factor) were observed in the west of the basin. The middle and eastern parts where high values were monitored were faced with pollution risks originating from agricultural uses.

CLUSTER- II-(5 – 11 – 14 – 21): This cluster sites mainly located in between Tikarpada and Tigiria. As Tikarpada does not have any industry or urban settlement on its banks (except two small sub-divisional towns and there is no major waste water outfall.

Factor 2: (organic pollution factor) scores were distributed in the basin almost uniformly. Depending on the presence of infrastructure and waste water treatment efficiency, highest and lowest scores were observed even at the stations located next to each other. So, the settlements having no treatment plants increased the organic pollution risk.

CLUSTER- III-(8 – 9 – 15): This cluster mainly in between Cuttack and Bhubaneswar. Asthe river enter into deltaic region characterized by high population density and intense agricultural activities and presence of industries which leads to deterioration of water quality in these monitoring stations and it is mostly affected due to untreated domestic wastewater, industrial effluents and agricultural runoffs.

Factor 3: High factor scores (urban land use factor) were obtained in the north west and also in the regions where population density is relatively high (especially in the center of the provinces and their surroundings)

HIGH FLOW PERIOD

The high flow period may have positive effects with dilution of surface water by rain and stormwater. On the other hand, runoff water increases pollutant concentrations, thereby decreases quality. To assess the water quality of the Mahanadi River under high flow conditions, factor analysis was applied data sets obtained from 21 monitoring stations between November – January. Descriptive statistics of the data are presented in **Table 6**.

Table 6.Descriptive statistics of water quality data under high flow conditions (November – January)

DESCRIPTIVE STATISTICS OF WATER QUALITY DATA UNDER HIGH-FLOW CONDITIONS(NOVEMBER-JANUARY) [2000-2014]								
PARAMETERS	**MEAN**	**NUMBER OF DATA**	**MEDIAN**	**STANDARD DEVIATION**	**VARIANCE**	**COEFFICIENT OF VARIANCE**	**MINIMUM**	**MAXIMUM**
EC	182.301429	21	179	19.4750877	379.279043	0.10682905	147	218.75
TDS	116.095238	21	114	12.7941579	163.690476	0.11020399	89	136
Na+	20.5038095	21	20.4	6.54355444	42.8181048	0.31913847	11.18	33.1
K+	2.05952381	21	1.9	0.45596575	0.20790476	0.22139377	1.5	3
Ca^{2+}	50.1761905	21	48.8	8.60696838	74.0799048	0.17153491	36	76.2
Mg^{2+}	26.9142857	21	28.6	9.53835865	90.9802857	0.35439761	13.5	41.3
$S0_4^{\ 2-}$	5.22957143	21	5.57	2.06995335	4.28470686	0.39581701	0.251	8.6
NO_3 -N	3.264	21	2.4	2.85921286	8.1750982	0.87598433	0.235	12.64
TKN	4.82428571	21	3.36	4.21625731	17.7768257	0.87396509	1.3	21.84
BOD	1.48571429	21	1.3	0.72130834	0.52028571	0.48549599	0.6	3.1
COD	10.6380952	21	10.7	2.50029522	6.25147619	0.23503223	7.4	17.7

To identify the association between the variables and to estimate the strength of the relationship, Pearson correlation matrix is used which provides information about not only the strength but also the direction of a relationship. In high flow period (**Table 7**), Electrical Conductivity – TDS, TDS - NO_3 -N, Sodium – Magnesium, Potassium – Magnesium, Calcium – TKN, Magnesium – BOD, Sulphate – BOD, NO_3 -N – BOD, TKN – BOD was found to exist positively correlated. This signifies that the parameters change with direct proportionality. Some parameters were found to be in fair negative correlation signifying that these parameters change with inverse proportionality.

Table 7.Pearson Correlation matrix for High Flow Periods

PEARSON CORRELATION MATRIX FOR HIGH FLOW PERIODS											
Variables	**EC**	**TDS**	**Na+**	**K+**	**Ca^{2+}**	**Mg^{2+}**	**$S0_4^{2-}$**	**NO_3 -N**	**TKN**	**BOD**	**COD**
EC	**1**	0.461	0.124	0.050	0.259	0.065	-0.133	0.149	0.225	0.311	0.026
TDS	**0.461**	**1**	-0.023	-0.178	0.078	-0.045	-0.218	0.121	-0.049	-0.063	0.000
Na+	0.124	-0.023	**1**	0.303	-0.299	0.661	-0.223	0.141	0.053	0.335	0.024
K+	0.050	-0.178	**0.303**	**1**	0.069	0.388	0.061	-0.233	0.146	-0.025	-0.034
Ca^{2+}	0.259	0.078	-0.299	0.069	**1**	0.085	-0.013	0.063	0.136	-0.096	-0.038
Mg^{2+}	0.065	-0.045	**0.661**	**0.388**	**0.085**	**1**	0.084	0.168	0.120	0.371	0.132
$S0_4^{2-}$	-0.133	-0.218	-0.223	0.061	-0.013	0.084	**1**	0.335	-0.074	0.392	-0.393
NO_3 -N	0.149	**0.121**	0.141	-0.233	0.063	**0.168**	**0.335**	**1**	0.131	0.523	-0.288
TKN	0.225	-0.049	0.053	**0.146**	**0.136**	0.120	-0.074	0.131	**1**	0.420	-0.159
BOD	**0.311**	-0.063	**0.335**	-0.025	-0.096	**0.371**	**0.392**	**0.523**	**0.420**	**1**	-0.314
COD	0.026	0.000	0.024	-0.034	-0.038	0.132	-0.393	-0.288	-0.159	-0.314	**1**

Results of factor analysis including factor loading matrix, eigen values and total cumulative variance values are given in (**Table 8, 9, 10).**

Table 8. Factor loading analysis and total variance explained for high flow condition

Principal Component Analysis/ Factor Analysis											
	F1	**F2**	**F3**	**F4**	**F5**	**F6**	**F7**	**F8**	**F9**	**F10**	**F11**
Eigenvalue/Component Variances	2.507	1.898	1.714	1.277	0.977	0.856	0.645	0.469	0.393	0.159	0.105
Variability (%)/ Percentage Variance Explained	22.788	17.251	15.578	11.611	8.883	7.784	5.866	4.265	3.576	1.442	0.955
Cumulative %	22.788	40.040	55.617	67.228	76.111	83.896	89.761	94.027	97.603	99.045	100.000

Table 9. Calculation of Eigen vectors for high flow condition

Eigenvectors/Principal Component Analysis					
VARIABLE	F1	F2	F3	F4	F5
EC	0.222	0.035	**0.588**	0.062	-0.031
TDS	-0.002	-0.033	**0.578**	-0.255	-0.224
Na+	0.352	**0.477**	-0.073	-0.304	0.004
K+	0.155	0.382	-0.178	**0.486**	-0.125
Ca^{2+}	0.010	-0.103	0.319	**0.607**	-0.374
Mg^{2+}	**0.397**	**0.410**	-0.090	0.027	-0.338
$S0_4^{2- -}$	0.233	-0.406	-0.354	0.114	-0.359
NO_3 -N	**0.388**	-0.320	0.074	-0.259	-0.187
TKN	0.293	-0.012	0.164	0.356	**0.691**
BOD	0.545	-0.146	-0.013	-0.108	**0.179**
COD	-0.239	0.397	0.128	-0.122	-0.078
Eigenvalue/Component Variances	2.507	1.898	1.714	1.277	0.977
Variability (%)/ Percentage Variance Explained	22.788	17.251	15.578	11.611	8.883
Cumulative %	22.788	40.040	55.617	67.228	76.111

Table 10. Calculation of Factor loadings for high flow condition

Principal Component Analysis (Factor)/Factor loadings/Component loadings					
VARIABLE	F1	F2	F3	F4	F5
EC	0.352	0.048	**0.769**	0.070	-0.030
TDS	-0.003	-0.045	**0.756**	-0.289	-0.221
Na+	0.557	**0.657**	-0.095	-0.343	0.004
K+	0.246	0.526	-0.233	**0.550**	-0.124
Ca^{2+}	0.015	-0.141	0.417	**0.686**	-0.370
Mg^{2+}	**0.629**	**0.565**	-0.117	0.031	-0.334
$S0_4^{2-}$	0.369	-0.559	-0.464	0.128	-0.355
NO_3 -N	**0.614**	-0.440	0.097	-0.293	-0.184
TKN	0.463	-0.017	0.214	0.402	**0.683**
BOD	0.864	-0.201	-0.017	-0.122	**0.177**

COD	-0.378	0.547	0.167	-0.138	-0.077
Eigenvalue/Component Variances	2.507	1.898	1.714	1.277	0.977
Variability (%)/ Percentage Variance Explained	22.788	17.251	15.578	11.611	8.883
Cumulative %	22.788	40.040	55.617	67.228	76.111

Five factors that are indicated below explained 76.111 % of total variance.

a) **Factor 1:**Mg^{2+}, NO_3 -N, BOD**,** EC, Na+, K+, Ca^{2+}, $S0_4^{2-}$ and TKN.

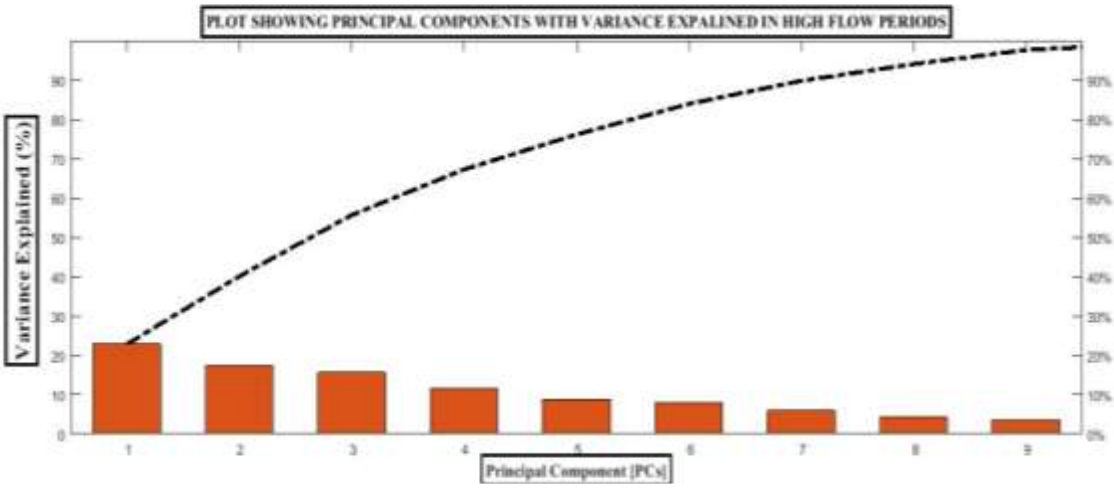
b) **Factor 2:**Na^{+}, EC, K+, Mg^{2+} and COD

c) **Factor 3:** EC, TDS, Ca^{2+}, NO_3 -N, TKN and COD

d) **Factor 4:** K+, Ca^{2+}, EC, Mg^{2+}, $S0_4^{2-}$ and TKN

e) **Factor 5:**TKN, Na+ and BOD.

From the data set, five major factors were obtained having eigen value or factor loadings >1 as depicted in scree plot as shown in the **figure 9.**

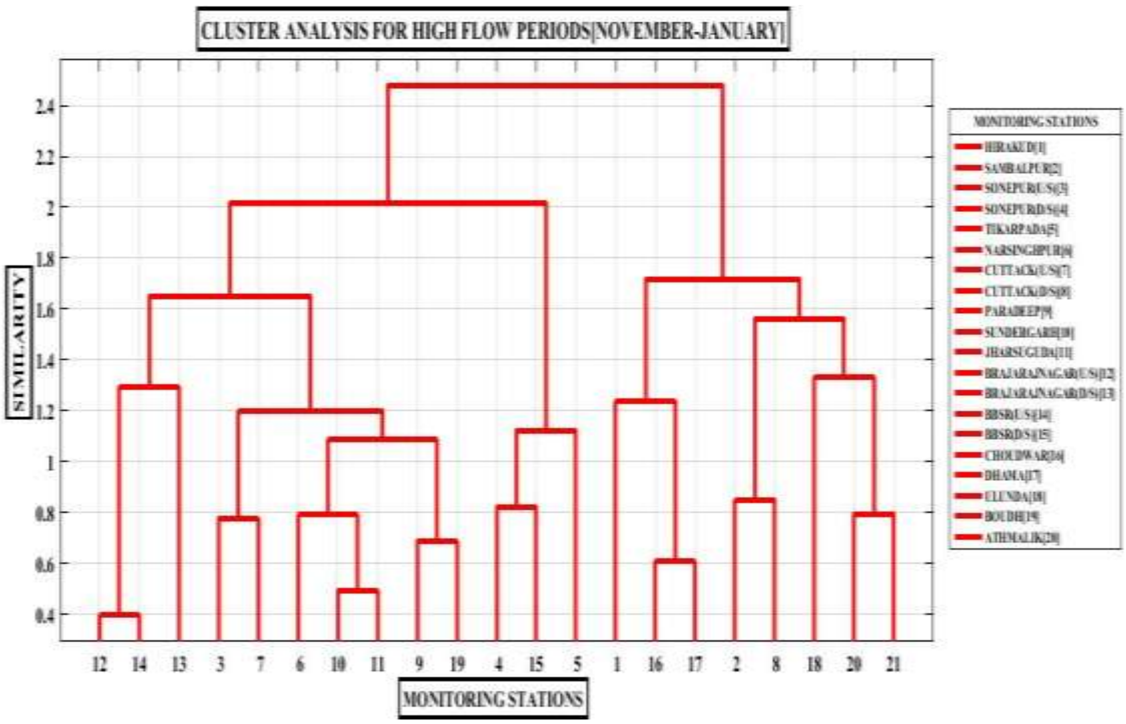


(Figure 9. Scree plot for high flow period**)**

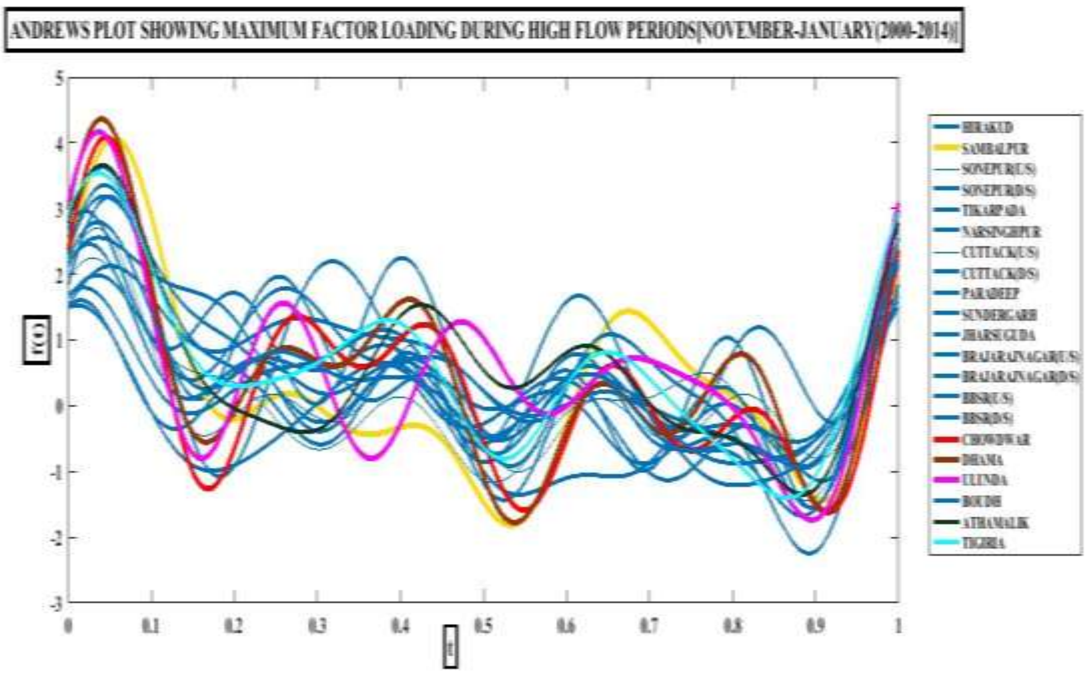
Among total five significant factors, F1, explaining about 22.788% of the total variance, has strong positive loading on Mg^{2+}, NO_3 -N, BODand moderate positive loadings on EC, Na+, K+, Ca^{2+}, $S0_4^{2-}$ and TKN. These factors represent the contribution of excess localized anthropogenic input into water bodies, runoff from agricultural fields using phosphatic fertilizers and some industrial effluents. F2, explaining about 17.251 % of the total variance, has strong positive loading on Na+ and moderate loadings on EC, K+, Mg^{2+} and COD which represent the direct input of organic matter and domestic wastewater containing chemicals that are susceptible to oxidation from the nearby cities.F3, explaining about 15.578% of the total variance, has strong positive loading on EC, TDS and, moderate loading on Ca^{2+}, NO_3 -N, TKN and COD. In these areas, farmers use the fertilizer, which represents point and non-point source pollution from orchard and agriculture areas. F4 explaining about 11.611% of the total variance has strong positive loadings on K+, Ca^{2+} and moderate positive loadings on EC, Mg^{2+}, $S0_4^{2-}$ and TKN.F5 explaining about lowest variance of 8.883% having strong positive loadings on TKN and moderate positive loadings on Na+ and BOD. The factor also represents the release of organic waste in to the river system.

It is suggested that, F1 represents the urban land use characteristics shown by presence of potassium and sodium ion. This factor explained 22.788 % of variance. F2 is strongly correlated with sodium ion and magnesium ion which are mainly originated from agricultural uses. F3 was marked by BOD, TKN, Kjedahl-N. Thus, urban land use was the major pollution source in this hydrological period.

In Clustering approach, sampling sites classification was performed by theuse of cluster analysis. The relationships among the stations (**Figure 10**) were obtained through cluster analyses using Ward's method (linkage between groups), with Euclidian distance as a similarity measure and were synthesized into dendrogram plots. Since we used hierarchical agglomerative cluster analysis, the number of clusters was also decided by water environment quality, which is mainly affected by land use and industrial structure.



(Figure 10. Dendrogram showing clustering of sampling sites for high flow period according to surface water quality characteristics of the Mahanadi River basin)



(**Figure 11.** Andrew plots showing physio-chemical parameters and their loadings on sampling stations of the Mahanadi River basin)

Considering different clusters and its distribution of factor loadings on different sampling sites as shown in (**figure 10, 11**) it is concluded that:

CLUSTER- I (3, 6, 7, 9, 10, 11, 12, 13, 14, 19): Sampling sites, mainly located in between the Sonepur upstream to Boudh including Narsinghpur, Cuttack, Paradeep, Sundergarh, Jharsuguda, Brajarajnagar and Bhubaneswar are clustered in this group.

Factor 1: High factor scores of F1 (Urban land use factor) represent the contribution of excess localized anthropogenic input into water bodies, runoff from agricultural fields using phosphatic fertilizers and some industrial effluents. They were observed at the northwest part, downstream of the basin.

CLUSTER- II (4, 5, 15): This cluster sites mainly located in between Sonepur (D/s) to Bhubaneswar (U/s) city.Though Sonepur is the district headquarters with all consequent activities, the deterioration in the water quality at sonepur D/s is not as much as expected. This is primarily because Sonepur D/s on Mahanadi is actually the downstream of its confluence with Tel, which has a significant annual average flow with very low pollution load.

Factor 2: Represent the direct input of organic matter and domestic wastewater containing chemicals that are susceptible to oxidation from the nearby cities. Relatively high values of agricultural use factor (F2) obtained in the middle of the basin, where agricultural is the most important economic activity. Low scores were monitored at the west part.

CLUSTER- III (1,2, 8, 16, 17, 18, 20): This cluster mainly in between Hirakud and Athamalik. The deterioration in the water quality in these monitoring stations is mostly due to untreated domestic wastewater, industrial effluents and agricultural runoffs.

Factor 3: Low and high scores of organic pollution factor (F3) were distributed in the basin, because F3 depends on point pollution sources and is affected by infrastructure (sewage network and treatment plants) of the settlements. Farmers use the fertilizer, which represents point and non-point source pollution from orchard and agriculture areas.

V. Conclusion

In this case study, multivariate statistical techniques were used to evaluate spatial variations in surface water quality of the Mahanadi River basin. Hierarchical cluster analysis grouped 21 sampling sites into three clusters of similar water quality characteristics. Based on obtained information, it is possible to design an optimal sampling strategy, which could reduce the number of sampling stations and associate costs. It is clearly seen in low flow period that F1, explaining 36.651% of the total variance, has moderate positive loadings on NO_3 -N, BOD and COD and Strong positive loading on EC, TDS, Sulphate and TKN which are contributed by local anthropogenic activities rather than agricultural/ land drainage. In high flow period, F1, explaining about 22.788% of the total variance, has strong positive loading on Mg^{2+}, NO_3 -N, BODand moderate positive loadings on EC, Na+, K+, Ca^{2+}, $S0_4{}^{2-}$ and TKN. These factors represent the contribution of excess localized anthropogenic input into water bodies, runoff from agricultural fields using phosphatic fertilizers and some industrial effluents.

To identify the association between the variables and to estimate the strength of the relationship, Pearson correlation matrix is used which provides information about not only the strength but also the direction of a relationship.Strong positive correlations exist between EC- TDS, EC – Sulphate, Sodium – Magnesium, Potassium – BOD, Calcium – Magnesium, NO_3 -N – BOD, TKN – BOD, BOD – CODfor low flow periods. In high flow period, Electrical Conductivity – TDS, TDS - NO_3 -N, Sodium – Magnesium, Potassium – Magnesium, Calcium – TKN, Magnesium – BOD, Sulphate – BOD, NO_3 -N – BOD, TKN – BOD was found to exist positively correlated. This signifies that the parameters change with direct proportionality. Some parameters were found to be in fair negative correlation signifying that these parameters change with inverse proportionality.

The factors obtained from factor analysis indicate that parameters responsible for water quality variations are mainly related to untreated or partially treated municipal sewage, domestic and industrial wastewater. The factors indicative of water quality in different hydrological periods and locations differed in Mahanadi Basin. Under high flow conditions pollutants mainly originated from urban land use and 22.788 % of total variance was explained by the urban land use factor. On the other hand, water quality was controlled by agricultural pollutant sources during the low flow period. Although the agricultural use factor explained 36.651% of the variance, for the land use factor, it was only 15.081 % under dry weather conditions. So, the major pollutant source changed from urban land uses to agricultural uses during the low flow period. The main reason for this was the negative effect of runoff to surface water quality, because the storage ability, the buffering capacity of roads and buildings to rain or storm water in urban areas, had been drastically weakened. Thus, major pollution threats in low and high flow periods were urban and agricultural land uses which are defined as non-point pollution sources. Therefore, priority should be given to minimization of these sources to improve water quality in the basin.

With serious situation of water pollution in the Mahanadi watershed, the management of water quality of the different zones is becoming more and more important as well as the planning of the whole watershed. According to the sources of pollution, different measures should be adopted, in order to control the total quantity of the pollutants and achieve the goal of sustainable use of the water resources. This study shows that factor analysis is a useful method that could assist decision makers in determining the extent of pollution via practical pollution indicators. It could also provide a crude guideline for selecting the priorities of possible preventative measures in the proper management of the surface water resources of the basin.

References

[1]. APHA-AWWA-WPCF, 1985. Standard Methods for the Examination of Water and Waste Water. American Public Health Association, Washington, DC.

[2]. Almasri, M. L. and J. J. Kaluarachchi (2004). Assessment and management of long-term nitrate pollution of groundwater in agriculture-domonated watersheds. Journal of Hydrology, I295 (1-4): 225-245.

[3]. Abbasi, S. A. and P.C. Nipaney (1995). An assessment of drinking water quality of the open wells in Malappuram coast, Kerala. Poll Res. 14 (3): 313-316.

[4]. Bishwanath, G. and N. Banerjee, 2004. Impact of informal regulation of pollution on water quality in rivers in India, Journal of Environmental Management, 73: 117-130.

[5]. Banerjee S.K., M. Banerjee and K.M. Agarwal (1999). Study of Tikara and Brahmani river ecosystems. Env Eco, 17(2): 296-305.

[6]. P. J. Puri, M. K. N. Yenkie, S. P. Sangal, N. V. Gandhare, G. B. Sarote and D. B. Dhanorkar - "Surface water (Lakes) quality assessment in Nagpur city (India) based on Water quality index (WQI)", Vol.4, No.1, 43-48 (2011).

[7]. B. N. Tandel, Dr. J. Macwan and C. K. Soni - "Assessment of Water Quality Index of Small Lake in South Gujarat Region, India."

[8]. S. Chandra, A. Singh and P. K. Tomar - "Assessment of Water Quality Values in Porur Lake Chennai, Hussain Sagar Hyderabad and Vihar Lake Mumbai, India", Chem Sci Trans., 1(3), 508-515, 2012.

[9]. Wu-Seng Lung, A. M. Asce - "Lake Acidification Model: Practical tool", J. Environ. Eng.113:900-915, 1987.

[10]. T. M. Heidtke, A. M. Asce and W. C. Sonzogni - "Water Quality Management for the Great Lakes", J. Water Resour. Plann. Manage. 112:48-63, 1986

[11]. V. Pradhan, M. Mohsin, B. H. Gaikwad - "Assessment of physico chemical parameters of Chilika Lake water", International Journal of Research in Environmental Science and Technology, 2(4): 101-103, 2012.

[12]. Dr. M. K. Mahesh, B. R. Sushmitha, H. R. Uma - "Assessment of Water Quality for Hebbal Lake of Mysore", ISSN No. 2277 - 8160, Volume: 2, Issue: 2, Feb 2013.

[13]. M. S. Islam, B. S. Ismail, G. M. Barzani, A. R. Sahibin and T. M. Ekhwan - " Hydrological Assessment and Water Quality Characteristics of Chini Lake, Pahang, Malaysia", American-Eurasian J. Agric. & Environ. Sci., 12 (6): 737-749, 2012.

[14]. V. B. Y. Sheikh, P. R. Bhosale, B. N. Nagargoje - "Water Quality Assessment of Nagzari Dam of Maharashtra." Journal of Applied Technology in Environmental Sanitation, Volume 3, Number 3: 111-116, October 2013.

[15]. S. Hussaina, V. Maneb, S. Takdea, A. Pathanc, M. Farooquic - " Comparison between Treated and Untreated water so as to study water treatment plant of Ahmadpur Dist. Latur," International Journal of Modern Engineering Research (IJMER) www.ijmer.com, Vol.1, Issue2, pp- 564-569, ISSN: 2249-6645.

[16]. R. W. Gaikwad, V. V. Sasane - "Assessment of ground water quality in and around Lonar lake and possible water treatment", International Journal of Environmental Sciences, Volume 3, No 4, 2013.

[17]. S. N. Thitame and G. M. Pondhe, - "Assessment of seasonal variation in physico-chemical characteristics and quality of Pravara River water for irrigation use in Sangamner, Dist Ahmednagar, Maharashtra", Journal of Chemical and Pharmaceutical Research, J. Chem. Pharm. Res., 2(2): 316-320, 2010.

[18]. M. Pejaver, M. Gurav - "Study of Water Quality of Jail and Kalwa Lake, Thane, Maharashtra", J. Aqua. Biol. Vol. 23(2), 44 -50, 2008. [14] R. M. Khan, M. J. Jadhav, I. R. Ustad - "Physicochemical Analysis of Triveni Lake Water of Amravati District in (M.S.) India. Bioscience Discovery, 3(1):64-66, Jan. 2012.

Abhijeet Das, et. al. "Water Quality Monitoring and Its Assessment on Mahanadi Basin." *IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE)*, 18(3), 2019, pp. 39-55.