Surface Water Quality Analysis Along Mahanadi River (Downstream of Hirakud to Delta)

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Abstract: - **In the present research program the status of pollution of water of a major river namely Mahanadi of Odisha (downstream of Hirakud dam) has been analyzed. The study was conducted to assess and ascertain the physico-chemical properties of Mahanadi river water from sixteen different water quality monitoring stations of State Pollution Control Board. The analysis was carried out by taking certain important water quality determining parameters like pH, Dissolved Oxygen (DO), Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Chloride, Total Dissolved Oxygen (TDS), Nitrate, Sulphates, Total Hardness (TH), Electrical Conductivity (EC) and Fluoride. Analyzed parameters like pH, DO, TH, Chloride, Sulphate and TDS were found within permissible limit prescribed by IS 10500 except Nitrate and Fluoride content which exceeds at some sites.**

It is realized from the study that the main pollutant of water in Mahanadi is the sewerage systems influenced by urban and industrial growths in Sambalpur, Bbsr (D/s) and Cuttack town. The study puts an alarm for utilizing Mahanadi water in Cuttack D/s, Paradeep, Bbsr D/s and Choudwar at these zones for intense agricultural activities and industrial purposes. Also it focuses in order to provide better survival of flora and fauna of the system the pollution should be checked at the source i.e. at Cuttack d/s and Choudwar.

Keywords: Mahanadi River, Physico-chemical parameters, Industrial/urban sewage, Industrial.

INTRODUCTION:

Water, a prime natural resource, is a basic need for sustenance of human civilization. Sustainable management of water resources is an essential requirement for the growth of the state's economy and well being of the population. As per National water policy, 2002, water resources development and management will have to be planned for a hydrological unit such as drainage basin as a whole or for a sub-basin for sustainable use incorporating quantity and quality aspects as well as environmental considerations.

The water environment quality is a very important and is a subject of major concern for economic development of any country. The water resource problems related to degradation have increasingly been serious because of rapid industrialization and urban sprawl. Anthropogenic influences such as urbanization, industrial and agricultural activities, increasing consumption of water recourses along with natural process i.e. change in precipitation inputs, erosion, effectively deteriorate surface water quality and impair their uses for drinking, industrial, agriculture, recreating and other purposes.

The Mahanadi watershed is the most developed and urbanized region in the state of Odisha. The increasing deterioration of water quality of the watershed is mainly attributed to the uncontrolled and improper disposal of solid and toxic waste from industrial effluents, agricultural runoff and other human activities. This alarming water pollution not only causing degradation of water quality but also threatens human health and balance of aquatic ecosystem, and economic development of the state.

In the present study, data matrix obtained during 14 years monitoring program (2000 to 2014) is subjected to different multivariate statistical approach to extract information about the similarities or dissimilarities between sampling sites, and the influences of possible sources on water quality parameters of the Mahanadi watershed.

The *specific objectives of the research* are to
- Classify the watershed into several zones with different water quality.
- Extract and establish the parameters that are most important in assessing variation in water quality of different zones,
- Find out a good approach to assess the water quality of each cluster reasonably that can be helpful to the managers to take the effective measures to manage the water resource respectively.

REVIEW OF LITERATURE:

Water is one of the vital needs of all living beings. Humans need water in many daily activities like drinking, washing, bathing, cooking etc. If the quality of water is not good then it becomes unfit for drinking and other activities. The quality of water usually described according to its physical, chemical and biological characteristics. Hence it becomes necessary to find the suitability of water for drinking, irrigation and Industry purpose.

Dugan [1972] suggested that all biological reactions occur in water and it is the integrated system of biological metabolic reactions in an aqueous solution that is essential for the maintenance of life. Pani [1986] in his study realized that due to increasing industrialization on one hand and exploding population on the other, the demands of water supply have been increasing tremendously. Moreover considerable part of this limited quality of water is polluted by sewage, industrial waste and a wide range of synthetic chemicals. Heavy metal are considered as major environmental pollutants and regarded to be Cytotoxic,

Mutagenic, and Carcinogenic. The Heavy Metal pollution of natural environment has been consistently increasing through effluents, sedimentation of rocks and mining activities (Manjit [1988]). Priti Singh et.al [2005] assess and map the spatial distribution of surface water quality of the Mahanadi, Odisha by using GIS.APHA's standard laboratory procedure has been adopted to assess the quality of ground water. The spatial distribution map of pH, Chlorides, Magnesium and sulphate shows that, these parameters are within range as per standard. Samantray et al. were studied the water quality of Mahanadi and its distributaries rivers, streams, Atharabanki river and Taldanda Canal adjoining Paradeep in three different seasons namely summer, pre-monsoon and winter..Their findings highlighted the deterioration of water quality in the rivers due to industrialization and human activities (Samantray et al., 2006). Kamal [2007] carried out on physicochemical parameter of river water affects the biological characteristics and indicates the status of water quality. Different types of Physicochemical parameters of water are pH, DO, BOD, COD, Chloride, TDS, Nitrate, Sulphates, TH, EC and Fluoride. These parameters are solely responsible for water quality. Khare et.al [2010] carried out on water quality assessment of Mahanadi, Sambalpur. He was done water analysis for the parameters like pH, DO, BOD, COD, TDS, calcium, Magnesium and Hardness for lake water. Venkatesharaju *et al.*, [2010] signifies water recourses have critical importance to both natural and human development. It is essential for agriculture, industry and human existence. Water is one of the most abundant compounds of the ecosystem. Mona A. Hagras et.al [2011] assessed the quality of groundwater and to characterize the hydrochemical characteristics of the surface water in Odisha, surface water samples were collected from different cities of Odisha analyzed for 15 water quality parameters. Lohani et.al [2011] depicts drinking water quality management through various physicochemical parameters and health hazard problems with their remedial measures in Bhubaneswar city of Odisha. Sahu [2015] describes the effect of poor water quality on human health was noted for the first time in 1854 by John Snow, when he traced the outbreak of cholera epidemic in London to the Thames river water which was grossly polluted with raw sewage. Rout [2016] carried out an analysis was carried out by taking certain important parameters like pH, dissolved oxygen (DO), biological oxygen demand (BOD), chemical oxygen demand (COD), Chloride, total dissolved oxygen (TDS), Nitrate, sulphates, total hardness (TH), electrical conductivity (EC) and Fluoride. Vega et al., [2016] signifies the application of different multivariate statistical techniques, such as cluster analysis (CA), principal component analysis (PCA) helps in the interpretation of complex data matrices to better understand the water quality and ecological status of the studied systems.

STUDY AREA AND DATA COLLECTION
STUDY SITE:

The river Mahanadi is one of the major inter-state east flowing rivers in peninsular India. It originates at an elevation of about 442 m. above Mean Sea Level near Pharsiya village in the Amarkantak hills of Bastar Plateau lying extreme south of Raipur district of Chattisgarh. The basin extends over an area approximately 141,600 km^2, out of which 65,628 km^2 lies in Odisha, occupying 42.15% of the state geographical area.

In the recent past a lots of work has been carried out on the role of different urban and industrial effluents upon the water quality of the Mahanadi river system, as well as other water bodies in India. The present study deals with 16 stations (Figure1,2,3,4,5,6) and their loading of 19 different physicochemical parameters in Mahanadi waters covering a short range, a station located further downstream of Cuttack, within the course of the river in the state of Odisha. The physicochemical parameters such as NO_2-N, NO_3-N, NH_4-N, TKN and total phosphorous (TP) were analysed, along with pH, DO, BOD, COD, TSS, TDS, and other metals such as Zn, Ni, Pb and Cu etc., in order to assess the impact of different effluents upon the quality of the river water.
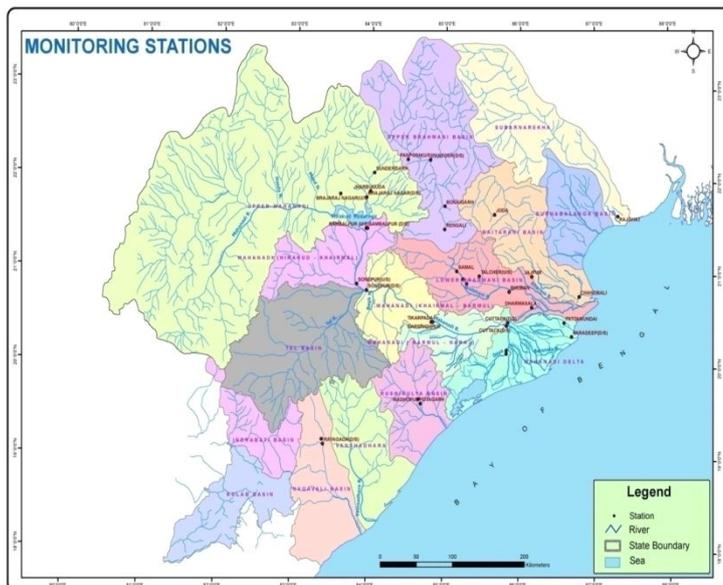

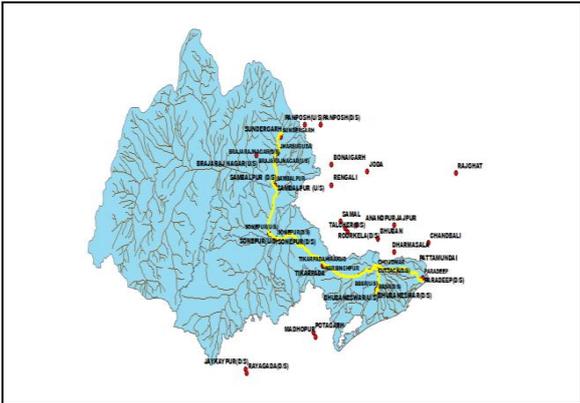Figure 1.Map of Mahanadi basin in Odisha (India), indicating monitoring stations

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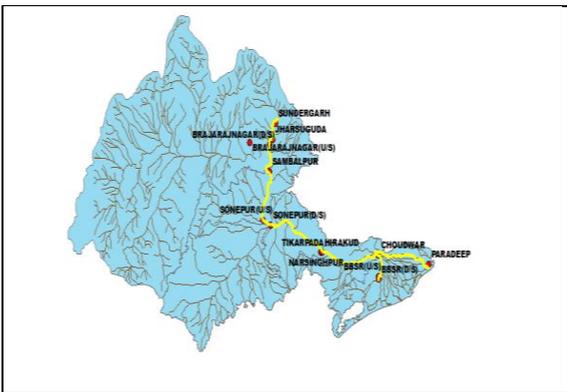Figure2. Plotting of monitoring stations on river map of odisha

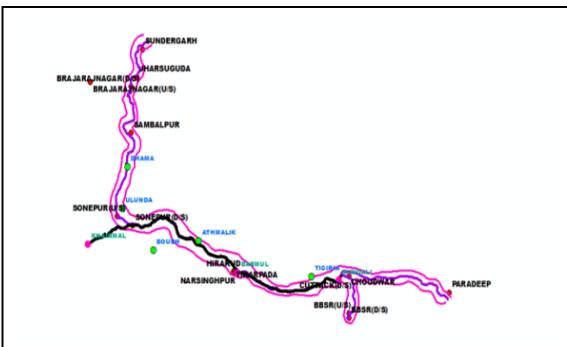Figure3. Plotting of monitoring stations on mahanadi river basin:
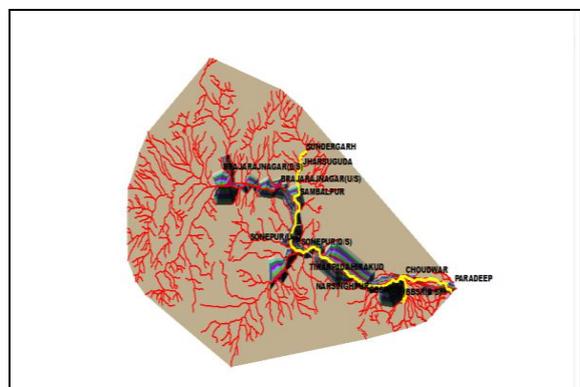

Figure4. Flow path of mahanadi river basin

Figure5. Tin of mahanadi river basin
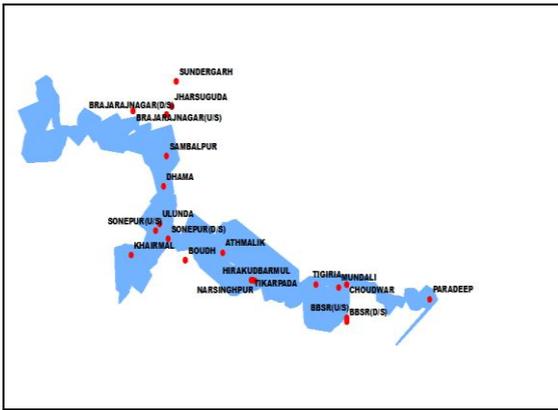
Figure6. Tin surface contour of mahanadi river basin

METHODOLOGY
GIS APPLICATION

Geographic Information System:

GIS is a system of hardware and software used for storage, retrieval, mapping, and analysis of geographic data. A geographic information system, or GIS, is a computerized data management system used to capture, store, manage, retrieve, analyze, and display spatial information. GIS is an interdisciplinary tool, which has application in various fields such as Geography, Geology, Cartography, Engineering, Surveying, Rural & Urban planning, Agriculture, Water resources, etc.

Inverse Distance Weight (IDW):

The IDW function can be use when the set of points is dense enough to capture the extent of local surface variation needed for analysis.IDW determines cell values using a linear-weighted combination set of sample points. The weight assigned is a function of the distance of an input point from the output cell location. The greater the distance, the less influence the cell has on the output value.

MANN-KENDALL TREND ANALYSIS

The yearly average data of water quality parameters collected over a period of 14 years (2000-2014) of 16 monitoring stations were obtained from State Pollution Control Board, Odisha. The water quality trend analysis was conducted for all the districts of Orissa on yearly basis. The trend was analyzed using non- parametric Mann-Kendall test (Mann1945; Kendall, 1975). The MK test has been employed by a number of researchers to ascertain the presence of statistically significant trend in hydrological climatic variables such as temperature, precipitation with reference to climate change. The MK test checks the null hypothesis of no trend versus the alternative hypothesis of the existence of increasing or decreasing trend. The regional water resources study was done by analyzing the yearly water quality data for 16 stations of Odisha for the period of 2000 to 2014(Table1).

RESULTS AND DISCUSSION

WATER QUALITY MODELLING USING GIS APPLICATION:

Spatial patterns of water quality trends for 16 sites in the Mahanadi River basin of Odisha were examined for nineteen parameters. This study suggests that spatial analysis of watershed data at different scales should be a vital part of identifying the fundamental spatial distribution of water quality.

As may be seen from the (Figure7&8), pH remains mostly alkaline and the water is rich in oxygen. So the parameters conform to the quality criteria for Class-A.
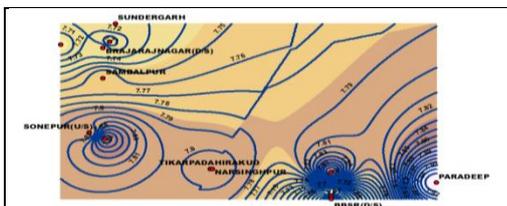

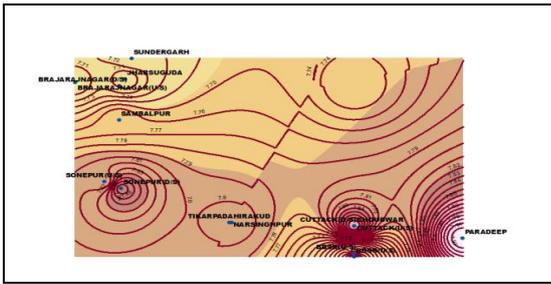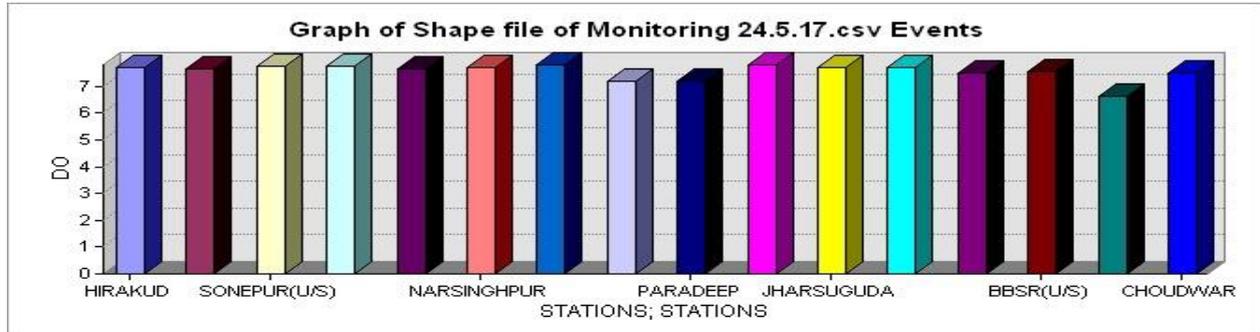Figure7. Interpolation of PH using IDW technique

Figure8. Interpolation of DO using IDW technique

As shown in (figure9), Except a few occasional deviations of small magnitudes from the stipulated value of 3 mg/l, the BOD at all the sampling stations generally conform to Class-B water quality except at Sambalpur D/s(Mahanadi), Cuttack D/s and FD/s (Kathojodi), Bhubaneswar D/s and FD/s (Daya). Even at these five stations, the BOD is not alarmingly high and the value rarely exceeds 5 mg/l.
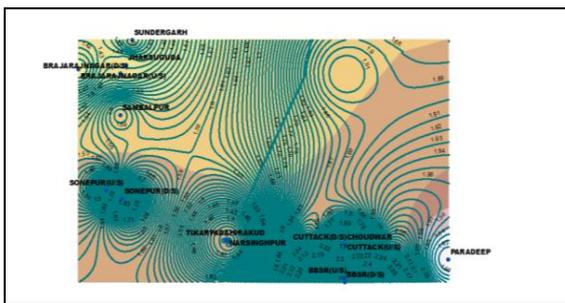
Figure9. Interpolation of BOD using IDW technique
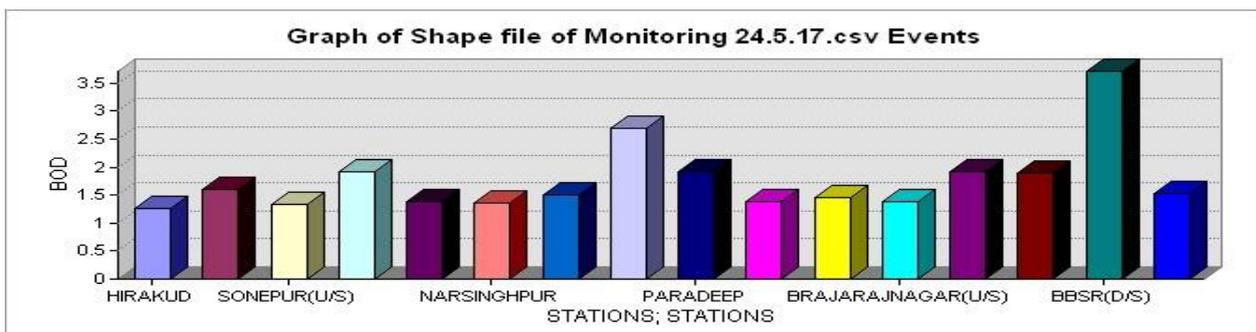
The TC values at all stations as shown in (Figure10), except Sambalpur D/s, Shankarmath and Huma on Mahanadi River, Cuttack (D/s) and FD/s (both on iahanadi and kathojodi rivers) and Bhubaneswar D/s and FD/s in Daya generally conforms to Class-C inland surface water quality. The magnitude and frequency of violations TC from the stipulated value (less than 5000 MPN/100ml) at these seven stations are far too large for water quality to be classified as Class-C.

Figure10. Interpolation of TC using spline technique

As described in Figure11, EC are considered to be three primary water quality criteria for water to be used for irrigation purpose (Class E). EC values in IB, Mahanadi , Kathojodi , Kuakhai and Birupa rivers are presented in Table. From the data, it can be seen that the EC 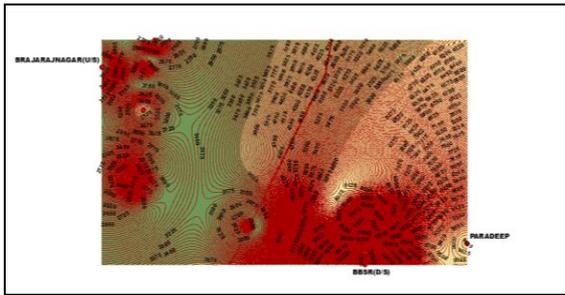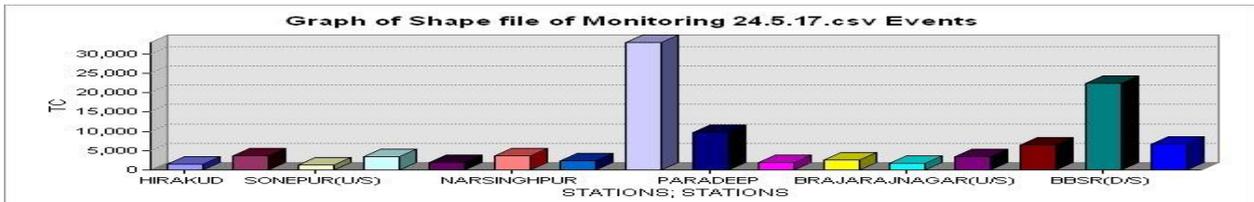values except at Paradeep U/s and D/s (due to tidal effect of sea water) are far too low compared to the prescribed values in Table to cause any concern to consider the suitability of the entire stretch of river water to be used for irrigation.
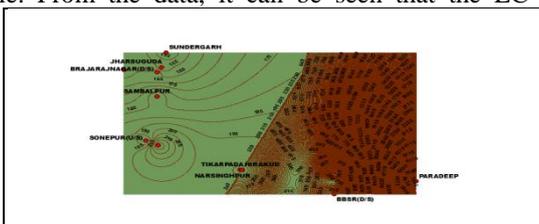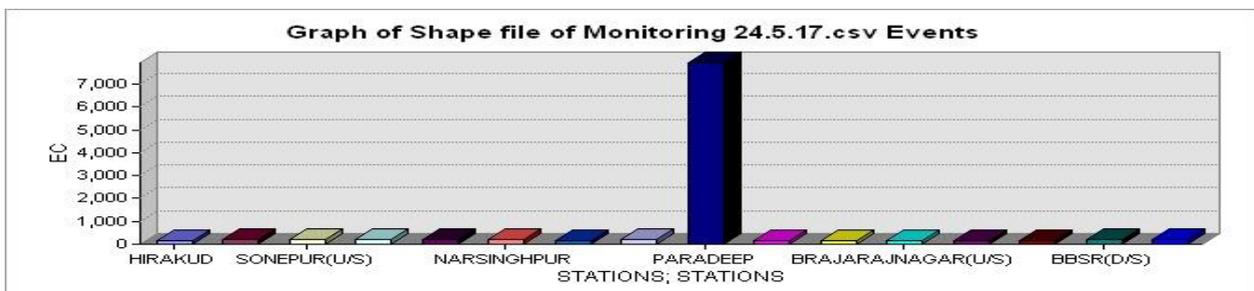

Figure11. Interpolation of EC using IDW technique

WATER QUALITY TREND OF MAHANADI BASIN

MAHANADI RIVER

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. From Sambalpur D/s to Sonepur (about 78 km along the river course), the river travels through a region with no major urban settlement or waste water outfall. Sonepur is the confluence point of Mahanadi with two of its important right bank tributaries namely Ong and Tel. Thus the water quality at Sonepur U/s, which is immediately downstream of Ong confluence, is quite satisfactory. 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. Moreover, in spite of being the district headquarters, sonepur is still a small town (population: about 19000) with no noticeable growth in urban activities.

The 102 km, stretch of the river from Sonepur D/s to Tikarpada does not have any industry or urban settlement on its banks (except two small sub-divisional towns- (Boudh and Athamalllick) and there is no major waste water outfall. From Tikarpada to Narasinghpur (about 60 km), the river flows almost completely undisturbed. The Tikarpada-Narasinghpur sub- basin is neither agriculturally nor is industrially prosperous and human activities on its banks scarce. Hence relatively clean, unpolluted water is expected at Tikarpada and without much change in quality at Narasinghpur.

During its course from Narasinghpur to Cuttack (about 56 km), the river enters into its deltaic region, characterized by

high population density and intense agricultural activities. Hence there is some deterioration in the quality of water entering into Cuttack (Cuttack U/s) particularly in respect of TC, but still conforming to Class C. Within the city (Population: about 5.35 lakhs) the river receives considerable untreated waste water and the water quality gets further deteriorated at Cuttack D/s.

IB RIVER:
Water quality of this left bank tributary of Mahanadi at four locations- Sundergarh, Jharsuguda, Brajarajnagar (U/s and D/s). Till about late nineties, the water quality at Brajarajnagar was a matter of much concern due to discharge of effluent from a large paper mill. The mill has been closed since December 1998. Since none of the three towns is a large urban centre and there is no organized domestic waste water discharge to the river, the water quality generally remains at the Class-C level. Of late, Jharsuguda has turned into an important industrial hub of the state. However, the impact of industrial activities has not much impact on the water quality of IB River.

BHEDEN RIVER:
Water quality of his left bank tributary of IB River is monitored at only one location-Jharsuguda, which is the downstream of M/s Vedanta Aluminium Ltd. As the plant was in the commissioning phase during the period of study, no significant impact on the water quality of Bheden river at Jharsuguda is noticed. Water quality generally remains at the Class-C level,

KATHOJODI RIVER:
The monitoring station at Cuttack D/s on Kathojodi, a distributary of Mahanadi, is characterized by an untreated domestic waste water discharge outfall at its upstream and expectedly, there is significant deterioration of water quality to below Class-C with respect to BOD, TC and large deviations in FC to make the water unacceptable for most beneficial uses.

BIRUPA RIVER:
Birupa, another distributary of Mahanadi is monitored at the downstream of Choudwar, a small town, which had in the past, significant industrial activities with a textile, a large pulp and paper and a charge chrome industry with its thermal power plant. Presently only the charge chrome industry is in operation with marginal water pollution potential. Except occasional deviation in the coliform count, the water quality generally conforms to Class-C.

KUAKHAI AND DAYA RIVERS:
The monitoring stations on kuakhai (distributary of kathajodi River) at Bhubaneswar FU/s and U/s in the upstream of the water intake point (sub surface water through bore wells) of the Public Health Engineering Department, for the Bhubaneswar city. The water quality generally conforms to Class-C.
Bhubaneswar D/s on Daya (distributary of Kuakhai) is just beyond the city limits. The river receives the city waste water, atleast through one organized outfall, the Gangua Nallah, in between, as a consequence of which the water quality is downgraded beyond Class-c and unacceptable for most beneficial uses in respect of BOD, TC, and frequent violations of FC. However, the water quality trend is improved to some extent at Bhubaneswar FD/s.

Table1. RESULT OF MANN-KENDALL TREND ANALYSIS OF MONITORING STATIONS

STATIONS	PARAMETER	SIGNIFICANCE LEVEL		
		1%	5%	10%
BBSR(D/S)	TC	RISING	RISING	RISING
	FE	NO	NO	RISING
	NITRATE	NO	NO	RISING
	B	NO	NO	RISING
	EC	NO	NO	RISING
	COD	NO	RISING	RISING
	TOTAL ALKALINITY	NO	FALLING	FALLING
	TSS	NO	NO	RISING
BRAJARAJNAGAR D/S	BOD	FALLING	FALLING	FALLING
	NH_4-N	NO	NO	FALLING
	SAR	NO	FALLING	FALLING
	TDS	NO	NO	FALLING
	TH	NO	FALLING	FALLING
	NITRATE	NO	FALLING	FALLING
	FE	NO	NO	RISING

CHOUDWAR(D/S)	BOD	FALLING	FALLING	FALLING
	FE	NO	NO	RISING
HIRAKUD	TC	RISING	RISING	RISING
	COD	NO	RISING	RISING
	NH$_4$-N	NO	FALLING	FALLING
	B	NO	RISING	RISING
	SAR	NO	NO	FALLING
	CL	NO	NO	RISING
JHARSUGUDA	PH	NO	NO	RISING
	BOD	FALLING	FALLING	FALLING
	TOTAL ALKALINITY	FALLING	FALLING	FALLING
	NH$_4$-N	NO	FALLING	FALLING
	TH	NO	NO	FALLING
	NITRATE	FALLING	FALLING	FALLING
NARSINGHPUR	PH	NO	RISING	RISING
	BOD	FALLING	FALLING	FALLING
	TC	NO	NO	RISING
	TSS	NO	NO	RISING
	TOTAL ALKALINITY	FALLING	FALLING	FALLING
	NH$_4$-N	NO	FALLING	FALLING
	SAR	NO	FALLING	FALLING
	TDS	NO	NO	FALLING
SAMBALPUR	BOD	NO	FALLING	FALLING
	TOTAL ALKALINITY	NO	NO	FALLING
	NITRATE	NO	FALLING	FALLING
SONEPUR(D/S)	BOD	NO	FALLING	FALLING
	TOTAL ALKALINITY	NO	NO	FALLING
	NH$_4$-N	NO	NO	FALLING
	B	NO	NO	RISING
	SULPHATE	NO	RISING	RISING
SUNDERGARH	PH	NO	NO	RISING
	BOD	FALLING	FALLING	FALLING
	AMMONIACAL NITROGEN	NO	NO	FALLING
	SAR	NO	FALLING	FALLING
	TKN	NO	NO	FALLING
	FE	NO	NO	RISING
	B	NO	RISING	RISING
	NITRATE	NO	FALLING	FALLING
TIKARPADA	DO	NO	NO	RISING
	BOD	FALLING	FALLING	FALLING
	TC	RISING	RISING	RISING
	TOTAL ALKALINITY	NO	FALLING	FALLING
	SAR	NO	NO	FALLING
	TH	NO	FALLING	FALLING
	NITRATE	NO	FALLING	FALLING

PARADEEP	DO	NO	NO	RISING
	BOD	FALLING	FALLING	FALLING
	TOTAL ALKALINITY	FALLING	FALLING	FALLING
	NH₄-N	NO	NO	FALLING
	TH	NO	FALLING	FALLING
	CL	NO	FALLING	FALLING
	F	NO	FALLING	FALLING
CUTTACK(D/S)	BOD	FALLING	FALLING	FALLING
	TC	NO	RISING	RISING
	TSS	NO	RISING	RISING
	TOTAL ALKALINITY	NO	NO	FALLING
	TDS	FALLING	FALLING	FALLING
	TH	NO	FALLING	FALLING
	NITRATE	FALLING	FALLING	FALLING

CONCLUSION

- River Mahanadi is said to be the lifeline of the state Odisha. Most of the agriculture, industry and all round developments are due to rich water resource potential of this river. But the present concern is the increasing deterioration of water quality of the watershed is mainly attributed to the uncontrolled and improper disposal of solid and toxic waste from industrial effluents, agricultural runoff and other human activities. *This alarming water pollution not only causing degradation of water quality but also threatens human health and balance of aquatic ecosystem, and economic development of the state.*

- From the assessment of physico-chemical study it could be clearly concluded that *the status and quality of Mahanadi River water in Sambalpur city be an eye opener* which is very much prone towards alarmed condition for Sambalpur city and its population.

- Mann-Kendall test was applied for three significance levels i.e. 1%, 5% and 10%. On the basis of Z-statistics of each significance level, *the trends in different stations of River Mahanadi have been determined.*

- In BBSR (D/s) , there is a rising trend occurs at 10% significance level due to these water quality parameters like TC, Fe, Nitrate, Boron, EC, COD and TSS and falling trend occurs due to total alkalinity. This result due to the river receives the city waste water, at least through one organized outfall, the Gangua Nallah, in between, as a consequence of which the water quality is downgraded.

- In Brajarajnagar (D/s), there is falling trend occurs at 10% significance level due to these water quality parameters like BOD, NH₄-N, SAR, TDS,TH, Nitrate and rising trend due to Fe. This results as the water quality at Brajarajnagar was a matter of concern due to discharge of effluent from a large paper mill.

- In Choudwar (D/s), there is a falling trend of BOD and rising trend of Fe at 10% significance level. This results due to industrial activities with a textile, a large pulp and paper and a charge chrome industry with its thermal power plant.

- In Hirakud, there is a rising trend occurs due to parameters like TC, COD, B, CL and falling trend occurs due to NH₄-N and SAR at 10% significance level. This results due to the Sambalpur city which is famous for bathing and waste water (untreated) disposal which is responsible for deterioration of water quality.

- In Jharsuguda, there is a falling trend occurs due to water quality parameters like BOD, Total alkalinity, NH₄-N, TH, Nitrate and rising trend occurs due to PH at 10% significance level. This results as the water quality of his left bank tributary of IB River is monitored at only one location-Jharsuguda, which is the downstream of M/s Vedanta Aluminium Ltd.

- In Narsinghpur, there is a rising trend due to water quality parameters like PH, TC, TSS and falling trend due to BOD, Total alkalinity, NH₄-N,SAR, TDS at 10% significance level. This occurs due to the industrial and human activities.

- In Sambalpur, there is falling trend occurs due to the water quality parameters like BOD, Total alkalinity and nitrate at 10% significance level. This occurs as 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.

- In Sonepur (D/s), there is a falling trend occurs due to water quality parameters like BOD, Total alkalinity, NH₄-N and rising trend due to boron and sulphate at 10% significance level. As sonepur is the district headquarters with all consequent activities, the deterioration in the water quality gets affected.

- In Sonepur (D/s), there is a falling trend occurs due to water quality parameters like BOD, Total alkalinity, NH_4-N and rising trend due to boron and sulphate at 10% significance level. As sonepur is the district headquarters with all consequent activities, the deterioration in the water quality gets affected.

- In Sundergarh, there is a rising trend occurs due to water quality parameters like PH, Fe, boron and falling trend due to BOD, ammoniacal nitrogen, SAR, TKN and nitrate at 10% significance level. This results due to the paper mill industry near Brajarajnagar D/s.

- In Tikarpada, there is a rising trend occurs due to water quality parameters like DO and TC and falling trend occurs due to BOD, SAR,TH, Total alkalinity, nitrate at 10% significance level. As there is no industry nearby but two small sub-divisional towns-Boudh and Athamalik generally disturb the water quality.

- In Paradeep, there is a rising trend occurs due to water quality parameters like DO and falling trend due to BOD, Total alkalinity, NH_4-N, CL, F, TH at 10% significance level. This results due to the presence of oil refinery industries which is the main cause for the deterioration of water quality.

- In Cuttack (D/s), there is a rising trend of TC, TSS and falling trend of BOD, TDS, TH, Total alkalinity, nitrate occurs at 10% significance level. This results as the river enters into its deltaic region, characterized by high population density and intense agricultural activities.

REFERENCES

[1] Adentunde and Kaluarachchi.J.J (2007). Assessment and management of long term nitrate pollution of groundwater in agriculture-dominated watersheds. Journal of Hydrology, Vol. I295 (1-4): pp.225-245.

[2] Abbasi, S. A. and Swarnalatha.P.C. (2008). An assessment of drinking water quality of the open wells in Malappuram coast, Kerala. Poll Res. Vol. 14 (3): pp.313-316.

[3] Bishwanath, G. and Manjit, N. (1988). Impact of informal regulation of pollution on water quality in rivers in India, Journal of Environmental Management, Vol.73: pp.117-130.

[4] Banerjee S.K., Guruprasad.M and Agarwal K.M. (2005). Study of Tikara and Brahmani river ecosystems. Env Eco, Vol.17 (2): pp.296-305.

[5] Bhuvaneswaran, Priti singh.M and Rajeswari.S (2005). Water quality of river Adyar in Chennai city – the river a boon or a bane. Indian J Environ Prot., Vol. 19 (6): pp. 412-415.

[6] Chandra, R., Bahadur.Y and Samantaray (2006). Monitoring the quality of river Ramganga waters of Bareilly. Poll Res., Vol.15 (1): pp.31-33.

[7] Chatterjee, C. and Sayeed.M (2009). Bacteriological status of river water in Asansol town in West Bangal, J Env Polln, Vol. 8 (2): pp.217-219.

[8] Desai,Vega K.V. (2015). Water quality of Dudhsagar river of Dudhsagar (Gao), India. Poll Res. Vol. 14(4): pp.377-382.

[9] Dugan, Goraba.R (2008). The Chemistry of our Environment. Wiley Inter Science Pub. John Wiley and Sons, New York.

[10] Girija T.R., Lohani. and Chandramouli V. (2011). Water quality assessment of an untreated effluent impacted urban stream: the Tributary of the Mahanadi River, India. Environmental Monitoring and Assessment, Vol. 130: pp.221–236.

[11] Guru Prasad, B. and Satya Narayan.T, 2004. Assessment of subsurface water quality in different regions of Mahanadi river basin, Indian J. of Env. Protection, Vol. 24(1): pp. 60-64.

[12] Gyananath, G, Venketasharaju.S and Samiuddin.S (2010). Water quality analysis of river Godavari during 'Holi Mela' at Nanded. Poll Res. Vol. 19(4): pp.673-674.

[13] Garg, V.K, Khare.R, Malik.A and Pahwa.M (2010). Assessment of water quality of western Yamuna canal from Tajewala (Haryana) to Haiderpur treatment plant (Delhi). Indian J. of Env. Protection, Vol. 22(2): pp.191-196.

[14] Hagras, S.K. (2010). Physicochemical and biological characteristics of water of Maithon Reservoir of D.V.C. Poll Res., Vol. 18(4): pp.541-544.

[15] Herzog, Yogendra.D.J (2008). Evaluating the potential impacts of mine wastes on ground and surface waters. Fuel and Energy Abstracts, Vol. 37(2): pp.139.

[16] Pani V. K. (1995). Water chemistry of Tawa River and reservoir in Central India. Energy Env Monit, Vol.11 (2): pp.167-176.

[17] Rout, C. N., Becker.E (2016). Public water supplies of the 100 largest cities in the U.S. US Geol. Sur. Water Supply Paper, pp.1812: 364.

[18] Sahoo (2015). Methods for chemical analysis of water and wastes, 353.3. Environmental Protection Agency, Washington, DC, US.

[19] Panda U.C., Rath S., Nayak P.and Vega. D (2016). Application of factor and cluster analysis for characterization of river and estuarine water systems- A case study: Mahanadi River (India). Journal of Hydrology, vol.331: pp.434-445.