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Water Quality Modelling Along Mahanadi River
(Downstream of Hirakud Dam To Delta)

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WATER QUALITY MODELLING ALONG MAHANADI RIVER (DOWNSTREAM OF HIRAKUD DAM TO DELTA)

A

Thesis Submitted To

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BHUBANESWAR, ODISHA

In partial fulfillment of the requirement for the award of the degree of

MASTER OF TECHNOLOGY

IN

WATER RESOURCES ENGINEERING

Submitted by,

ABHIJEET DAS
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Under The Guidance of

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DEPARTMENT OF CIVIL ENGINEERING

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DEPARTMENT OF CIVIL ENGINEERING

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ODISHA-751003

2017

CERTIFICATE

This is to certify that the thesis entitled **"WATER QUALITY MODELLING ALONG MAHANADI RIVER (DOWNSTREAM OF HIRAKUD DAM TO DELTA)"** submitted by **Abhijeet Das**, Registration No. **1507106199**, in partial fulfillment of the requirements for the Degree of Master of Technology with specialization in Water Resources Engineering during session 2015-17 in the Department of Civil Engineering, College of Engineering and Technology, Ghatika, Bhubaneswar, ODISHA is an authentic work carried out by him under my supervision and guidance.

I believe that the thesis fulfills part of the requirement for the award of the Degree of Master of Technology.

To the best of my knowledge, the matter embodied in the thesis has not been submitted to any other University/Institute for the award of any Degree or Diploma.

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Abhijeet Das

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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. COD values were invariably higher than BOD indicating the presence of considerable amount of chemically oxidizable matter which was non-biodegradable.EC also considerably recorded high particularly in summer season.

These physicochemical parameters indicates the deterioration of water quality which is the result of various anthropogenic disturbances like industrialization, construction activities, utilization of agricultural and forest land for other developmental purposes. Other sources which contribute more or less in water quality depletion are disposal of untreated domestic and sewage effluents and different types of solid wastes directly to river.

Categorizing and then grouping the stations in different essential groups in order to take precautionary measure as well as delineating the utility zones of river segments for different purposes was essential. So it was analyzed by applying the multivariate statistical techniques including Cluster Analysis (CA), Agglomerative Hierarchical Cluster analysis (AHC) and Principal Component Analysis(PCA) grouped 16 sampling sites into three clusters namely less polluted (LP), moderately polluted (MP), and highly polluted (HP) sites under the similarity of surface water quality parameters. The application of principal component analysis to the evaluated data set of three different clusters, generates five PCs for LP and

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seven PCs for MP and one PCs for HP having component variance value >1.The PCs obtained from factor analysis indicates that the increase in load of nitrate (NO_3), ammoniacal (NH_4-N), total Kjeldahl nitrogen (TKN), iron(Fe) and decrease in DO, pH level of water in HP and MP sites, display the intensity of organic pollution in the river that are mainly attributed to agriculture runoff, industrial effluents and regional anthropogenic contributions from both point and non-point sources. Thus these methods are believed to be valuable for water resource manager to identify the complex nature of water quality issues and determine the relative precedence to enhance the water quality of surface water body.

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.

The trend analysis has been done using Kendall rank test at 1%, 5% and 10 % significance level to all the monitoring stations of River Mahanadi.

- 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.
- In Brajarajnagar (D/s), there is falling trend occurs at 10% significance level due to these water quality parameters like BOD, NH_4-N, SAR, TDS,TH, Nitrate and rising trend due to Fe.
- In Choudwar (D/s), there is a falling trend of BOD and rising trend of Fe at 10% significance level.

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- In Hirakud, there is a rising trend occurs due to parameters like TC, COD, B, CL and falling trend occurs due to NH_4-N and SAR at 10% significance level.
- In Jharsuguda, there is a falling trend occurs due to water quality parameters like BOD, Total alkalinity, NH_4-N, TH, Nitrate and rising trend occurs due to PH at 10% significance level.
- In Narsinghpur, there is a rising trend due to water quality parameters like PH, TC, TSS and falling trend due to BOD, Total alkalinity, NH_4-N,SAR, TDS at 10% significance level.
- In Sambalpur, there is falling trend occurs due to the water quality parameters like BOD, Total alkalinity and nitrate at 10% significance level.
- 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 significance level.
- 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.
- 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.
- 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.
- 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

CHAPTER 01

INTRODUCTION

1.1 GENERAL

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.

Water quality monitoring is an integral part of the water resource management plans. Monitoring comprises all activities to obtain" information" with respect to the water system. Its scope is also related to the types of water use i.e. in stream use or abstractive use and nature of the source such as surface water (rivers, lakes), ground water or sea water.

The requirements for utilizing available water resources (Surface and ground) in a judicious and equitable as well as sound economic manner are outlined in the State Water Policy. Clause 7 of water Policy-2007 for the state Odisha emphasizes upon monitoring of both surface and ground water quality and sharing of information among the data users group.

The State of Odisha is located in the south eastern part of India, between 17°31´ and 22°27´N Latitude and 81°27´ and 87°30´E Longitude with a population of 36.7 million (2001 census). The annual overall availability of surface water in Odisha is about 85.89 billion cubic meters. The state has 11% of the water resources of the country. The per capita availability of water in 2001 was 2259 cubic meters. With increasing population and the consequential increase in demand for food and water and with the growth in mining and industrial activities, the demand for water from various sectors in next twenty years will have significant impact on the per capita availability of water. Further, the degradation in quality of water resources by direct and indirect human interference such as discharge of untreated/ partially treated industrial and municipal waste water will make the resource scarce. It is therefore imperative to manage this resource as rationally and efficiently as possible to make it sustainable.

State Pollution Control Board, Odisha monitors the water quality of nine rivers of Odisha under National Water Quality Monitoring Programmes (NWMP) of Central Pollution Control Board (CPCB). CPCB is an apex body in the field of water quality management in India and provides technical and financial support for water quality monitoring programmes conducted by State Pollution Control Boards.

Water quality is a complex subject, which involves physical, chemical, hydrological and biological characteristics of water and their complex and delicate relations. From the user's point of view, the term "water quality" is defined as "those physical, chemical or biological characteristics of water by which the user evaluates the acceptability of water". For example for drinking water should be pure, wholesome, and potable. Similarly, for irrigation dissolved solids and toxicants are important, for outdoor bathing pathogens are important and water quality is controlled accordingly.

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. In order to study spatial and temporal variation in surface water chemistry a regular monitoring program that will provide a representative and reliable estimation of the quality of surface water is highly essential. Thus monitoring program including frequent water samplings at many sites and determination of large number of physicochemical parameters are usually conducted resulting in a large data matrix, which needs a complex data interpretation.

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 system, allows the identification of possible factors that influences water environment system, and offers a valuable tool for reliable management of water resources. The 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 CA to group water body into several zones with different water quality and PCA to find the most important factor that describe the natural and anthropogenic influences.

Surface water (rivers, streams and ponds), atmospheric water (rain-water, snow and hail) and springs are the main source of water available to the people in general. The qualities of these water bodies vary widely depending on the location and environmental factors. The major source of ground water is precipitation that infiltrates the ground and moves through the soil and pore spaces of rocks. Other sources include water infiltrating from lakes and streams, recharge ponds and waste-water treatment system. As ground water moves through soil, sediment and rocks, many impurities such as disease-causing micro-organisms are filtered out. Many water resources in developing countries are unhealthy because they contain harmful physical, chemical and biological agents. To maintain a good health however, water should be safe to drink and meet the local standards and international standards to taste, odour and appearance.

1.2 SOURCES OF WATER IN ODISHA:

The main sources of water in the state are from the Bay of Bengal, from lakes like Chilika and Ansupa, from 11 rivers such as: Mahanadi, Brahmani, Baitarani, Rushikulya, Budhabalanga, Subarnarekha, Salandi, Kathajodi, Birupa, Kusabhadra, Daya and many rivulets. The water sources include ground water, tanks, ponds, open wells and tube wells.

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1.3 QUALITY OF WATER:

The pure water that is H_2O in which two parts of hydrogen and one part of oxygen are present. Obviously, this form of pure water is not available in all the above mentioned sources. The quality of water depends on the quantity of harmful elements present in it. The water from sea and Chilika Lake is salty and the water from rivers, tanks and ponds is very often muddy and contain impurities of suspension, colloids and dissolved particles. The quality of drinking water depends on the quantity of harmful elements present in it. The drinking water should be clear, odourless and tasteless and its pH value should be between 7 & 8.5..The permissible organic impurities include Bacillus coli less than 100ml/lit and other coli bacteria not more than 10 numbers.

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.

1.4 OBJECTIVE OF THIS STUDY:

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.
- To perform time series analysis, trend Analysis and PCA Analysis of water quality parameters.
- To interpret the complex water quality data matrices as well as to identify the possible sources or factors that influences the water quality by using different analysis methods viz., principal Component Analysis (PCA) and Cluster Analysis (CA).
- To compare all the employed models in terms of the predictive ability as well as to carry out the analysis of the estimated water quality parameters so as to obtain the most suitable model.

CHAPTER 02

REVIEW OF LITERATURE

2.1 WATER QUALITY INVESTIGATIONS

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. The groundwater quality based on Sodium percent, Sodium Absorption Ratio and Residual Sodium Carbonate will help to identify the suitability of water for irrigation purpose. Rapid industrialization and use of chemical fertilizers and pesticides in agriculture are causing deterioration of water quality and depletion of aquatic biota. Due to use of contaminated water, human population suffers from water borne diseases. Parameters that may be tested include temperature, pH, turbidity, salinity, nitrates, TDS, Cations, Anions and phosphates.

Dugan [1972] suggests 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. Most human activities involve the use of water in one way or other. It may be noted that man's early habitation and civilization sprang up along the banks of rivers. Although the surface of our planet is nearly 71% water, only 3% of it is fresh. Of these 3% about 75% is tied up in glaciers and polar icebergs, 24% in groundwater and 1% is available in the form of fresh water in rivers, lakes and ponds suitable for human consumption.

Pani [1986] suggests 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. Fresh water which is a precious and limited vital resource needs to be protected, conserved and used wisely by man. But unfortunately such has not been the case, as the polluted lakes, rivers and streams throughout the world testify. According to the scientists of National Environmental Engineering Research Institute, Nagpur, India, about 70 % of the available water in India is polluted.

Ahluwalia and Manjit [1988] Suggests 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. High concentrations of all heavy metals are toxic to biological systems and effect of some heavy metal compounds on growth and differentiation in a blue green and green algae.

Ghatak and Konar [1992] suggests physico-chemical and biological Characteristics of river water was found generally gradually changed due to drainage of various industrial effluents. The concentrations of Dissolved Oxygen, Phosphate of waste were significantly decreased but carbon dioxide was increased at various sites and resulted in decreases of Phytoplankton communities of the river water.

WHO [1993] suggests to monitor the water resource and ensure sustainability, national and international criteria and guidelines established for water quality standards are being used. The chemistry of water is very dynamic, largely controlled and modified by its medium of contact. Since the chemistry of water directly hints the quality of water for various purposes, its monitoring and assessment gained substantial importance in the present century. A tremendous increase in the population increased the stress on both surface and the groundwater. It is believed at the beginning of the human civilization itself, groundwater was the most trusted form of drinking water because of the filtering effect of the aquifer. However, in the present world drinking the water directly from the source without proper treatment is a tough task.

The surface water analysis for physical and chemical properties is very important for Public health studies. These studies are also main part of pollution studies in the environment. The groundwater contains dissolved solids possesses physical characteristics such as odor, taste and temperature. The natural quality of groundwater depends upon the physical environment, the origin, and the movement of water. As the water moves through the hydrological cycle, various chemical, physical and biological processes change its original quality through reactions with soil, rock and organic matter. Natural processes and human activities cause the changes in groundwater quality, directly or indirectly. According to WHO organization, about 80% of all the diseases in human beings are caused by water.

Jones [1995] suggests a river is a system comprising both the main course and the tributaries, carrying the one-way flow of a significant load of matter in dissolved and particulate phases from both natural and anthropogenic sources. The quality of a river at any point reflects several major influences, including the lithology of the basin, atmospheric inputs, climatic conditions and anthropo-genic inputs. On the other hand, rivers play a major role in assimilation or transporting municipal and industrial wastewater and runoff from agricultural land. Municipal and industrial wastewater discharge constitutes a constant polluting source, whereas surface runoff is a seasonal phenomenon, largely affected by climate within the basin.

Goel [1997] Suggests Water resources are said to be polluted when, because of man's action in adding or causing the adding of matter to the water or altering the physical, chemical or biological characteristics of water to such an extent that it‘s utility for any reasonable purpose or its environmental value is demonstrably depreciated. The quality of physicochemical and biological characterizations of water is an index to provide a complete and reliable picture of the conditions prevailing for tropic status in the water bodies.

Vega et al., [1998] suggests the application of different multivariate statistical tech-niques, 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, allows the identification of possible factors/sources that influence water systems and offers a valuable tool for reliable management of water resources as well as rapid solution to pollution problems.

Tank et.al [2001] study focused on the hydrochemistry of groundwater in the Jaipur city to assess the quality of groundwater for determining its suitability for drinking and agricultural purposes. Groundwater samples were collected from eleven stations of Jaipur city during monsoon season and were analyzed for physico-chemical parameters such as pH, EC, TDS, sodium, potassium, calcium, magnesium, chloride, sulphate, carbonate, bicarbonate, nitrate and fluoride. Comparison of the concentration of the chemical constituents with WHO (world health organization) drinking water standards of 1983, the status of groundwater is better for drinking purposes. The parameters like pH, sodium, potassium, carbonate, bicarbonate, chloride are within permissible limit as per W.H.O but calcium, magnesium and nitrate values exceeding the limit. The calculated values of SAR, RSC and percentage sodium indicate that the water for irrigation uses is excellent to good quality. US Salinity diagram was used for evaluating the water quality for irrigation which suggests that the majority of the groundwater samples were good for irrigation.

Vikas Tomar et.al [2002] describes the surface water analysis for physical and chemical properties are very important for Public health studies. These studies are also main part of pollution studies in the environment. The surface water contains dissolved solids possesses physical characteristics such as odor, taste and temperature. The natural quality of surface water depends upon the physical environment, the origin, and the movement of water. As the water moves through the hydrological cycle, various chemical, physical and biological processes change its original quality through reactions with soil, rock and organic matter. Natural processes and human activities cause the changes in surface water quality, directly or indirectly. According to WHO organization, about 80% of all the diseases in human beings are caused by water.

Chidanand Patil et.al [2003] carried out Physical, chemical, bacteriological analysis of water samples from different locations located around landfill site at Mahanadi to ascertain the magnitude of dumpsite pollution on surface water quality. During the study period, many areas were selected around the landfill area at a distance of 500, 750 and 1000m. The parameters analyzed during the study period were pH, Total dissolved solids (TDS), Total Hardness, Nitrate, Most Probable Number (MPN) and heavy metal such as Lead using standard laboratory procedures. The pH ranged from 6.01 to 7.3 indicating acidic in nature in the month of Feb and March, but in the month of April and may all the parameters within the levels.

The pH of water in river within 500-700m is contaminated by the leachate of landfill. Concentrations of Hardness, TDS, and Nitrate ranged from 0 to 80 mg/L, 49 to 190 mg/L, 4 to 79.89 mg/L respectively. The analysis was done for four months from Feb to May. The results showed that within 500 m bore wells were contaminated by E-Coli bacteria, also nitrate concentration is above the permissible level described by W.H.O and Bureau of Indian Standards for drinking water and pH were acidic in nature. The polluted water requires certain levels of treatment before use. Public enlightenment on waste sorting, adoption of clean technology, using climate change mitigation strategies and the use of sanitary landfill to prevent further contamination of ground water flow are recommended.

Kumar et.al. [2004] suggests an assessment of various physico-chemical characteristics of river water such as pH, temperature, DO, Hardness, Phosphate, Sulphate, Nitrate, and COD were carried out at three sites of Sabarmati River in morning hours. They choose National Sanitary Foundation WQI as it is an excellent management and general administrative tool in communicating water quality information. This index has been widely tested and applied to data from a number of different geographical areas all over the world in order to calculate WQI and it is taken into consideration nine parameters and a weight was given to each factor according to its importance in water quality. . A water quality index expressed as single number is developed to describe overall water quality conditions. Therefore it is necessary for monitoring the water quality of river by analysis of various physiochemical parameters.

Acharya [2005] suggests a study was carried out to evaluate the impact of domestic waste generated from Cuttack city on river Kathajodi. Samples were collected in three seasons for two consecutive years both at upstream and at downstream. The results obtained in different seasons have been compared graphically. From analysis it was observed that almost all parameters are in increasing trend (except DO) towards D/S. The stations located upstream of the river was found to be less polluted but the contamination of the river starts from downstream near Govt press due to dumping of waste and waste water. The water of the river assumed a dark hue due to discharge of raw domestic sewage. The pollution load decreases towards the last patch of the river within the study area as a result of dilution.

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.TDS and Nitrate concentrations in ground water of the study area exceed the permissible limit at central location at Paradeep, Odisha. TDS in groundwater can also be due to natural sources such as sewage, urban runoff and industrial waste **(Joseph, 2001)** limit. The permissible turbidity of water was 28 to 42 NTU which is higher as per the APHA limit. Electrical conductivity is the capacity of electrical current that passes through the water. It is directly related to concentration of ionized substances in water and may also be related to problems of excessive hardness. According to BIS and ICMR the desirable limit of Conductivity is 600 μm/cm. Solutions of most inorganic acids, bases, and salts are relatively good conductors. In contrast, the conductivity of distilled water is less than 1 μmhos/cm.

Panda et al., [2006] Suggests Rivers are the main inland water resources for domestic, industrial and irrigation purposes and often carry large municipal sewage, industrial waste water and seasonal run off from agricultural land to the coastal region. These are the main reasons for nutrient enrichment of river water as compared to other environments.

Samantray et al. were studied the water quality of Mahanadi and its distributaries rivers, streams, Atharabanki river and Taldanda Canal adjoining Paradip in three different seasons namely summer, pre-monsoon and winter. Four parameters namely pH, Dissolved Oxygen, Biochemical Oxygen Demand and Fecal Coliform were considered to compute Water Quality Index based on National Science Foundation studies. Six water samples from Mahanadi River and three water samples from its distributaries were analysed to assess the water quality. Surface waters were collected from all the rivers and streams on a monthly basis for the year 2006.Their findings highlighted the deterioration of water quality in the rivers due to industrialization and human activities **(Samantray et al., 2006).**

Kamal [2007] Suggests physico-chemical parameter of river water affects the biological characteristics and indicates the status of water quality. Different types of physico- chemical parameters of water are pH, DO, BOD, COD, Chloride, TDS, Nitrate, Sulphates, TH, EC and Fluoride. These parameters are solely responsible for water quality. Quality of water generally refers to the component of water which is to be present at the optimum level for suitable growth of plant and animals. Aquatic organisms need a healthy environment to live and have adequate nutrients for their growth. The productivity depends on the physicochemical characteristics of the water body. The maximum productivity obtained when the physical and chemical parameters are at optimum level.

Adetunde et.al [2007] have studied the area and investigated Physicochemical and bacteriological qualities of surface water in the North areas and south local government areas of State, Odisha. Water samples were collected from different areas of North and South local areas. The results showed that most of the physical and chemical parameters were within the acceptable guide line limits of the WHO for drinking and domestic water. The well water is mostly soft, alkalinity ranged from 30- 390mg/l and 40- 236mg/l for North and South respectively. PH ranged between 6.2-8.8 in both areas, SO_4^{2-} and CL^- ions concentrations fell within WHO set standards. Hardness ranged between 40- 504mg/l and 60 to 384mg/l for North and South areas respectively. Surface water in some areas is moderately hard to very hard. Such microbial contamination posed a threat to well water quality and could lead to an increase risk level of outbreak of water borne diseases in the two local government areas of State. The limit of total hardness value for drinking water is to be within 300 mg/l of CaCO3.Higher concentration of hardness was found may be due to natural accumulation of salt, or surface runoff, water enter from direct pollution by human activities. Nephelometer instrument measures the intensity of scattered light by turbid particles at right angle to the incident beam of light in comparison with the intensity of light passing through the sample. Scattering of light is a function of Tyndall effect exhibited by colloidal suspended particles. Turbidity of samples is measured by Nephelometer based on this principle. The maximum Permissible level is 5 NTU.

Jena [2008] Suggests Mahanadi is the largest river in Odisha. The assessment of water quality analysis of river Mahanadi in Sambalpur town becoming utmost importance because of various reasons like rapid urbanization, agricultural and industrial waste, and sewage water comprises of domestic, medical and other wastes due to anthropogenic activities. Open defecation is another reason behind the pollution of river water. According to municipal report, more than 50 percent of latrine drains of the town are directly connects to the main drains which eventually fall on the river. About 40 percent population of the city defecates in open and about 30000 people take bath in the river bank.

Swarna Latha [2008]. Suggests according to BIS and ICMR the desirable limit of TDS is 500 mg/l. If TDS value is more than 500 mg/l, it may cause gastro intestinal irritation. High TDS presence in the water decreases the quality and affects the taste of water **(Guru Prasad, 2005).**

In now days due to increase in population, industrialization, agricultural activities and urbanization, large quantities of sewage and industrial wastewater are discharged into water bodies has significantly contributed to the pollution of the surface and ground water. The objective of the present study was to assess water quality of various ground water sources in India for drinking and agriculture. For the assessment of water pollution status of the water bodies, the following water quality parameters were analyzed: (1) pH (2) Conductivity (3) Temperature (4) Total dissolved solid (TDS) (6) Total Alkalinity (7) Hardness (8) Cations and Anions (9) Carbonates and Bicarbonates. (10) Sulphates.

M.R.G. Sayyed et.al [2009] assessed the surface water from the south-eastern part of Odisha city for the seasonal variation in their quality parameters. Using Piper diagram the hydrogeochemical faeces were identified and the surface waters were classified with regards to the changes in their major chemical compositions. Based on the hydro-geochemical faeces it has been found that the surface water regime is severly deteriorated by the anthropogenic activities. The predominant SO_4 and Cl in the wells of Jharsuguda and Sundergarh areas have strong influence of leachate throughout the year due to solid waste disposal site. The pH is important parameter of water, which determines the suitability of water for various purposes such as drinking, bathing, cooking, washing and agriculture etc. The pH level of water having desirable limit is 6.5 to 8.5 as specified by the BIS. Pure water is said to be neutral, with a pH of 7. Water with a pH below 7.0 is considered acidic while water with pH greater than 7.0 is considered as basic or alkaline.

Shimaa M. Ghoraba et.al [2008] collected many ground water samples from different districts of Mahanadi, Odisha. The various parameters are selected for the testing of samples. All samples were analyzed for pH, Calcium, Carbonate, Magnesium, Sodium, Potassium, Chlorides, Sulphate and Nitrate, TDS and bicarbonate. The results revealed highly variable hydrochemistry. The chloride is found to be most predominating. The Surface water in Brajarajnagar has high concentrations of fluoride, iron and nitrate in many districts. The pH part of the Durov diagram reveals that surface water in study area is alkaline and electrical conductivity of most of samples lies in the range of drinking water standards adapted in Odisha. From the SAR and conductivity plot it was found that most of groundwater cannot be used on soil without restricted drainage and special requirement of Management for salinity control. Comparision of data with **WHO(2011)** standards for drinking water indicate that the groundwater in the most of study area are suitable for drinking purpose except some few places. The groundwater recorded a wide range in TDS. Chloride is one of the most important parameter in assessing the water quality and higher concentration of chloride indicates higher degree of organic pollution **(Yogendra and Puttaiah, 2008).** According to BIS and ICMR the permissible limit of chloride in drinking water is 250 mg/l. High concentration of chloride was observed may be due to natural processes such as the passage of water through natural salt formations in the earth or it may be an indication of pollution from industrial or domestic use (Renn, 1970). In drinking water, high chloride content may lead to laxative effects (**Raviprakash and Rao, 1989; Dahiya and Kaur, 1999).**

K.C.Khare et.al [2010] he was done 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. The analysis of Water quality indicates the temperature in the range of $24^0{}_{C.}$The pH was 7.3 to 8.45.It shows slightly alkaline water. The DO varied from 4.8 to 5.7 mg/l.The total hardness ranged from 160 to 298 mg/l which is higher than permissible limit. The turbidity of water was 28 to 42 NTU which is higher as per the APHA limit.

Venkatesharaju *et al*.,[2010] Suggests 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. The healthy aquatic ecosystem is depended on the physico-chemical and biological characteristics of water. As of now only earth is the planet having about 70 % of water but due to increased human population, industrialization, use of fertilizers in the agriculture and manmade activity it is highly polluted with different harmful contaminants which can cause various water borne diseases.

Mona A. Hagras et.al [2011] to assess 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 Province and analyzed for 15 water quality parameters Surface water suitability for domestic and irrigation purposes was assessed by using WHO and USDA standards.SAR values and the sodium percentage (Na%) in locations indicate that majority of the groundwater samples are suitable for irrigation. This investigational study indicates that water in many cities of Paradeep is unsafe for human consumption due to presence of both bacterial and chemical contamination.

Lohani et.al [2011] suggests Drinking water quality management through various physico-chemical parameters and health hazard problems with their remedial measures in Bhubaneswar city of Odisha. They have studied the physico-chemical and bacteriological study and its adverse effect in Bhubaneswar the capital of Odisa well known as temple city of India are undertaken. Water samples from different locations were collected in post monsoon period. Standard procedures were adopted to calculate their physical, chemical and biological parameters. Bhubaneswar has a typical interface of sedimentary terrain along with alluvium deposits, has got variability in its physical and chemical constituents. The variations are also remarkable on the basis of their lithological aspects. Different parameters of groundwater samples were examined using WHO and Indian Standards to find their suitability for drinking and domestic purposes. Systematic approach between various parameters is simultaneously carried out. Each element and its impact to health problem are discussed. The results are then interpreted to provide the details of the quality and quantity problem suggesting whether water of different locations are within the permissible limit for drinking and domestic purposes as far as different standards are concerned.

Sahu [2012] 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. Since then the science of water quality monitoring progressed. In the third world countries 80% of all diseases are directly related to poor drinking water and insanitary conditions. As water is one of the most basic needs of the habitants, its safeness must be studied before use. The physico-chemical quality of river water is very important from the health point of view. Thus, constant monitoring of river water quality is needed so as to record any alteration in quality and outbreak of health disorders. The present study reports on the river water quality of fourteen different stations of Mahanadi basin as given below. The present study aims at detecting the quality of water in respect of physico chemical parameters Studies. The possible number of such parameters necessary to completely specify the quality of water is very large. However at present fourteen parameters are considered to characterize the Mahanadi River water.

Rout [2015] Suggests 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. 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. COD values were invariably higher than BOD indicating the presence of considerable amount of chemically oxidizable matter which was non - biodegradable.

CHAPTER 03

STUDY AREA AND DATA COLLECTION

3.1 STUDY SITE:

The State Pollution Control Board, Odisha, is monitoring the water quality of nine river basins of the state, viz. Mahanadi, Brahmani, Baitarani, Rushikulya, Nagavali, Subarnarekha, Budhabalanga, Kolab and Vansadhara under the National Water Quality Monitoring Project (NWMP) and State Water Quality Monitoring Project (SWMP) at the monitoring stations, given in Table-1. The report describes summary of the findings made during the period 2000-2014.

Table 3.1.1 WATER QUALITY MONITORING STATIONS

SL NO	RIVER BASIN	NWMP	SWMP
1.	**Mahanadi**	Ib: Sundergarh, Jharsuguda, Brajarajnagar U/s, D/s Beden: Beden R.before Jharsuguda Hirakud reservoir , Power Channel D/s Mahanadi: Sambalpur U/s, D/s, Sambalpur FD/s at Huma, Sonepur U/s, D/s, Tikarpada, Narasinghpur, Mundali, Cuttack U/s, D/s, Pradeep U/s, Pradeep D/s Tel: Monmunda Kathojodi: Cuttack D/s Serua: Sankhatrasa Kuakhai: Bhubaneswar FU/s,U/s Daya: Bhubaneswar D/s, FD/s Birupa:Choudwar D/s	Mahanadi: Sambalpur FD/s at Shankarmath, Power channel U/s, Cuttack FD/s. Kathojodi: Cuttack U/s, Cuttack FD/s at Mattagajpur.
2.	**Brahmani**	Sankh: Sankh U/s Koel: Koel U/s Brahmani : Panposh U/s, D/s, Rourkela D/s, Samal, Talcher FU/s, U/s, D/s, FD/s,Dhenkanal D/s,Bhuban, Dharmasala, Kabatabandha, Pottamundai Kharasrota: Khanditara, Aul	Brahmani: Rourkela FD/s at Attaghat, Dhenkanal U/s Nadira: Nadira D/s at Dasnalli Kisindajhor: Kisindajhor Kharasrota: Binjharpur
3.	**Baitarani**	Baitarani: Joda, Anandpur, Jajpur, Chandbali Dharma: Dharma Kusei: Deogan	
4.	**Rushikulya**	Madhopur, Potagarh	

5.	**Nagavali**	Penta U/s, Jaykaypur D/s, Rayagada D/s	
6.	**Subernarekha**	Rajghat	
7.	**Budhabalanga**	Baripada D/s, Balasore D/s	Balasore U/s
8.	**Kolab**	Kerandi river at Sunabeda	
9.	**Vansadhara**	Muniguda, Gunupur	

3.2 WATER QUALITY ASSESSMENT:

The following water quality parameters are determined at all locations.

Physical parameters: Temperature, pH , Alkalinity, Total Suspended solids(TSS).

Indicators of organic pollution: Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Free ammonia- Nitrogen, Ammonical (Ammonium+ammonia)-Nitrogen, Total Kjeldahl Nitrogen (TKN).

Bacteriological parameters: Total Coliform and Fecal Coliform.

Mineral constituents: Electrical Conductivity(EC) , Total Dissolved Solids(TDS), Boron, Sodium Absorption Ratio (SAR), Hardness, Chloride, Sulphate,Fluoride.

Nutrients: Nitrate (Nitrate + Nitrite)-Nitrogen, Phosphate- Phosphorous

Metals: Chromium (Cr) (total and hexavalent), Iron (Fe), Nickel (Ni), Copper (Cu), Zinc (Zn), Cadmium (Cd), Mercury (Hg), Lead (Pb).

Biological Indices: Saprophytic Index (SI) and Diversity Index (DI).

3.3 Water quality of the rivers has been assessed in term of three classification schemes-viz. Use based, Biological and Wholesomeness.

3.3.1 Use Based Classification:

The standards prescribed for the tolerance limits for inland surface waters (IS.2296-1982-Second revision) for the following uses are considered.

Class A - Drinking water source without conventional treatment but after disinfection.
Class B - Outdoor bathing.
Class C - Drinking water source with conventional treatment followed by disinfection.
Class D - Fish culture and wild life propagation.
Class E - Irrigation, industrial cooling or controlled waste disposal.

3.3.2 Biological Assessment of Water Quality:

Biological assessment is based on the fact that pollution of water bodies will cause changes in the physical and chemical environment of water which in turn will disrupt the ecological balance of the ecosystem. Through bio-monitoring, the cumulative effects of all the pollutants can be determined and the overall health of the ecosystem can be assessed.

Bio-monitoring results are generally expressed in terms of two indices, namely the saprobic index (SI) and Diversity index (DI). The criteria used for classification of water quality on the basis of biological indicators are given as below.

Table 3.3.2.1 **Biological Indicators**

Indicator	Water Quality
High Biodiversity DI >0.6, SI =6-10, BOD < 3 mg/l	Clean
Moderate Biodiversity DI= 0.2-0.6, SI= 2-6 BOD = 3 to 6 mg/l	Slight to moderate pollution
Poor Biodiversity DI < 0.2, SI, BOD > 6 mg/l	Heavy to severe Pollution.

3.3.3 Water Quality in terms of wholesomeness

The basic objective of the water (Prevention and Control of pollution) Act, 1974, which governs the water quality management in the country, is to provide for the prevention and control of water pollution and maintaining or restoring the wholesomeness of water. Since the act does not define the level of "wholesomeness" to be maintained or restored, the CPCB linked wholesomeness to the quality are required by humans. Criteria were developed for different uses which were used as the Indian standards by the Indian Standards Institution later named as Indian Standards.

Over the years it was felt that the designated use concept with the objective protecting the direct beneficial uses to humans and classifying water quality accordingly needs to be reviewed and wholesomeness should incorporate an overall integrated view of the water ecosystem. The first priority in water quality assessment and management should be to maintain and restore to a desirable level of its environmental quality. Accordingly specific requirements for "Acceptable", Desirable and Excellent" Levels of wholesomeness with short medium and long terms goals have been laid down (Water Quality-Criteria and Goals, CPCB, MINARS/17/2001/2002).

3.4 WATER QUALITY STATUS

3.4.1 Mahanadi Basin:

About 46% of the catchment (65,628 sq. km out of a total of 1, 41,134 sq. km) of Mahanadi is in Odisha. Rest 54% of the catchment lies in Madhya Pradesh / Chhatisgarh. Since several large towns and industries (Rajnandagoan, Bhillai, Durg , Shimoga, Raipur , Bilaspur , Korba etc.) are located on the banks of tributaries of the river in Madhya Pradesh/ Chattisgarh, they carry considerable pollution load. In Odisha, the river Ib with its share of pollutants drains into Hirakud reservoir. But in spite of this, the reservoir water at Hirakud almost conforms to Class- B, except for TC values.

The water quality at all stations except Sambalpur D/s, Cuttack D/s (Kathojodi), Bhubaneswar D/s and FD/s (Daya), Paradeep D/s can be classified as Class-C/D/E. The water quality at the downstream of Sambalpur, Cuttack and Bhubaneswar may be classified as Class-D/E. In all cases, the parameters responsible for downgrading the water quality is TC, besides BOD for Sambalpur D/s, Cuttack D/s(Kathojodi) and Bhubaneswar D/s and FD/s. Water Quality at paradeep does not qualify even for class E due to several parameters (TC, EC,SAR, Chloride) which may be attributed to the tidal effect.

Taking into consideration the observed biological indices and the BOD values, it may be concluded that the river stretch at Brajarajnagar(Ib), Sambalpur (Mahanadi), Cuttack(Mahanadi), Cuttack(Kathojodi) and Bhubaneswar (Kuakhai) is in a state of slight to moderate pollution.

The water qualities at all stations are below acceptable level, due to almost to FC and TKN. An additional factor at paradeep is EC.

3.4.2 <u>Brahmani Basin:</u>

The water quality at all stations, except Panposh D/s, Rourkela D/s and Talcher D/s, can be classified as Class C/D/E. Water Quality at these three stations may qualify for class D/E. Based Taking into consideration the observed biological indices and the BOD values, it may be concluded that the river stretch at Panposh, Rourkela and Talcher is in a state of slight to moderate pollution.

The present level of wholesomeness of water at all stations is below acceptable level due to mostly to FC and TKN.

3.4.3 <u>Baitarani Basin:</u>

The Water Quality at Joda, Anandpur, Jajpur and Kusei can be classified as Class C. Water Quality at Chandbali and Dharma do not qualify for Class E due to tidal effect. Considering pH, BOD,DO, EC and N values, the present level of wholesomeness of the river water may be considered as “Excellent”. Taking into consideration the TSS values, the water quality at Joda, Anandpur and Jajpur is downgraded to “Acceptable” Level. However, on introduction of FC and TKN values in the above assessment, the river water quality is below “acceptable” during the period under report.

3.4.4 <u>Rushikulya Basin:</u>

The water quality at Madhopur can be classified as class-C. Water quality at Potagada is not qualifying the tolerance limits for class-E because of tidal effect. Bio-monitoring studies on the river at Madhopur and Potagada revealed that the river stretch at these locations are in a state of slight to moderate pollution.In terms of wholesomeness, the water quality is acceptable with respect to all parameters except fecal coliform and TKN.

3.4.5 <u>Nagavali Basin:</u>

The water quality at Penta U/s, Jaykaypur D/s and Rayagada D/s conform to class-C. Biomonitoring studies reveal that the river stretch at these three stations is in a state of slight to moderate pollution.

Considering pH, DO, BOD, EC and N values, the present level of wholesomeness of the river water may be considered as “Desirable”. However inclusion of parameters like FC and TKN into water quality assessment, the river water quality is below “acceptable” during most periods under report.

3.4.6 Subernarekha Basin:

The water quality at Rajghat conforms to class-C inland surface water. Biomonitoring studies reveals that the river stretch at Rajghat is in a state of slight to moderate pollution. In terms of wholesomeness the water quality satisfies the criteria for the ‘desirable’ class with respect to all the parameters except fecal coliform and TKN, in respect of which the water is below acceptable quantity.

3.4.7 Budhabalanga Basin:

The water quality at Budhabalanga River conforms to class C inland surface water. Biomonitoring studies reveal that the river stretch at Baripada D/s, Balasore U/s and Balasore D/s are in a state of slight to moderate pollution.In terms of wholesomeness, the water quality satisfies the criteria for the “desirable” class with respect to all the parameters, except fecal colliform and TKN, in respect of which the water is below acceptable quality.

3.4.8 Kolab Basin:

Water quality of kerandi river (a major tributary of kolab river in odisha part) at Sunabeda conforms to Class C inland surface water. Biomonitoring studies reveal that the river stretch at Sunabeda is in “clean” category. In terms of wholesomeness the water quality satisfies the criteria for the “Excellent class” with respect to all the parameters except fecal coliform in respect of which the water is of acceptable quality.

3.4.9 Vansadhara Basin:

Water quality of Vansadhara river at Muniguda and Gunupur conform to class C inland surface water. Bio-monitoring Studies reveal that the river stretch at Muniguda and Gunupur are in “slight to moderate pollution” category. In terms of wholesomeness, the water quality mostly satisfies the criteria for the “ Excellent” class with respect to all the parameters except TSS, Fecal Colliform and TKN in respect of which the water is of below acceptable quality.

3.5. RIVER BASINS IN ODISHA

The total geographical area of Odisha (1,55,707 square km) is divided into eleven river basins covering a geographical area of 1,50,460 square km and minor river basins of 5247 square km which drains directly into the Bay of Bengal. Out of eleven river basins, seven basins like Mahanadi, Brahmani, Subernarekha, Nagavalli, Vansadhara, Kolab and Budhabalanga are interstate either due to their origin fall-out in the sea of the adjoining state. All the rivers flowing in the state are either originating from Central Plateau of India or Eastern Ghat region and flow along the direction of lower contour to join the main stream, which ultimately flow in eastward direction to join Bay of Bengal.

3.5.1 Based on the catchment area of the Basin Rivers in Odisha can be divided into three groups as follows:

Table 3.5.2

Large	River basins with catchments of 20,000 sq.km and above	Mahanadi, Brahmani, Godavari (Indravati and kolab)
Medium	River basins with catchments of 2000 sq.km to 20,000 sq km	Baitarani, Subernarekha, Budhabalanga, Rushikulya, Vansadhara and Nagavali.
Minor	River basins with catchments of 2000 sq.km	Bahuda

Fig.3.5.3 COVERAGE OF RIVER BASIN AREAS (IN PERCENTAGE) IN ODISHA

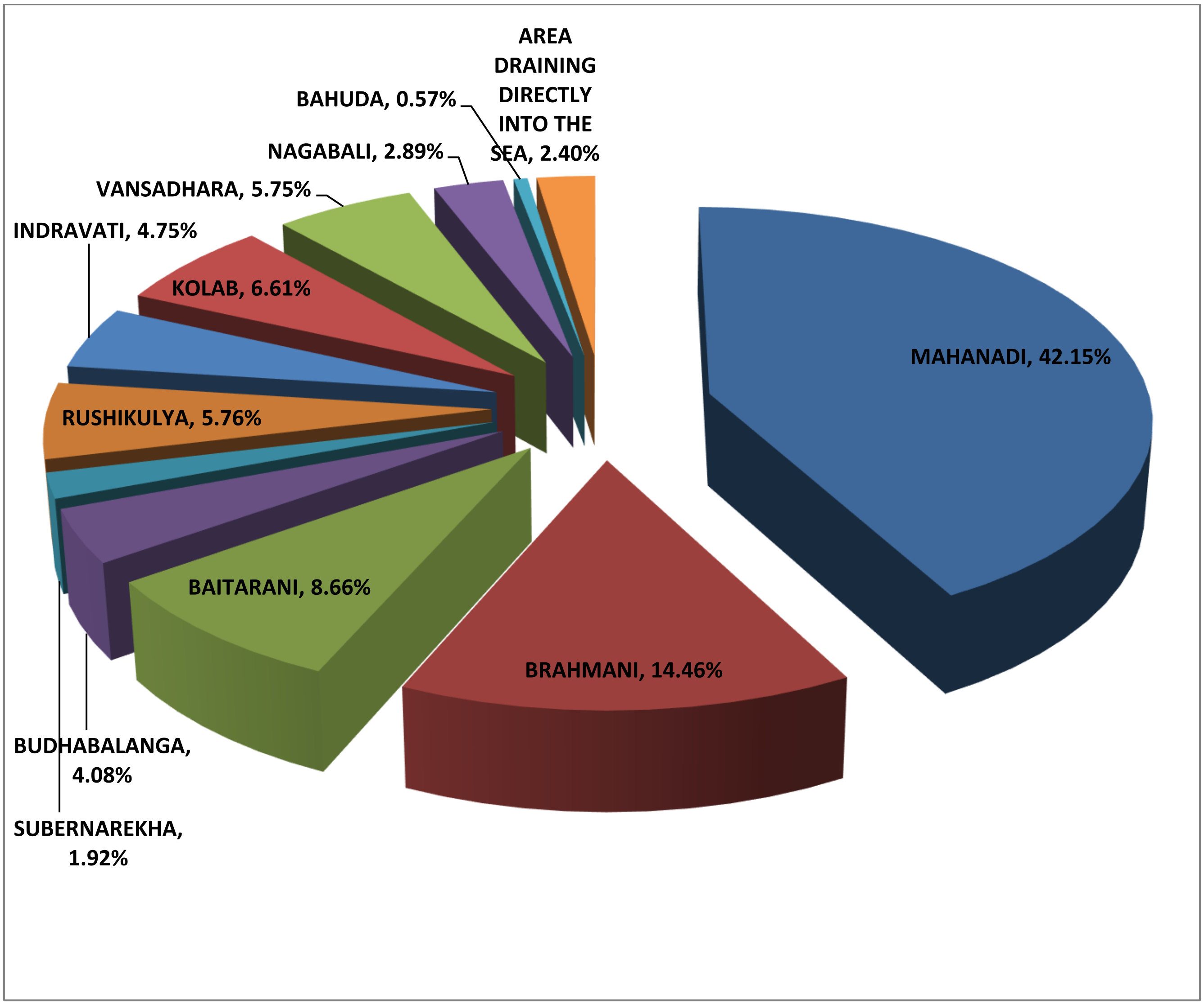


Table 3.5.4 BASIN FEATURES OF MAJOR RIVERS FLOWING IN ODISHA

Main features	Mahanadi	Brahmani
Origin	From Amarakantak hills of the Bastar Plateau near Pharsiya village in Chattisgarh.	Formed by the combined waters of koel and sankh rivers at Vedavyasa near Rourkela of Sundergarh District.
Basin area (sq. km)	1,41,134	39,116
Basin area in Odisha (sq.km)	65,628	22,516
% to Geographical area of state	42.15	14.46
Population in the basin in odisha (2001 census)	34,21,612	51,10,660
Total length(km)	851	799
Total length in Odisha (km)	494	461
Water Resource(Million m³)(Average)	59155	18577
Water Resource (Million m³) (75% Dependable)	48732	14011
Per capita water availability (2001) (m³)	3551.06	3634.95
Major Tributaries	Seonath,Hasdeo,Mand, Ib, Jonk, Ong, Hariharjore, Tel, Jeera	Koel,Kuradhi,Mankara,Samakoi,Ramiala, Karo,Sankh,Rukura,Gohira,Tikira,Singhdajhor, Nigra,Barjor,Nandira.
Major Distributaries	Kathjodi, Birupa, Kuakhai,Daya,Bhargavi,KushabhadraBiluakhai,Devi,Kandala,Luna,Chitrotpala,Karandia,Paika and Badagenguti	Kharasuan
Districts covered in Odisha (% of geographical area of the district)	Sundergarh (39%), Jharsuguda(100%), Sambalpur(79%), Angul (33%),Dhenkanal(11%), Cuttack(99%),Jagatsinghpur (100%), Khordha(98%), Puri(70%), Phulbani(81%), Sonepur(100%),Balangir(100%),Bargarh(100%)	Sundergarh(59%),Deogarh(85%),Sambalpur(21%) Angul(66%), Keonjhar(21%), Dhenkanal(89%), Jajpur(63%), Kendrapada (42%), Cuttack(1%)

Main Features	Baitarani	Rushikulya	Nagavali	Subernarekha
Origin	Gonasikha	Near village	Bijipur hills of Eastern	Near Nagri village of Chotanagpur plateau in

	hills of keonjhar district	Madhabari of Phulbani district	ghats in kalahandi district	Ranchi district
Basin area(Sq.km)	14,218	8963	9275	19277
Basin area in Odisha(sq.km)	13,482	8963	4500	2983
% to geographical area of state	8.66	5.76	2.89	1.92
Population in the basin in Odisha (2001 census)	38,29,931	29,42,901	5,78,143	11,50,904
Total length(km)	440	175	217	446
Total length in Odisha(km)	360	175	125	81
Water Resource (Million)m³(Average)	7568	3949	2853	2308
Water Resource (Million m³) (75% Dependable)	5434	2782	2322	2308
Per capita water availability (2001) (m³)	1976.01	1341.87	4291.89	2365.24
Major Tributaries	Deo,Salindi, Kanjhari,Musal, Arredi, Siri, Kukurkata, Gahira, Remal.	Mahanadi, Bhagua, Badanadi, Dhanel.	Jhanjavati, Vegavati, Subarnamukhi	Kanchi, Kakari, Khadkei.

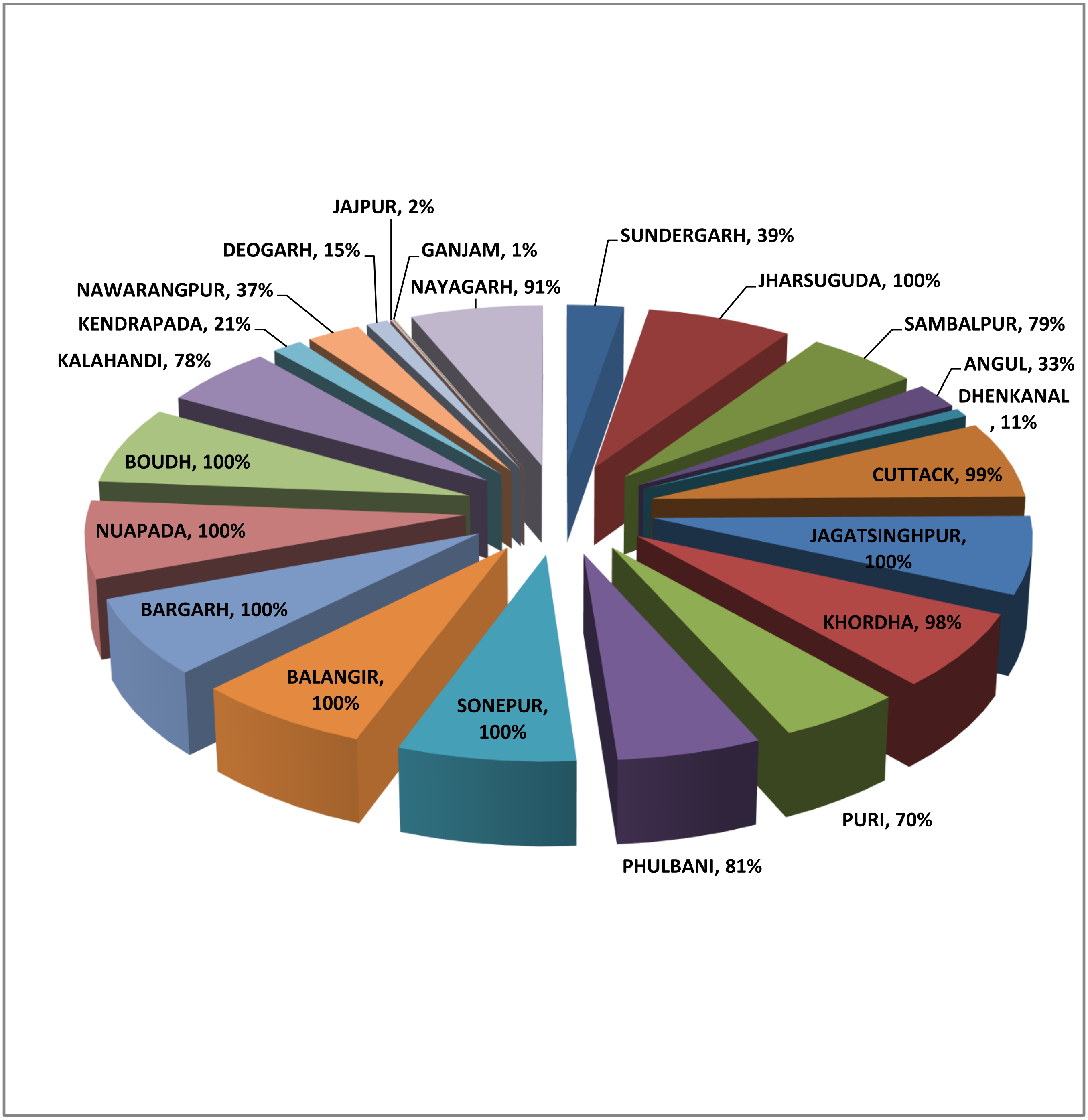
Districts covered in Odisha (% of geographical area of the district)	Keonjhar(79%),Bhadrak(100%), Jajpur(35%), Kendrapada(37%),Mayurbhanj(10%), Balasore(30%),Sundergarh(2%),Angul (0.5%).	Ganjam(90%), Phulbani(10%), Gajapati(9%), Nayagarh(9%), Khurda(2%)	Koraput(23%), Rayagada(29%), Kalahandi(6%)	Mayurbhanj(21%),Balasore(21%).
Main Features	Budhabalanga		Kolab	Vansadhara

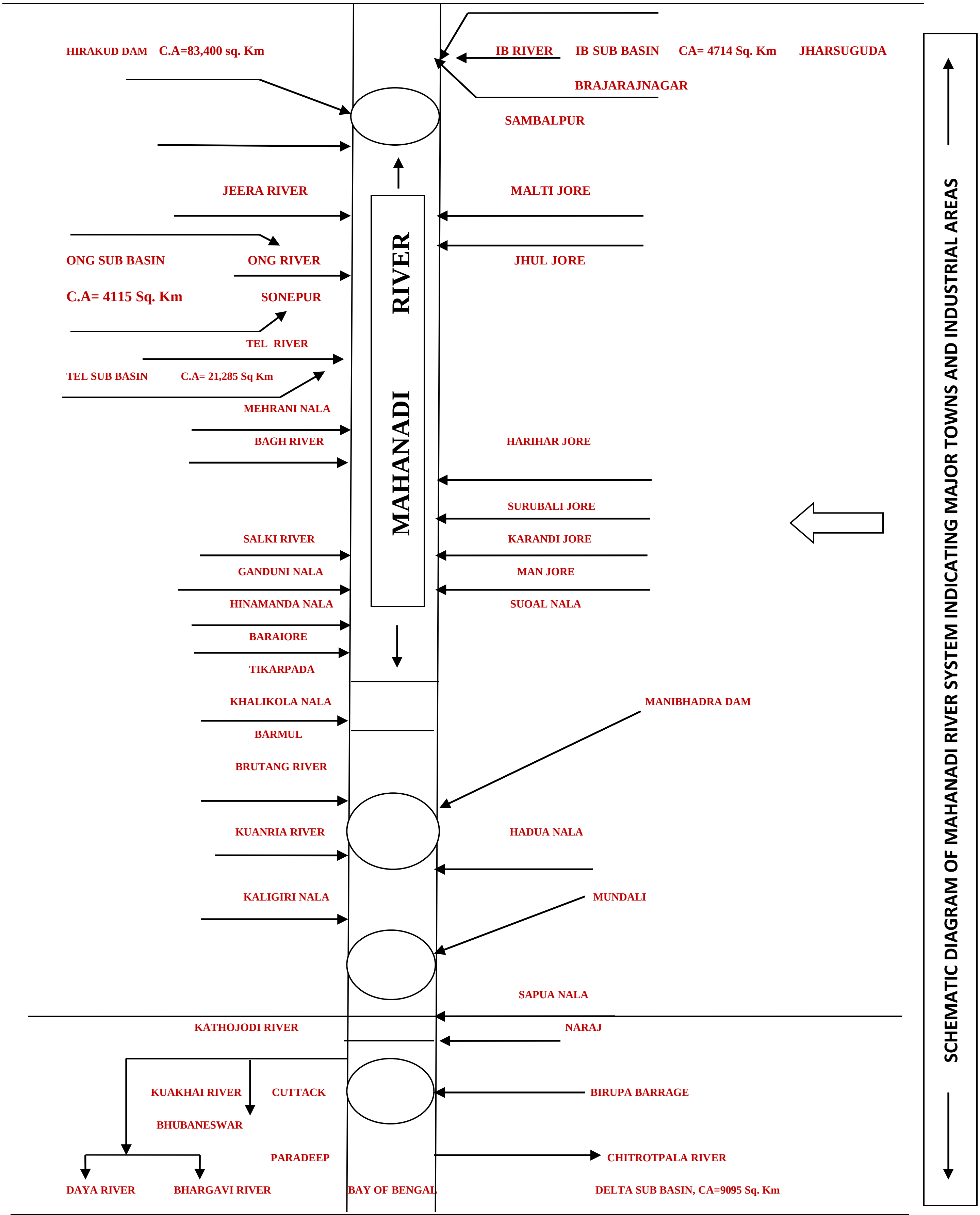
Origin	Similipal range of hills in Mayurbhanj district	Hill ranges of koraput district	Near village Lanjigarh of kalahandi district
Basin area(Sq.km)	4838	20,247	11,377
Basin area in Odisha(sq.km)	4838	10,300	8,960
% to geographical area of state	3.11	6.61	5.75
Population in the basin in Odisha (2001 census)	18,58,710	11,08,684	10,23,338
Total length(km)	198.75	418	239
Total length in Odisha(km)	198.75	60	160
Water Resource (Million)m³(Average)	3111	11089	5083
Water Resource (Million m³) (75% Dependable)	2521	8885	3881
Per capita water availability (2001) (m³)	1616.61	2263.65	8174.97
Major Tributaries	Sunei, Kalo, Katra, Sana, Nadi	Kerandi, Potteru, Sileru, Machkund	Chauldhua, Pandaka Lake, Gangudi, Sananadi,Harabhanji, Pedagoda, Mahendratanaya.
Districts covered in Odisha (% of geographical area of the district)	Mayurbhanj(39%), Balasore(19%)	Malkanigiri(100%), Koraput(51%)	Rayagada(56%), Gajapati(88%), Phulbani(9%), Kalahandi(6%)

3.6 MAHANADI:

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.

Fig. 3.6.1 AREA COVERAGE OF DISTRICTS (IN PERCENTAGE) IN MAHANADI BASIN IN ODISHA




HIRAKUD DAM C.A=83,400 sq. Km
IB RIVER
IB SUB BASIN
CA= 4714 Sq. Km
JHARSUGUDA
BRAJARAJNAGAR
SAMBALPUR
JEERA RIVER
MALTI JORE
ONG SUB BASIN
ONG RIVER
JHUL JORE
C.A= 4115 Sq. Km
SONEPUR
TEL RIVER
TEL SUB BASIN
C.A= 21,285 Sq Km
MEHRANI NALA
BAGH RIVER
HARIHAR JORE
MAHANADI RIVER
SURUBALI JORE
SALKI RIVER
KARANDI JORE
GANDUNI NALA
MAN JORE
HINAMANDA NALA
SUOAL NALA
BARAIORE
TIKARPADA
KHALIKOLA NALA
MANIBHADRA DAM
BARMUL
BRUTANG RIVER
KUANRIA RIVER
HADUA NALA
KALIGIRI NALA
MUNDALI
SAPUA NALA
KATHOJODI RIVER
NARAJ
KUAKHAI RIVER
CUTTACK
BIRUPA BARRAGE
BHUBANESWAR
PARADEEP
CHITROTPALA RIVER
DAYA RIVER
BHARGAVI RIVER
BAY OF BENGAL
DELTA SUB BASIN, CA=9095 Sq. Km
SCHEMATIC DIAGRAM OF MAHANADI RIVER SYSTEM INDICATING MAJOR TOWNS AND INDUSTRIAL AREAS

3.6.2 LOCATION OF STUDY AREA:

The river basin (80º30'E - 86º50'E and 19º20'N-23º35'N) extends over an area approximately 141,600 km^2, has a total length of 851 km and an annual run off of 50 x 109 m^3 with a peak discharge of 44,740 m^3s^- **(Dixit *et al*., 2013).**

3.6.3 CLIMATE OF STUDY AREA:

The climate of the Mahanadi basin lying in Odisha is a tropical monsoon type and having maximum precipitation in July, August and first half of September. During winter season the minimum temperature is generally varies from 4 º C to 12 º C. The average annual rain fall is 1572 mm, of which 70% is precipitated during the southwest monsoon between mid June to mid October **(Dixit *et al*., 2013).**

3.6.4 Waste water Generation

3.6.4.1 Industrial sources:

List of major industries which are operating in Mahanadi basin is given in below table

Name of the industries and location	Product
1.Mahanadi	
Arati steel Ltd, Athagarh	Steel
Hindalco industries Ltd. Sambalpur	Power
Hindalco Industries Ltd.(Smelter) Sambalpur	Aluminium Smelter Plant
Orissa Power Generation Corporation(OPGC) , Banharpali	Power
Bargarh Co-operative Sugar Mills Ltd, Bargarh	Sugar
ACC Cement, Bargarh	Cement
Bijayananda Co-Operative Sugar Mill Ltd, Bolangir	Sugar
Nayagarh Sugar Complex Ltd ,Nayagarh	Sugar
Cosboard Industries Ltd, Cuttack	Cardboard and paper

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SMV Beverages Pvt. Ltd, Cuttack	Soft Drinks
Paradeep Phosphates Ltd, Jagatsinghpur	Phosphatic Fertiliser
IFFCO Ltd, Jagatsinghpur	Phosphatic Fertiliser
Skol Breweries Ltd, Jagatsinghpur	Beer
IB	
Vedanta Aluminium Ltd Jharsuguda	Aluminium Smelter Plant
Sterlite Energy(P) Ltd, Jharsuguda	Power
TRL Krosaki Refractories , Belpahar	Refractories
Ultra Tech Cement Ltd, Jharsuguda	Cement
Bhusan Power and Steel Ltd, Jharsuguda	Iron and Steel, Power
BIRUPA	
Indian Metals and Ferro Alloys Ltd.(CPP), Choudwar	Power
Indian Metals and Ferro Alloys Ltd.(Ferroalloys) Choudwar	Chargechrome

Besides the large scale industries listed in the above table, there are several medium and small scale industries generating an estimated total about 100,000m^3 of waste water per day. It should, however, be noted that the entire amount of waste water may not necessarily go the river system. In certain cases, the waste water is actually diverted to marshes and other detention basins, some of which overflow during the rainy season only.

3.6.4.2 MINING SOURCES

There are 15 number of coal mines of Mahanadi coal fields limited operating in the basins. Together they discharge 14,000 m^3 of water per day, during the non-monsoon months which increase to about 33,000 m^3 per day during the monsoon as per State Pollution Control Board, Odisha data book.

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Table 3.6.5 COAL MINES OPERATING IN MAHANADI BASIN IN ODISHA

NAME OF COAL MINES	TYPE
JHARSUGUDA DISTRICT	
Ib-River Colliery	Opencast
Ib-Property Colliery	Opencast
Orient Colliery	Underground
Orient-III Colliery	Underground
Ib-Block 5^{th} Colliery	Opencast
Gandghora Colliery	Opencast
New-Gandghore Colliery	Opencast
N-W Block Gandghora Colliery	Opencast
Rampur Colliery	Underground
Belpahar	Opencast
Lilari	Opencast
Samaleswari	Opencast
Lakhanpur	Opencast
SUNDERGARH DISTRICT	
Basundhara	Opencast
Kulda	Opencast

3.6.6 DOMESTIC SOURCES

There are 44 urban local bodies in the basin in the below (Table) including some of the important cities and towns of Orissa like Bhubaneswar, Cuttack, Sambalpur, Puri, Paradeep. The estimated waste water discharge from the urban settlements in Mahanadi basin is about 345000m^3 per day. None of the places except Cuttack has any organized sewerage system or sewage treatment plant. Consequently most of the untreated domestic waste water finds its way to the riverine system, contributing a BOD loading of about 68.6 tons per day (Assuming the BOD concentration of sanitary waste water is 200 mg/l). Since the villages do not have any organized water supply or drainage system, the waste water generated almost totally absorbed in the soil.

Table 3.6.6.1 URBAN LOCAL BODIES IN MAHANADI BASIN IN ODISHA

DISTRICT	SL NO	ULB	POPULATION(2001 CENSUS)
Sundergarh	1	Sundergarh Muncipality	38402
Jhaarsuguda	2	Belpahar Municipality	32807
	3	Brajarajnagar Muncipality	76941
	4	Jharsuguda Muncipality	75570
Bragarh	5	Barpalli NAC	19154
	6	Baragarh Muncipality	63651
	7	Padampur NAC	15438
Sambalpur	8	Burla NAC	42806
	9	Hirakud NAC	26397
	10	Kuchinda NAC	13584
	11	Rairakhol NAC	13722
	12	Sambalpur Muncipality	157763
Nuapada	13	Khariar NAC	13402
	14	Khariar Road NAC	16627
Kalahandi	15	Bhawanipatna Muncipality	60745
	16	Junagarh NAC	15579
	17	Kesinga NAC	16914
Bolangir	18	Bolangir Muncipality	85203
	19	Kantabanjhi NAC	20090
	20	Patnagarh NAC	18685
	21	Titlagarh NAC	30251

Phulbani	22	Phulbani Muncipality	33887
Sonepur	23	Binika NAC	14537
	24	Sonepur Muncipality	17535
	25	Tarava NAC	7993
Boudh	26	Boudh NAC	17996
Nayagarh	27	Khandapada NAC	8754
	28	Nayagarh NAC	14311
Angul	29	Athamallick NAC	11383
Cuttack	30	Cuttack Muncipal Corporation	535139
	31	Athagarh NAC	15850
	32	Banki NAC	15987
	33	Choudwar Muncipality	52498
Khurda	34	Bhubaneswar Muncipal Corporation	657477
	35	Balugaon NAC	15824
	36	Jatani Mumcipality	57827
	37	Khurda Muncipality	39034
Puri	38	Konark NAC	15015
	39	Nimapara NAC	16914
	40	Pipili NAC	14263
	41	Puri Muncipality	157610
Kendrapada	42	Kendrapada Muncipality	41404
Jagatsinghpur	43	Jagatsinghpur Muncipality	30688
	44	Paradeep Muncipality	73633

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3.7 AGRICULTURAL SOURCES

The basin has 29 completed, 9 ongoing and 35 numbers of proposed major and medium irrigation projects. Besides these, there are 748 completed and 638 ongoing minor irrigation projects in the basin. The quantity of water used for irrigation in the Mahanadi basin is quite large. About 88% of the water utilized for irrigation is used by crops, held back as soil moisture and lost through evaporation and transpiration. The remaining 12% of the total water used for irrigation constitutes the runoffs. The waste water flow from agricultural sector in Mahanadi Basin is of the order of 2160 million m^3 per year of which the return water from Odisha portion is about 1564.34 million m^3 per year. A part of pesticides and nutrients applied as fertilizers gets washed or leached with agricultural return waters. The amount of nutrients so leached increase with the intensity of application of pesticides and fertilizers. Assuming the loss of N,P,K and pesticides as 10%,5% (Due to Lower Solubility), 10% and 5% respectively, their estimated concentration in return water due to application of fertilizers and pesticides is given in below.

Table 3.7.1 ESTIMATED CONCENTRATION IN RETURNS WATER ON APPLICATION OF FERTILIZER

COMPONENT	CONSUMPTION((T) /YEAR) (DURING 2010-2011)	ESTIMATED CONCENTRATION IN RETURN WATER(1564.34 MILLION M³/YEAR)(Mg/l)
N	135717.66	8.68
P	74919.09	2.39
K	41948.57	2.68
Pesticides	483	0.02

3.8 DATA COLLECTION:

3.8.1 WATER QUALITY MONITORING AND ASSESSMENT

The State Pollution Control Board, Orissa is monitoring the water quality of six rivers ie Mahanadi, Brahmani, Baitarani, Rusikulya, Nagavali and Subernarekha under the National water quality Monitoring Project (OPCB).The overall objectives of the water quality analysis are to

1. Assess the present water status.
2. Find out the water quality trend over a period of time.
3. Plan rational Water Quality Management.

3.8.2 WATER QUALITY MONITORING:

3.8.2.1 Water Quality Monitoring Stations:

Details of the monitoring stations along with the criteria for their selection are described in Table

Mahanadi

Monitoring Station	Approximate distance(km) from starting point in orissa	Latitude(E)	Longitude(N)	Frequency Of Monitoring	Criteria for location of monitoring station
Mahanadi					
Hirakud Reservoir	0	20º30´	84º51´	Quarterly	Multipurpose dam(Irrigation and Hydroelectricity)
Sambalpur U/S	5	21º30´	83º57´	Monthly	Intake point, major human settlement
Sambalpur D/S	15	21º30´	83º58´	Monthly	Impactct of industrial and municipal sewage discharge
Sonepur(U/S)	75	20º54´	83º50´	Quarterly	Downstream of confluence of major tributary(River Ong)
Sonepur(D/S)	85	20º50´	83º58´	Quarterly	Downstream of confluence of major tributary(River Tel) and municipal sewage discharge
Tikarpada	175	20º30´	84º50´	Quarterly	Crocodile breeding research centre and sanctuary
Narsinghpur	215	20º30´	84º51´	Quarterly	Thickly populated area with intensive agricultural practice.
Cuttack(U/S)	265	20º28´	85º50´	Monthly	Upstream of cuttack city
Cuttack(D/s)	275	20º28´	85º50´	Monthly	Impact of discharge from jagatpur Industrial Estate and municipal sewage discharge
Paradeep(D/S)		20º21´	86º42´	Quarterly	Impact of discharge from paradeep Industrial Area
Ib					

Sundergarh		22º06´	84º03´	Monthly	Intake point of major human settlement
Jharsuguda		21º54´	84º00´	Monthly	Impact point of industrial and mine discharge
Brajaraj nagar(U/S)		21º52´	83º00´	Monthly	Intake point of major human settlement
Brajaraj nagar(D/S)		21º50´	83º57´	Monthly	Impact of industrial discharge
Kathajodi					
Cuttack(D/S)		20º30´	85º51´	Monthly	Impact of discharge from cuutack Industrial Estate and municipal sewage discharge
Kuakhai					
Bhubaneswar(U/s)		20º12´	85º50´	Monthly	Water intake point of Bhubaneswar
Bhubaneswar(D/S)		20º10´	85º50´	Monthly	Impact of municipal sewage discharge
Birupa					
Choudwar		20º28´	85º50´	Quarterly	Impact of discharge from choudwar Industrial Area
Brahmani					
Panposh(U/s)	0	22º15´	84º30´	Monthly	Water quality of interstate river after confluence of sankh and koel and before any industrial activity in Orissa.
Panposh(D/s)	9	22º15´	84º48´	Monthly	Impact of industrial and municipal discharge from Rourkela
Rourkela(D/S)	13	20º58´	85º15´	Monthly	Water quality at further downstream of the major polluting source.
Bonaigarh	64	21º45´	85º00´	Quarterly	Water quality at further downstream of the major polluting source.
Rengali	114	21º30´	85º00´	Quarterly	A multipurpose dam

Samal	189	21º03´	85º10´	Quarterly	Samal Barrage,water intake,point of TSTPP,Kaniha
Talcher(U/S)	202	21º00´	85º28´	Quarterly	Water intake point of industries and mines.
Talcher(D/s)	219	20º55´	85º18´	Quarterly	Impact of industrial and municipal discharge.Downstream of the confluence of Nandira with brahmani.
Bhuban	279	20º50´	85º52´	Quarterly	A major human settlement with water intake point.
Dharmasala	335	20º40´	86º10´	Quarterly	Thickly populated area with intensive agriculture practice.
Pattamundai	390	20º30´	86º36´	Monthly	Thickly populated area with tidal effect.
Baitarani					
Joda	79	21º40´	85º40´	Quarterly	Major iron and manganese deposits of the state.
Anandpur	236	21º10´	86º10´	Quarterly	Major human settlement.
Jajpur	289	21º00´	86º10´	Quarterly	Mass bathing,religious importance.
Chandbali	345	20º47´	86º48´	Quarterly	Major human settlement, tidal impact.
Rushikulya					
Madhopur	168	19º37´	84º42´	Quarterly	Water intake point of chhatrapur and ganjam.
Potagarh	173	19º40´	84º40´	Quarterly	Impact of industrial activities, tidal effect
Nagavali					
Jaykaypur	35	19º13´	83º24´	Quarterly	Waste water discharge
Rayagada	45	19º10´	83º25´	Quarterly	Waste water discharge Rayagada town.
Subernarekha					
Rajghat	40	21º39´	87º19´	Quarterly	Interstate River

3.8.3 PARAMETERS:

The following water quality parameters are determined at all locations.
Physical parameters: Temperature, pH, Alkalinity, Total suspended solids (TSS).

Indicators Of Organic Pollution: Dissolved oxygen(DO), Bio-chemical Oxygen Demand(BOD),Chemical oxygen Demand(COD),Free ammonia nitrogen, Ammonical (Ammonium+Ammonia)-Nitrogen ,Total kjedhal Nitrogen(TKN)

Bacteriological parameters: Total colliform and fecal colliform

Mineral constituents: Eletrical conductivity (EC), Total Dissolved Solids(TDS), Boron, Sodium Absorption Ratio(SAR), Hardness, Chloride, Sulphate, Fluoride.

Nutrients: Nitrate(Nitrate+Nitrite)-Nitrogen, Phosphate-Phosphorous.

Metals and other toxic compounds: Chromium(Cr) (Total and HexavalentIron(Fe), Nickel(Ni),Copper(Cu),Zinc(Zn), Cadmium(Cd) ,Mercury(Hg), Lead(Pb), Cyanide(CN).

3.8.4 In terms of monitoring frequency the parameters are categorized as following:

Core Parameters: Monitored on regular basis at all the locations.

pH-	**:**	Biochemical Oxygen Demand
Temperature-	**:**	Ammonical-N
Conductivity-	**:**	Nitrate
Dissolved Oxygen-	**:**	Fecal coliform , Total colliform

3.8.5 General parameters: Monitored once in a year in summer season.

COD	:	Chloride
TKN	**:**	Sulphate
Total Dissolved Solids	**:**	Total Alkalinity
Total Suspended Solids	**:**	Phosphate
Hardness	**:**	Sodium
Fluoride	**:**	Potassium
Boron	**:**	Turbidity

3.8.6 Bio-Monitoring Prameters: Monitored on quarterly basis except during monsoon period.

Saprobity Index

Diversity Index

3.8.7 Trace Elements: Monitored once in a year in summer.

Chromium Total	**:**	Cadmium
Iron	**:**	Mercury
Nickel	**:**	Lead
Zinc	**:**	Cyanide

3.8.8 SIGNIFICANCE OF WATER QUALITY PARAMETERS:

PH, hardness, presence of a selected group of chemical parameters, biocides, highly toxic chemicals, and B.O.D are estimated.

PH is a measure of acidity. Neutral (neither acidic nor alkaline) water has a pH of 7. Water of low pH (less than 7 acidic) has the ability to dissolve many metals and carry their toxicity. Besides, highly acidic (low pH) or alkaline (high pH) nature of water may themselves be detrimental to certain vital biological processes.

It is a measure of hydrogen ion concentration. It is an indicator of relative acidity or alkalinity of water. Values of 9.5 and above indicate high alkalinity while values of 3 and below indicate acidity. Low pH values help in effective chlorination but cause problems with corrosion. Values below 4 generally do not support living organisms in the marine environment. Drinking water should have a pH between 6.5 and 8.5. Harbour basin water can vary between 6 and 9.

TSS: In water quality considerations, the term TSS is usually referred to larger settleable solids. Besides giving the problems in filtration and disinfection (the solids may prevent effective contact between the disinfecting agents and the target organism), TSS can adversely affect the fish population by any of the four means, namely by acting directly on the fish, preventing the successful development of fish eggs and larvae, modifying natural movement and migration of fish and reducing the abundance of food available to the fish. Use of water with a large amount of TSS for irrigation might leads to formation of crusts on top soil which inhibits water infiltration.

TSS ranged from 4.0 to 38.1.From yearly average it was found that TSS is in increasing order. It was also found that towards downstream TSS of water increases during rainy seasons and show higher values compared to summer and winter. This may be due to addition of waste along with rain water.

TDS: The TDS ranged from 48 to 136. From yearly average it was clear that the TDS value is in increasing trend. All the stations during summer show higher values compared to rainy and winter seasons. This may be due to low water level of river during summer month. It is clear the upstream of the river is free from municipal sewage contamination exhibit lower TDS values compared to stations at downstream. There was a sharp rise in the TDS value at downstream which receive the municipal sewage directly.

Alkalinity: The alkalinity of water is a measure of its capacity to neutralize acids. Except at very high pH (greater than about 9.5), the alkalinity of natural waters can be assigned entirely to dissolved bicarbonates and carbonates without serious error, unless associated with petroleum or natural gas or high dissolved carbon. As far as is known, alkalinity of water has little public health significance except that highly alkaline waters are usually unpalatable. Alkalinity in industrial water supplies is desirable because water with high alkalinity is much less corrosive. However high alkalinity is not desirable for industries involved in food production.

The Alkalinity of the water samples ranged in-between 35 to 68. From yearly average it was found that in all the stations the alkaline increases. There is sudden increase of alkaline value during rainy seasons in all stations; it may be due to addition of waste water along with rain water.

Biochemical Oxygen Demand (BOD): Most industrial and municipal wastes contain high concentrations of organic substances. Their presence encourages the growth of decomposers, which consume large quantities of oxygen. The amount of dissolved oxygen needed by decomposers to decompose organic materials in a volume of waste water is called Biochemical Oxygen demand. Thus BOD is a measure of the contamination of waste water.

It denotes the amount of oxygen needed by micro-organisms for stabilization of decomposable organic matter under aerobic conditions. High B.O.D. means that there is less of oxygen to support life and indicates organic pollution.

The BOD of water samples varied between 2.0 to 6.8.Yearly average shows BOD increases from the year 2000 to 2010. All the stations show a sudden hike of BOD in summer. However the stiffness of the hike decreased to a large extent during rainy seasons. The BOD value of water increases manifold towards downstream indicating that the water is grossly polluted by organic matter. The problem was acute during summer seasons as the metabolic activities of various aerobic and anaerobic microorganisms accelerated with the increase in water temperature.

COD: Besides, organic matter, the waste water may also contain chemicals that are susceptible to reaction with oxygen (oxidation). The extent of pollution due to these substances is expressed in terms of Chemical Oxygen demand (COD).

The COD of water samples varies from 9.0 to 26.0.Yearly average shows COD increases from the year 2000 to 2010. All the stations show a sharp hike in summer. However the values are decreased to a large extent during rainy season.

DO: Dissolved oxygen concentration in fresh water averages about 0.001% (10ppm) by weight, which is 40 times less than the weight of oxygen in an equivalent volume of air. While the concentration of oxygen in air varies little, the amount of DO in aquatic ecosystems varies widely, depending upon various factors. The aesthetic qualities of water require sufficient dissolved oxygen to avoid the onset of septic conditions with their attendant malodorous emissions. Insufficient DO in the water columns causes anaerobic decomposition of many organic materials present. Such decomposition tends to cause the formation of noxious gases such as hydrogen sulphide and methane, in addition to carbon dioxide. Traditionally, the waste treatment requirement was based on the removal of oxygen demanding materials so as to maintain the dissolved oxygen concentration in receiving waters at prescribed levels.

The DO content of water samples varies from 5.0 to 7.8 mg/l. From yearly average it was found that there is slight decrease in DO content from the year 2000 to 2014. Sudden depletion of DO was found during summer. There was a sudden depletion of DO and it continues till the last station.

Phosphate: Phosphates may enter into water bodies from human and animal excreta, runoffs from agricultural fields using phosphatic fertilizers and some industrial effluents. Excess phosphate may induce excessive plant growth leading to eutrophication and interfere with coagulation in water treatment plants.

The PO_4^{3-}concentration of water samples varies between 0.01 to 1.48 mg/l, Yearly average shows the phosphate content of water bodies is in increasing order from the year 2009 to 2010. The values obtained at stations located at upstream were lower compared to other stations.

Iron: Average abundance of iron in earth's crust is 6.22%, in soil it varies within the range 0.5 to 4.3%, in stream water is 0.7 mg/l and in ground water it varies within the range 0.1 to 10 mg/l. iron is an essential trace element required by both plants and animals. Major iron polluting sources are industrial wastes, mine draining waters and iron bearing ground water. Though the daily nutritional requirement for iron is 1-2 mg, excessive presence of iron is objectionable in water supplies, since it affects taste, stain clothes and plumbing fixtures. High concentrations in natural waters affect aquatic life.

The iron content of water samples varies from 1.8 to 4.8 mg/l. Higher values were observed during rainy seasons. Iron content in water bodies are in increasing order from the year 2000 to 2014. Enrichment of iron at downstream during rainy seasons might be attributed of stratified condition in the water which was enriched with organic matter under depleted oxygen conditions. Under this condition Fe2+ can be retained in water up to parts per million levels (Livingstone, 1963). The iron content can also be influenced by aquatic vegetation.

Chloride: Chlorides occur in all natural waters in widely varying concentrations. Water bodies may also receive chlorides through discharge of industrial effluents. Chlorides in reasonable concentrations are not harmful to humans. At concentrations above 250 mg/l they give a tasty to water, which is objectionable to many people. For this reason, chlorides are generally limited to 250 mg/l in supplies intended for public use. In many areas of the world where water supplies are scarce, sources containing as much as 2000 mg/l are used for domestic purposes without development of adverse effects once the human system becomes adapted to the water. Although chloride is essential for plants in low amounts, it can cause toxicity to certain crops at high concentrations.

The chloride content of water samples varied from 3.9 to 28.4 mg/l . From yearly average it was found that the chloride content is in increasing order. Maximum concentration was found during summer seasons. The stations located upstream recorded lower values compared to other stations may be due to the water at this stations are relatively free from anthropogenic activities. But towards downstream the value increases due to dumping of untreated waste water.

Nitrate: Nitrate can enter into water bodies through municipal, industrial waste waters and sewage discharges. In natural waters high nitrate may induce eutrophication. Nitrates at reasonable concentrations are rapidly excreted in the urine. High intake of nitrate, however, is a health hazard, under conditions that are favourable to their reduction of nitrite in the gastrointestinal tract, which then reacts with blood stream to produce met hemoglobin with consequent impairment of oxygen transport.

The concentration of NO^{3-}ion in water samples varies from 0.34 to 3.8 mg/l. Yearly average values shows the NO^{3-} concentration of water increases from the year 2000 to 2014. The samples collected in rainy seasons registered the maximum concentration of the ions. The variation in NO_3^- concentrations among the stations were less in the rainy season compared to winter and summer seasons.

Sulphate: sulphate ion is one of the major anions which occur in natural water. It is important in public water supplies because of its cathartic effects upon human when it is presented in excess amounts. For this reason the recommended upper limit is 200 mg/l in waters intended for public consumption. Sulphates are important in both public and industrial water supplies because of the tendency of water containing appreciable amounts to form hard scales in boilers and heat exchangers. Sulphates are also concern because they are indirectly responsible for two serious problems often associated with the handling and treatment of waste waters. These are odour and sewer corrosion problems resulting from reduction of sulphates to hydrogen sulphide under anaerobic conditions.

The sulphate content of the water samples varies from 1.4 to 6.6 mg/l during the study period. From yearly average it was noticed that the SO_4^{2-} concentration was in increasing order from the year 2009 to 2010. Summer and winter recorded less concentration compared to rainy season. The SO_4^{2-}concentration increases rapidly towards downstream.

SO_4^{2-} + Organic Matter $\Rightarrow S^{2-} + H_2O + CO_2$

$S_2^{-} + 2H^{+} \rightarrow H_2S$

TH: The hardness of the water samples varied from 24 to 69 mg/l during the study period. Yearly average shows that total hardness is in increasing order from the year 2009 to 2010. Higher values were recorded during rainy seasons. Slight increase in the values noticed at summer season, but no remarkable variation was observed among rest of the stations. The difference was found to be very prominent during the rainy season.

TC (Total Colliform Count): A wide range of pathogenic micro organisms are potentially transmittable to man through drinking and bathing. The coliform group of bacteria includes micro organisms of diverse characteristics-16 groups comprising of 256 species, which by physical and biochemical laboratory procedures are found to fit in the domain of coliform classification. In addition to groups and species which originate from the intestinal tract of human and other warm blooded animals, there are other types of coliform bacteria that are not derived from sewage or body wastes. The accepted standard tests for bacterial contamination of water involves the determination of the indicator organism the colliform group of bacteria as a whole (Total Coliform Count).Thus at present total coliform is taken as an indicator of the bacterial contamination and fecal coliform as the indicator of fecal contamination of water.

The TC count of the water samples varied from 440 to 22,000 per 100 ml during study period.. From yearly average it was found that TC counts were in increasing order from the year 2009 to 2010. There was an increase towards downstream throughout the year. The stations which were located at upstream showed very less counts during winter season.

FC (Fecal colliform): The FC of water samples varied from 80 to 11,000 per 100 ml during study period. Yearly average shows the FC counts were in increasing order from the year 2009 to 2010. There is sudden increase in the value towards downstream in all seasons. All the stations during rainy seasons showed higher counts compared to other seasons.

Ammonia: Ammonia is present in most waters as a normal biological degradation product of nitrogenous organic matter. Some industrial effluents also contain ammonia. Ammonia is known to be toxic to fishes and the toxicity varies with the pH of the water. In most natural waters, the pH range is such that the ammonium fraction of ammonia predominates. However in highly alkaline waters, the free ammonia fraction can reach toxic levels. Lethal concentrations of ammonia for a variety of fish species are in the range of 0.2 to 2.0 mg/l.

Total Kjeldahl Nitrogen(TKN): TKN values are more important for stagnant water, since higher TKN values indicate a potential for eutrophication or higher level of ammonia in water, which may be toxic.

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Boron(B): Although an essential element for plant growth, boron in excess of 2 mg/l in irrigation water, it becomes toxic for most of most of the field crops, affecting the metabolic activities of the plant.

Sodium Absorption Ratio(SAR): SAR gives the concentration of sodium, relative to the concentrations of calcium and magnesium and is a guide to judge the sodium hazards of irrigation water. SAR is calculated as per the procedure given in IS: 2296-1982.

SAR= (A*1.414)/(B+C)½

Where A, B and C are respectively the sodium, calcium and magnesium contents in milli quivalents per litre.

Hardness: Hardness is caused by divalent metallic cations. Such ions are capable of reaction with certain anions present in the water to form scales. The principal hardness causing cations are calcium, magnesium, strongtium, ferrous and maganous ions. The important anions with which they are usually associated are bicarbonate, sulphate, chloride, nitrate and silicates. Waters are commonly classified in terms of the degree of hardness as follows:

Hardness (Mg/l)	Degree of Hardness
0-60	Soft
61-120	moderately hard
121-180	Hard
More than 180	Very hard

Lead: Average abundance of lead in earth's crust is 13 ppm; in soil it varies within the range 2.6-25ppm, in stream water is 3 microgram/l and in ground water less than 1 mg/l. Lead has no beneficial or desirable nutritional affects. It is a toxic metal that tends to accumulate in the tissues of man and other animals. The common symptoms of lead poisoning are anemia, paralysis of nerves etc.

Lead is the main toxin causing problems in Flint. Corroded pipes are releasing up to ten times the allowable amount of lead into the water. Lead is toxic to almost every organ and affects children the worst. Developmental issues, stunted growth, deafness, behavioral problems, learning disabilities, and brain damage can all result from exposure to lead. If ingested during pregnancy, lead can cause premature birth. Lead exposure has even been linked to autism, prostate cancer, and reproductive problems for both men and women. It's damaging to the cardiovascular system and kidneys, too.

Cadmium: Average abundance of cadmium in earth's crust is 0.16 ppm; in soil it varies within the range 0.1 to 0.5 ppm, in stream water is 1 microgram/l and in ground water it varies within the range 1 to 10 microgram/l. Cadmium is toxic to man when ingested or inhaled. Drinking water containing excess cadmium leads to a disease called itai-itai, characterized by rheumatic symptoms with intense pain in the bones caused by a loss of bone minerals.

Mercury: Average abundance of cadmium in earth's crust is 0.09 ppm; in soil it varies within the range 30-60 ppb, in stream water is 0.07 microgram/l and in ground water it varies within the range 0.5 to 1 microgram/l. Mercury may be found in the surface waters through discharge of effluents from industries using mercury (e.g. electrolytic methods using mercury cell). Biologically it is nonessential or non-beneficial element. Its high toxic potential is known since a long time. Symptoms of mercury poisoning include pharyngitis, vomiting followed by ulcerative hemorrhage, hepatitis and circulatory collapse.

Although mercury is a naturally occurring element, "natural" does not mean "safe." Mercury is extremely toxic and can cause brain damage, blindness, nerve damage, cognitive disability, impairment of motor functions, headaches, weakness, muscle atrophy, tremors, mood swings, memory loss, and skin rashes. A byproduct of mining and industrial practices, mercury vapor can linger in the atmosphere and ride the winds halfway around the globe.

Chromium: Chromium is found in air, soil, some foods and most biological systems and is a essential trace element for humans. It is rarely found in natural waters. Average abundance of chromium in earth's crust is 122 ppm ; in soil it varies within the range 11 to 22 ppm , in stream water is 1 microgram/l and in groundwater it varies within the range 100 microgram/l. However its effect as an essential element is restricted to its trivalent stage. Hexavalent chromium on the other hand is irritating and corrosive to mucous membrane, it is absorbed via ingestion through the skin and by inhalation. Lung cancer, ulceration, variety of respiratory complications and skin affects has been observed with hexavalent chromium. Hexavalent chromium in appreciable quantities is found in the chromite mine discharge waters and the effluents of chromium based industries.

Iron: Average abundance of iron in earth's crust is 6.22%, in soil it varies within the range 0.5 to 4.3 %, in stream water is 0.7 mg/l and in ground water it varies within the range 0.1- 10 mg/l, iron is an essential trace element required by both plants and animals. Major iron polluting sources are industrial wastes, mine drainage waters and iron bearing ground water. Though the daily nutritional requirement for iron is 1-2 mg, excessive presence of iron is objectionable in water supplies, since it affects taste, stain clothes and plumbing fixtures. High iron concentrations in natural waters affect aquatic life.

Iron can be a troublesome chemical in water supplies. Making up at least 5 percent of the earth's crust, iron is one of the earth's most plentiful resources. Rainwater as it infiltrates the soil and underlying geologic formations dissolves iron, causing it to seep into aquifers that serve as sources of groundwater for wells. Although present in drinking water, iron is seldom found at concentrations greater than 10 milligrams per liter (mg/l) or 10 parts per million. However, as little as 0.3 mg/l can cause water to turn a reddish brown color. Iron is mainly present in water in two forms: either the soluble ferrous iron or the insoluble ferric iron. Water containing ferrous iron is clear and colorless because the iron is completely dissolved. When exposed to air in the pressure tank or atmosphere, the water turns cloudy and a reddish brown substance begins to form. This sediment is the oxidized or ferric form of iron that will not dissolve in water.

Nickel: Average abundance of nickel in earth's crust is 1.2 ppm and in soil it remains within 2.5 ppm. Nickel can occur as a leachate from nickel bearing ores and does not normally occur in natural waters. However, in stream water it may remain within 1 microgram/l and in groundwater it varies within the range 100 microgram/l. Nickel in excess amount is toxic to plants and certain types of aquatic life.

Nickel can occur as a leachate from nickel bearing ores and does not normally occur in natural waters. Nickel in excess amount is toxic to plants and certain types of aquatic life.

Copper: Average abundance of nickel in earth crust is 68 ppm and in soil it remains within 9-33 ppm. In stream water it ranges from 4 to 12 microgram/l and in ground water it remains below 0.1mg/l.

Copper is an essential trace element for propagation of plants and performs vital functions in several enzymes and plays a major role in synthesis of chlorophyll. Concentration of copper as found in natural waters is not known have to any adverse effect on humans. However long oral administration of excess quantities of copper may result in liver damage. Excess copper is also toxic to aquatic life.

Zinc: Average abundance of zinc in earth's crust is 76 ppm. In soil it varies within the range 25-68 ppm, in stream water it remains within 20 microgram/l and in ground water it remains below 0.1 mg/l.

Industrial effluents (Galvanizing, Electroplating etc) are the major sources of zinc in natural waters. Zinc is an essential and beneficial element in human metabolism. However under certain conditions dissolved oxygen and temperature, zinc can be toxic to aquatic life.

Cyanide: Cyanide is one of the simplest and most readily formed organic moieties. Cyanides and compounds of cyanide are almost universally present where life and industry are found. Besides being very important in a number of manufacturing processes, they are found in many plants and animals as metabolic intermediates which generally are not stored for long periods of time. Cyanide toxicity is essentially an inhibition of oxygen metabolism i.e. rendering the tissues incapable of exchanging oxygen.

3.9. WATER QUALITY ASSESSMENT

3.9.1 Use Based Water Quality Status

Meaningful evaluation of water quality status requires that the quality be viewed in the context of the uses which the society wishes to make of the stream, each of which requires special characteristics.

Table 3.9.1.2 Use Based Classification

Class	Use
A	Drinking water source without conventional treatment but after disinfection.
B	Organized outdoor bathing.
C	Drinking water source with conventional treatment followed by disinfection.
D	Fish culture and wildlife propagation.
E	Irrigation, Industrial cooling or controlled waste disposal.

3.9.2 Water Quality parameters relevant to the above uses are described in IS:2296/1982

In this report classification of river water is discussed in respect of those parameters considered to be of primary concern for the designated best use. These primary water quality criteria are derived from the criteria developed in other parts of the world namely USA, UK, Germany and Japan.

3.9.3 Water Quality in respect of primary criteria

The primary water quality criteria for the aforementioned use based classes are given in Table. Even with this restriction in parameters, classification based on one of them, may or may not necessarily by the same on the basis of other parameters. In such cases, the lowest classes indicated by one of the parameters should normally be viewed as the overall water quality status at the particular site.

Table 3.9.3.1 Primary Water Quality Criteria

PARAMETER	QUALITY CRITERIA				
	CLASS A	CLASS B	CLASS C	CLASS D	CLASS E
PH	6.5-8.5	6.5-8.5	6.5-8.5	6.5-8.5	6.5-8.0
DO(mg/L) Minimum	6.0	5.0	4.0	4.0	-
BOD(Mg/l) Maximum	2.0	3.0	3.0	-	-
TC(MPN/100)Max	50	500	5000	-	-
Free Ammonia-N (Mg/L) Max	-	-	-	1.2	-
EC(microSiemens/cm)	-	-	-	1000	2250
SAR Max	-	-	-	-	26
B(mg/l) Max	-	-	-	-	2.0

3.9.4 WATER QUALITY IN RESPECT OF OTHER PARAMETERS

Table 3.9.4.1 Tolerance limits for other parameters:

PARAMETER	TOLERANCE LIMITS(Mg/L)				
	CLASS A	CLASS B	CLASS C	CLASS D	CLASS E
TDS	500	-	1500	-	2100
HARDNESS (As $Caco_3$)	300	-	-	-	-
CHLORIDE	250	-	600	-	600
SULPHATE	400	-	400	-	1000
FLUORIDE	1.5	1.5	1.5	-	-
NITRATE (As NO_3)	20	-	50	-	-
Pb	0.10	-	0.10	-	-
Cd	0.01	-	0.01	-	-
Hg	0.001	-	-	-	-
Cr (VI)	0.05	0.05	0.05	-	-
Fe	0.3	-	50	-	-
Cu	1.5	-	1.5	-	-
Zn	15	-	15	-	-
CYANIDE	0.05	0.05	0.05	-	-

3.9.5 BIOLOGICAL ASSESSMENT OF WATER QUALITY:

Biological assessment is based on the fact that pollution of water bodies will cause changes in the physical and chemical environment of water which in turn will disrupt the ecological balance of the ecosystem. Through bio-monitoring, the cumulative effects of all the pollutants can be determined and the overall health of the ecosystem can be properly assessed.

Bio-monitoring results are generally expressed in terms of two indices namely the saprobic index (SI) and Diversity Index (DI). Determination of SI involves preparation of an inventory of the presence of benthic macro-in vertebrae fauna up to the family level with taxonomic precision and expressing the SI on a scale of 1-10. The methodology for DI involves pair-wise comparison of sequentially encountered benthic individuals up to the species level. The diversity is the ratio of total number of different animals (runs) and the total number of organisms encountered. The DI has a value between 0-1.The criteria used for classification of water quality on the basis of biological indicators are given in the Table(Environment Atlas of India, CPCB,2011).

3.9.5.1 WATER QUALITY IN TERMS OF WHOLESOMENESS

The basic objective of the water (Prevention and Control of pollution) Act,1974, which governs the water quality management in the country is to provide for the prevention and control of water pollution and maintaining or restoring the wholesomeness of water. Since the act does not define the level of “wholesomeness” to be maintained or restored, the CPCB linked wholesomeness to the quality are required by humans. Criteria were developed for different uses which were used as the Indian standards by the Indian Standards Institution later named as Indian Standards.

Over the years it was felt that the designated use concept with the objective protecting the direct beneficial uses to humans and classifying water quality accordingly needs to be reviewed and wholesomeness should incorporate an overall integrated view of the water ecosystem. The first priority in water quality assessment and management should be to maintain and restore to a desirable level of its environmental quality. Accordingly specific requirements for “Acceptable”, Desirable and Excellent” Levels of wholesomeness with short medium and long terms goals have been laid down(Water Quality-Criteria and Goals, CPCB,MINARS/17/2001/2002).

3.9.5.2 Parameters for the above classifications are grouped in three categories

1. Simple parameters (Sanitary Surrounding, General Appearance, Colour, Smell, Transparency, Presence of fish and insects)

2. Regular monitoring parameters.

3. Special parameters to be monitored when need or apprehensive arise.

3.9.5.3. Wholesomeness in terms of Regular Parameters

The requirements in respect of regular monitoring parameters for different classes are given in Table 2.6.

1. **Wholesomeness in terms of special parameters**

Acceptable limits for the special parameters that are relevant to the present study are given in Table 2.7.

Table 3.9.5.3 STANDARDS FOR REGULAR MONITORING PARAMETERS

SL NO	PARAMETER	REQUIREMENTS		
		EXCELLENT	DESIRABLE	ACCEPTABLE
1	pH	7.0-8.5	6.5-9.0	6.5-9.0
2	DO(% SATURATION)	90-110	80-120	60-140
3	BOD(MG/L)	Below 2	Below 5	Below 8
4	EC(micro mhos/cm)	< 1000	< 2250	< 4000
5	(Nitrite+ Nitrate)-N(mg/l)	< 5	< 10	< 15
6	Suspended solids (mg/l) (Non monsoon)	< 25	< 50	< 100
7	FC(MPN/100)	< 20	< 200	< 2000
8	BIO ASSAY(ZEBRA FISH)	No death in 5 days	No death in 3 days	No death in 2 days

Table 3.9.5.4 STANDARDS FOR SPECIAL PARAMETERS:

SL NO	PARAMETER (MG/L)	REQUIREMENT, MAX		
		EXCELLENT	DESIRABLE	ACCEPTABLE
1	TOTAL PHOSPHOROUS	0.1	0.2	0.3
2	TKN	1.0	2.0	3.0
3	(AMMONIUM+AMMONIA)N	0.5	1.0	1.5
4	ZINC	0.1	0.2	0.3
5	NICKEL	0.05	0.10	0.20
6	COPPER	0.02	0.05	0.10
7	CHROMIUM (TOTAL)	0.02	0.05	0.10
8	LEAD	0.02	0.05	0.10
9	CADMIUM	0.001	0.0025	0.005
10	MERCURY	0.0002	0.0005	0.001

3.9.6 WATER QUALITY IN TERMS OF COD AND ALKALINITY:

The two water quality classification schemes described earlier (use based and quality in terms of wholesomeness) do not stipulate any standard for COD and Alkalinity.
Some European Countries prescribe a maximum limit for COD as 20 and 25 mg/l for water quality to be classified as “Excellent” and “Good” respectively. In India the maximum permissible limit for COD for an industrial effluent to be discharged into inland surface water is 250 mg/l , under the Environment Protection Act. Hence even in the Indian Context. It is perhaps reasonable to assume that a COD concentration of 25 mg/l or less , may be the desirable limit in a water body, since discharge standards are generally based on the assumption of ten times dilution.

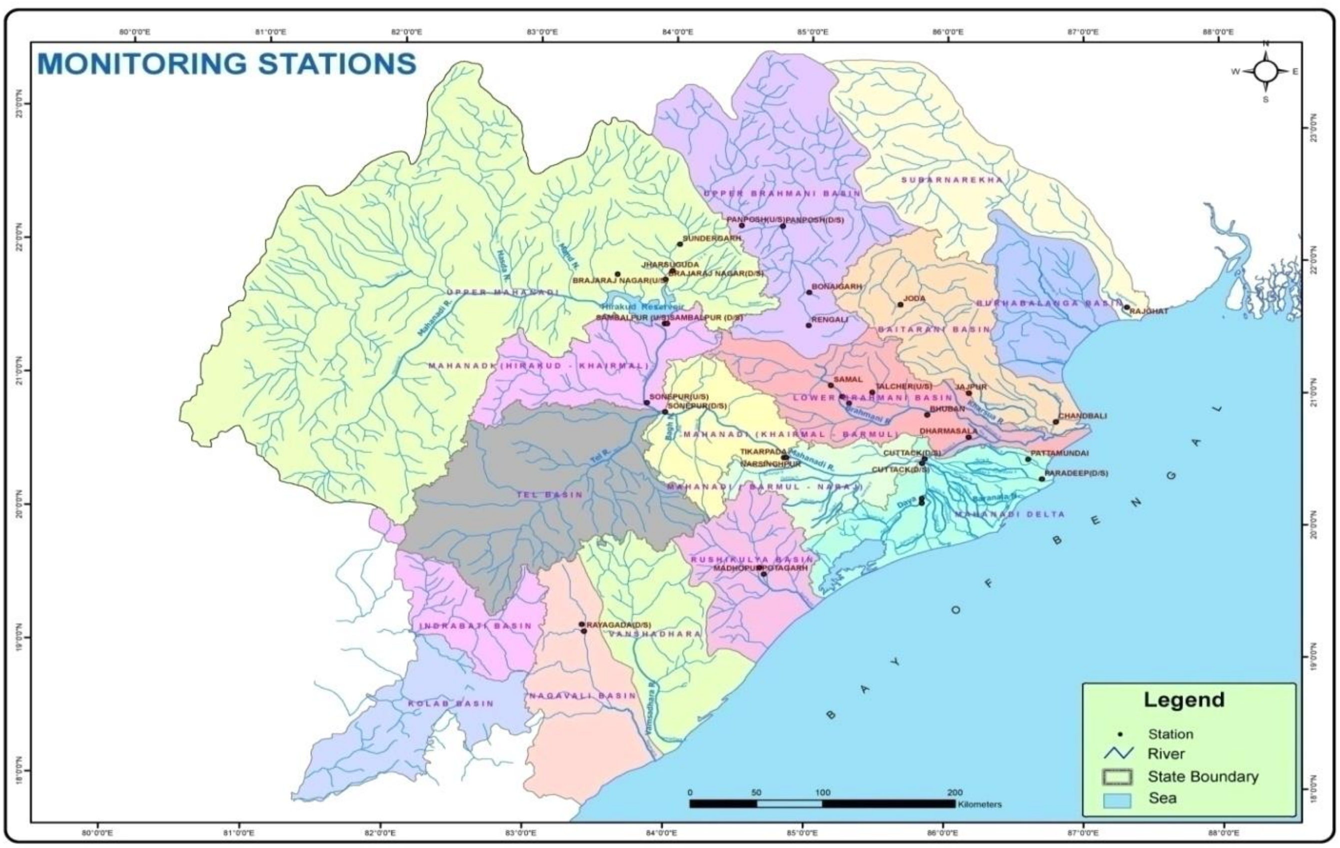
Alkalinity of natural water should be more than 20 mg/l (as $CaCo_3$) for aquatic life, unless natural concentration are less. Maximum alkalinity in water as a source of supply to many industries prior to treatment range from about 120-500 mg/l (as calcium carbonate). However for bottled and canned soft drink industries, the alkalinity should not exceed 85 mg/l.

Table3.9.8 CONVERSION OF LATITUDE AND LONGITUDE INTO DECIMAL DEGREES

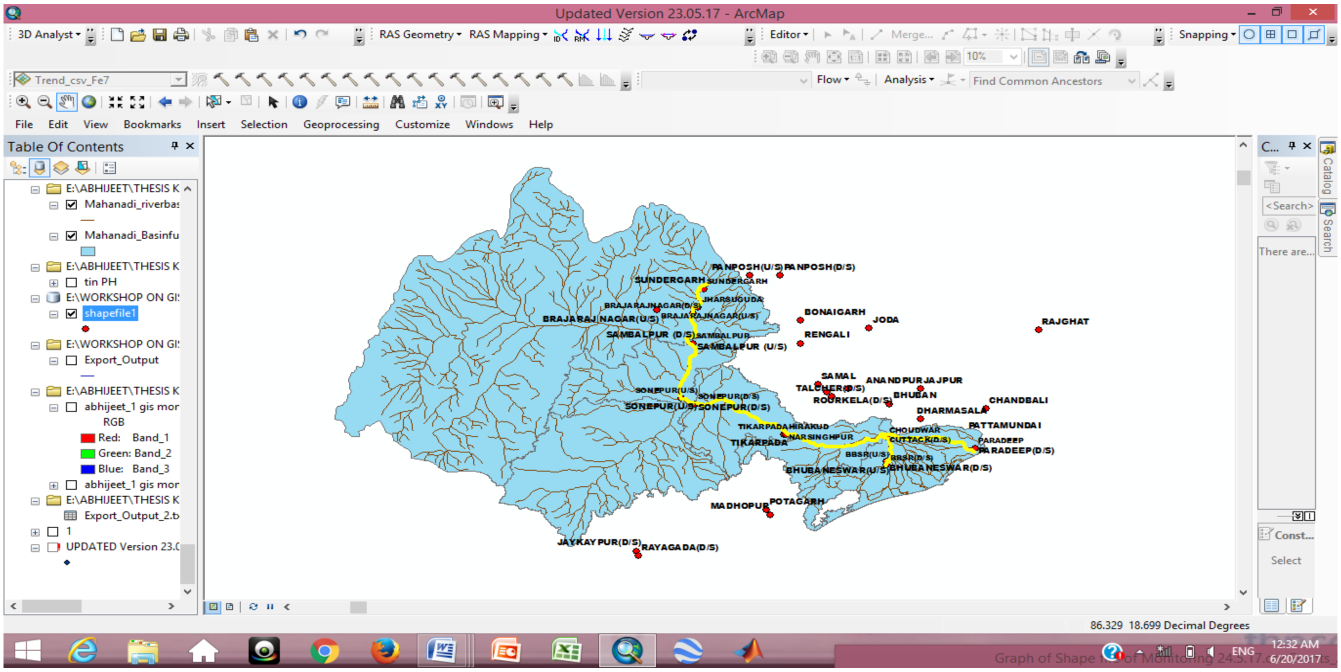
MONITORING STATIONS	APPROXIMATE DISTANCE(KM)	LAT(D)	LAT(M)	LAT D.D	LONG(D)	LONG(M)	LONG(D.D)
[MAHANADI]							
HIRAKUD RESERVOIR	0	20	30	20.5	84	51	84.85
SAMBALPUR (U/S)	5	21	30	21.5	83	57	83.95
SAMBALPUR (D/S)	15	21	30	21.5	83	58	83.966667
SONEPUR(U/S)	75	20	54	20.9	83	50	83.833333
SONEPUR(D/S)	85	20	50	20.833	83	58	83.966667
TIKARPADA	175	20	30	20.5	84	50	84.833333
NARSINGHPUR	215	20	30	20.5	84	51	84.85
CUTTACK(U/S)	265	20	28	20.467	85	50	85.833333
CUTTACK(D/S)	275	20	28	20.467	85	50	85.833333
PARADEEP(D/S)		20	21	20.35	86	42	86.7
[IB]				0			0
SUNDERGARH		22	6	22.1	84	3	84.05
JHARSUGUDA		21	54	21.9	84	0	84
BRAJARAJ NAGAR(U/S)		21	52	21.867	83	36	83.6
BRAJARAJ NAGAR(D/S)		21	50	21.833	83	57	83.95
[KATHOJODI]				0			0
CUTTACK(D/S)		20	30	20.5	85	51	85.85
[KUAKHAI]				0			0
BHUBANESWAR(U/S)		20	12	20.2	85	50	85.833333
BHUBANESWAR(D/S)		20	10	20.167	85	50	85.833333
[BIRUPA]				0			0
CHOUDWAR(D/S)		20	28	20.467	85	50	85.833333
[BRAHMANI]				0			0
PANPOSH(U/S)	0	22	15	22.25	84	30	84.5
PANPOSH(D/S)	9	22	15	22.25	84	48	84.8
ROURKELA(D/S)	13	20	58	20.967	85	15	85.25
BONAIGARH	64	21	45	21.75	85	0	85
RENGALI	114	21	30	21.5	85	0	85
SAMAL	189	21	3	21.05	85	10	85.166667
TALCHER(U/S)	202	21	0	21	85	28	85.466667
TALCHER(D/S)	219	20	55	20.91	85	18	85.3
BHUBAN	279	20	50	20.833	85	52	85.866667

DHARMASALA	335	20	40	20.667	86	10	86.166667
PATTAMUNDAI	390	20	30	20.5	86	36	86.6
[BAITARANI]				0			0
JODA	79	21	40	21.667	85	40	85.666667
ANANDPUR	236	21	0	21	86	10	86.166667
JAJPUR	289	21	0	21	86	10	86.166667
CHANDBALI	345	20	47	20.783	86	48	86.8
[RUSHIKULYA]				0			0
MADHOPUR	168	19	37	19.617	84	42	84.7
POTAGARH	173	19	40	19.667	84	40	84.666667
[NAGAVALI]				0			0
JAYKAYPUR(D/S)	35	19	13	19.217	83	24	83.4
RAYAGADA(D/S)	45	19	10	19.167	83	25	83.416667
[SUBERNAREKHA]				0			0
RAJGHAT	40	21	39	21.65	87	19	87.316667

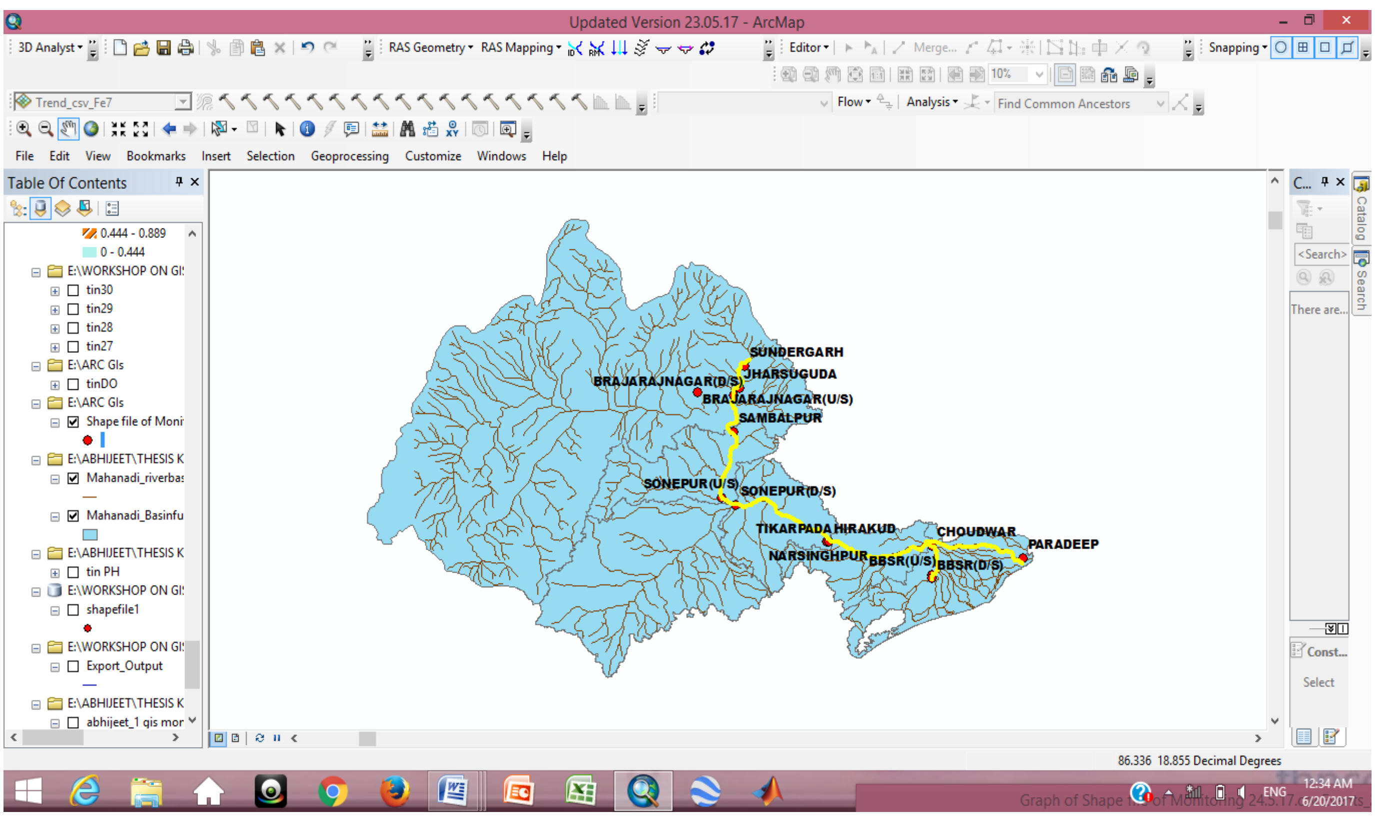
Fig. 3.9.8.1 <u>PLOTTING OF RIVER BASIN MAP OF ODISHA USING GIS APPLICATION</u>



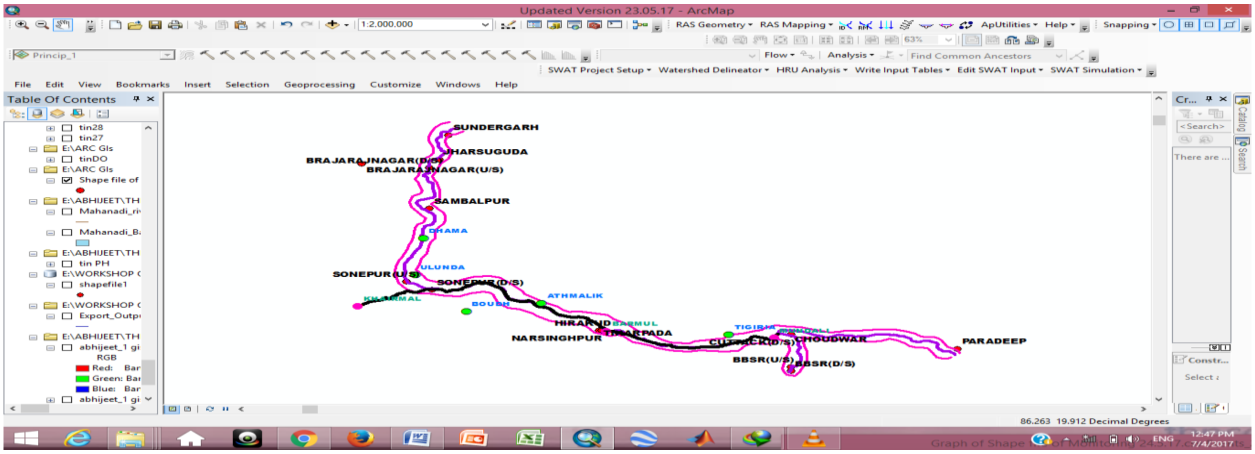
3.9.8.2 PLOTTING OF MONITORING STATIONS ON RIVER MAP OF ODISHA



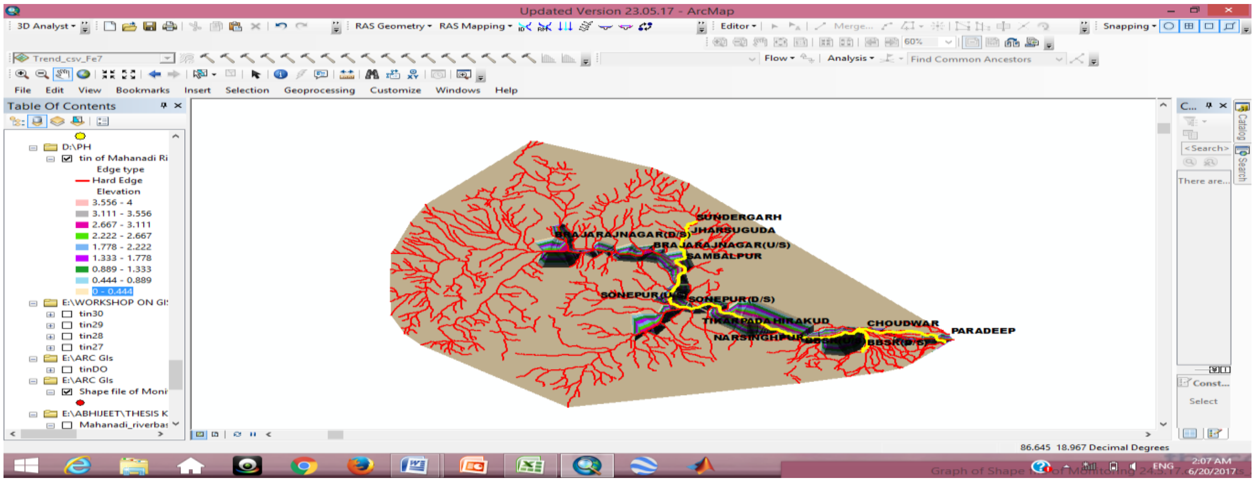
3.9.8.3 PLOTTING OF MONITORING STATIONS ON MAHANADI RIVER BASIN:



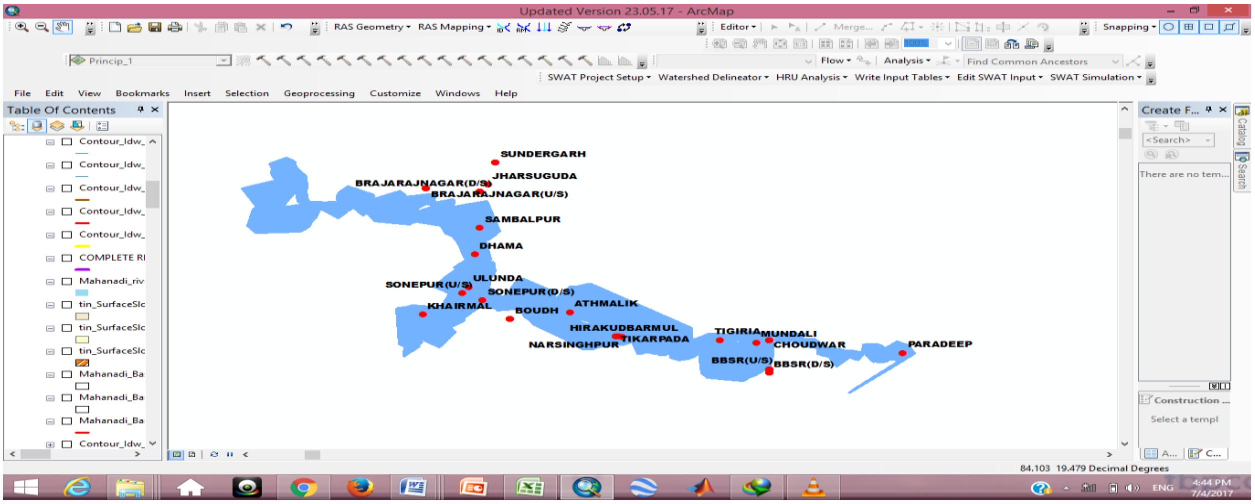
3.9.8.4 FLOW PATH OF MAHANADI RIVER BASIN



3.9.8.5 TIN OF MAHANADI RIVER BASIN



3.9.8.6 TIN SURFACE CONTOUR OF MAHANADI RIVER BASIN



3.9.8.7 DATA COLLECTION OF WATER QUALITY PARAMETERS OF MAHANADI BASIN OF YEAR 2000-2014

Out of all the basin information, we have concentrated our study to Mahanadi basin (Downstream of Hirakud only). Here is the table below which describes about the yearly average data collected of all the parameters of water quality of Mahanadi basin in the year 2000-2014.

YEARLY AVERAGE VALUES OF MONITORING STATIONS OF MAHANADI BASIN:

STATIONS	PH	DO	BOD	TC	EC	NO_3	TSS	ALKALINITY	COD	NH_4-N	FREE NH_3	TKN	SAR	TDS	TH	CL_2	SO_4^{2-}	F	FE
HIRAKUD	7.77	7.68	1.273	1561.4	178.15	2.5	33.272	81.27	8.36	0.53	0.0233	3.86	0.44	109.81	74.18	9.5	7.01	0.321	0.927
SAMBALPUR	7.77	7.64	1.606	3690.4	183.1	3.04	29.09	83.36	11.71	0.61	0.0269	7.87	0.46	86.54	75.81	10.79	7.36	0.318	0.874
SONEPUR(U/S)	7.8	7.73	1.34	1212.4	186.6	2.15	28.63	88.18	9.39	0.51	0.0209	3.89	0.49	122.45	82.27	14.9	6.3	0.324	0.597
SONEPUR(D/S)	7.866	7.73	1.906	3418.65	218.4	2.367	29.9	97	13.25	0.62	0.0317	5.45	0.505	137.18	86.81	10.76	7.14	0.362	0.934
TIKARPADA	7.8	7.66	1.389	1874.4	197.86	2.5	35.54	87	9.47	0.53	0.0273	5.65	0.53	143.81	77	10.72	6.89	0.302	1.33
NARSINGHPUR	7.81	7.72	1.346	3608.93	191.24	2.15	30.36	91.54	10.3	0.55	0.0249	5.45	0.472	131.818	75.81	10.4	6.82	0.349	1.34
CUTTACK(U/S)	7.88	7.8	1.497	2324.53	177.66	1.85	31.45	77.72	9.86	0.72	0.0344	3.84	0.509	126.63	73.81	10.95	8.68	0.363	1.58
CUTTACK(D/S)	7.86	7.21	2.68	32942.66	194.71	2.59	42.9	86	19.52	0.71	0.0375	6.05	0.533	135.27	82	13.009	8.44	0.349	1.33
PARADEEP	7.95	7.17	1.91	9637.13	7942.2	3.51	76.09	106.09	14.58	0.57	0.0232	11.069	22.66	13081.82	2158.9	5013.282	364.7	0.656	2.38
SUNDERGARH	7.73	7.79	1.372	1851.73	144.86	2.29	52	70.36	6.63	0.54	0.0322	7.07	0.598	92.63	52.36	10.04	4.83	0.308	1.77
JHARSUGUDA	7.7	7.68	1.45	2534.13	150.68	2.28	39.36	78.27	7.23	0.55	0.0197	3.44	0.559	100.27	56.63	10.47	5.19	0.31	1.137
BRAJARAJNAGAR(U/S)	7.7	7.7	1.39	1651.7	157.88	2.85	38	76.63	7.59	0.54	0.0224	5.94	0.63	98.81	58.45	10.51	4.92	0.307	1.174
BRAJARAJNAGAR(D/S)	7.73	7.475	1.92	3349.4	162.51	2.92	47.36	76.63	10.22	0.62	0.0258	7.92	0.61	110.63	62.7	11.74	4.97	0.334	0.99
BBSR(U/S)	7.72	7.564	1.88	6517.66	181.18	2.55	41.63	75.54	12.09	0.67	0.0265	4.87	0.62	127.54	72.27	13.21	5.53	0.291	1.52
BBSR(D/S)	7.58	6.635	3.71	22432.66	228.35	6.4	51.54	83.36	25.22	0.96	0.0276	7.06	0.805	155.36	78.818	20.87	10.72	0.285	1.75
CHOUDWAR	7.81	7.519	1.53	6607.4	187.31	3.15	42.74	87.45	14.68	0.59	0.0515	4.19	0.469	168.45	100.63	18.48	9.09	0.941	1.54

CHAPTER 04

METHODOLOGY

4.1 GIS APPLICATION:

4.1.1 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.

The GIS is much more than simple coding, storing and retrieving data about aspects of the earth surface. In a very real sense the data can be accessed, transformed and manipulated interactively and they can serve as a test bed for studying possible results of planning decisions.

Spatial features are stored in a coordinate system (latitude/longitude, state plane, UTM, etc.), which references a particular place on the earth. Descriptive attributes in tabular form are associated with spatial features. Spatial data and associated attributes in the same coordinate system can then be layered together for mapping and analysis. GIS can be used for scientific investigations, resource management, and development planning.

4.1.2 GIS Components

GIS, like other information systems, cannot exist on its own, but rather it exists in the context of an application. There must be an organization of people, facilities, and equipment responsible for implementing and maintaining a GIS. Three essential elements that constitute a GIS are computer software, hardware, and personnel **(REDDY, 2008).**

4.1.2.1 Software

Existing GIS software are extremely diverse in functionality, database structure, and hardware requirements. A GIS user today is presented with a wide variety of commercial GIS software. Some of the popular GIS software is Arc/Info, Arc View, MapInfo, MGE (Modular GIS Environment), Genasys, ERDAS, GRASS, IDRISI, and Atlas. This software is sophisticated and have a variety of functionalities for GIS applications and analyses. Most of this software comes with capabilities to handle data in various formats, thereby facilitating data transfer between GIS software. Some of the above software is hardware specific and others run on a variety of platforms. The marketing of GIS software today is increasingly oriented to an open system or platform-independent approach.

4.1.2.2 Hardware

The large memory and disk requirements of GIS software and data resulted in a trend toward workstations running the UNIX operating system in the late 1980s and early 1990s. However, rapidly declining computer hardware costs and increasing capabilities of personal computers have made GIS software available on a variety of computer platforms including personal computers, high performance workstations, minicomputers and mainframe computers. GIS applications often require use of special peripherals such as digitizers and scanners for developing digital data. Other hardware requirements for GIS applications include plotters and printers for output of the final GIS products, including hard copy maps and summaries.

4.1.2.3 People

One of the most significant elements of a GIS is people. People are responsible for designing, implementing and using GIS for an application. GIS projects usually require an interdisciplinary team including specialists from several disciplines such as geography, agriculture, photogrammetric, computer science and natural resources to address multifaceted aspects of the application. Successful design and implementation of a GIS project requires coordination of personnel from these different disciplines. GIS training for key project personnel should be considered.

4.1.2.4 GIS Models

- Most GIS use one of two basic spatial data models to represent the real world, namely the Vector model and the Raster model.
- In the vector model, objects or conditions in the real world are represented by the points and lines that define their boundaries.
- Raster data models represent geographical space by dividing it in a series of units, each of which is limited and defined by an equal amount of earth's surface. The matrix of cells, organized into rows and columns is called a grid.

4.2 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.

4.2.1 Mann-Kendall Test:

A stochastic process is a statistical process involving a number of random variables depending on a variable parameter. If the variable parameter is the time, then the process becomes a stochastic time series in this analysis the in-flow series. The most important aspect of the stochasticity is stationary. A series $\{Xt\}$ is called stationary if its statistical properties do not change with time. More precisely, $\{Xt\}$ is said to be completely stationary if, for any integer k, the joint probability distribution of $xt, xt+1, \dots, xt+k$ is independent on the time index$t$. In this study trend test is being used for testing the stationarity.

To identify trend in climatic variables with reference to climate change, the Mann-Kendall test has been employed by a number of researches with temperature, precipitation and stream flow data series (Burn, 1994, Douglas et. al 2002, Yue and Hashimo 2003, Burn et al. 2004, Lind storm and Bergstrom, 2004). It is a common practice to use a non parametric test to detect a trend in a time series. This test, being a function of the ranks of the observations rather than their actual values, is not affected by the actual distribution of the data and is less sensitive to outliers. On the other hand, parametric trend tests, although more powerful, require the data to be normally distributed and are more sensitive to outliers. The Mann–Kendall test is therefore more suitable for detecting trends in hydrological time series, which are usually skewed and may be contaminated with outliers. This test has been extensively used with environmental time series (Hipel and McLeod, 2005).

The Mann-Kendall trend test is based on the correlation between the ranks of a time series and their time order. For the statistics S is calculated as equation (1). This statistic represents the number of positive differences minus the number of negative differences for all the differences considered as

$$S = \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} sgn(x_j - x_i) \quad \text{-------------------------------------} \ (1)$$

Where n is the number of total data points, x_i and x_j are the data values in time series i and $j(j > i)$, respectively, and $sgn(x_j - x_i)$ is the sign function as:

$$sgn(x_j - x_i) = \begin{cases} +1, & if(x_j - x_i) > 0 \\ 0, & if(x_j - x_i) = 0 \\ -1, & if(x_j - x_i) < 0 \end{cases} \quad \text{---} \ (2)$$

The variance of Mann- Kendall test is calculated by equation (3) as

$$Var(S) = \frac{n(n-1)(2n+5) - \sum_{i=1}^{m} t_i(t_i-1)(2t_i+5)}{18} \quad \text{---} \ (3)$$

where$n$is the number of total data points, $m$is the number of tied groups. The tied group means a simple data having a same value. The $t_i$indicates the number of ties of extent$i$. In case of the sample size$(n > 10)$, the standard normal test statistic Z_s is estimated by equation (4) as

$$Z_s = \begin{cases} \frac{S-1}{\sqrt{Var(S)}}, & ifS > 0 \\ 0 & ifS = 0 \\ \frac{S+1}{\sqrt{Var(S)}}, & ifS < 0 \end{cases} \quad \text{-----------------------------} \ (4)$$

The positive values of Z_s show increasing trends while negative values represent falling trends. As 5 % significance level is taken standard for this study, the null hypothesis of no trend is rejected if $|Z_s| > 1.96$.

- A linear trend was fitted to each time series using the least-squares regression method. The liner trend value represented by the slope of regression line provides the rate of increase or decrease in water quality parameters.

4.3 CLUSTERING ANALYSIS OF MAHANADI RIVER BASIN:

4.3.1 INTRODUCTION

Water samples were collected from 16 stations along the course of the Mahanadi river system, starting from the Hirakud Reservoir to Choudwar. 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. The mean value of the data sets was taken into consideration for evaluating the pollution load in the water system. The measured parameters include pH, dissolved oxygen (DO), Biochemical oxygen demand (BOD), Total Colliform(TC), Electrical Conductivity(EC), Nitrate(NO_3), Total Suspended Solids(TSS), Alkalinity, Chemical Oxygen Demand(COD),NH_4-N, FREE NH_3, Total Kjeldahl nitrogen(TKN), Sodium Absorption Ratio(SAR), Total Dissolved Solids(TDS), Total Hardness(TH), Chloride(Cl^-) , Sulphate (SO_4^{2-}), Fluoride(F^-) and Iron(Fe).

Table 4.3.1.2 MINIMUM, MAXIMUM, MEAN AND STANDARD DEVIATION OF WATER QUALITY PARAMETERS AT DIFFERENT MONITORING STATIONS FROM 2000 TO 2014.

PARAMETERS	STATIONS	MINIMUM	MAXIMUM	MEAN	STANDARD DEVIATION
PH	16	7.58	7.95	7.77975	0.08827797
DO	16	6.635	7.8	7.543938	0.304818956
BOD	16	1.273	3.71	1.762438	0.631641034
TC	16	1212.4	32942.66	6575.949	8757.921972
EC	16	144.86	7942.2	667.6681	1940.001825
NO_3	16	1.85	6.4	2.818563	1.045870481
TSS	16	28.63	76.09	40.61638	12.1990147
ALKALINITY	16	70.36	106.09	84.15	8.954079145
COD	16	6.63	25.22	11.88125	4.862956405
NH_4-N	16	0.51	0.96	0.61375	0.112538882
FREE NH_3	16	0.0197	0.0515	0.028488	0.007854245
TKN	16	3.44	11.069	5.851188	2.005488111
SAR	16	0.44	22.66	1.930625	5.528575728
TDS	16	86.54	13081.82	933.0636	3239.747484
TH	16	52.36	2158.9	204.278	521.3723727
CL^-	16	9.5	5013.282	324.9769	1250.218733
$S0_4^{2-}$	16	4.83	364.7	29.28688	89.45926177
F	16	0.285	0.941	0.3825	0.17211469
FE	16	0.597	2.38	1.323313	0.436365247

4.4. STATISTICAL ANALYSIS:

In recent years, various statistical procedures based on multivariate data taken from river system have been used to formulate environmental classifications, which help for a better understanding of the chemical processes occurring in the river environment. For a better understanding of the natural and anthropogenic fluxes responsible for the characterization of water quality in the Mahanadi river system.

Principal component analysis and cluster analyses (CA) were carried out for data set obtained yearly from 2000-2014. The factor analyses were calculated using component variance values greater than 1.0 is considered the significant influences towards the geo-chemical processes.

The hierarchical clustering was carried out from data normalized to a zero mean and using Euclidian distances as a measure of similarity. Ward's method was selected because it possesses a small space-distorting effect and accesses more information on cluster content. The results indicate that the CA technique offers a reliable classification of surface water in the whole region and make it possible to design a future spatial sampling strategy in an optimal method that can reduce the number of monitoring sites.

4.5. CLUSTER ANALYSIS:

Cluster analysis (CA) is used to develop meaningful aggregations or groups of entities based on a large number of interdependent variables. The resulting clusters of objects should exhibit high internal (within-cluster) homogeneity and high external (between clusters) heterogeneity. Of all cluster analysis, hierarchical cluster is most common approach. In the study, hierarchical agglomerative CA was performed based on the normalized data set (mean of observations over the whole period) by means of the Ward's method using Euclidean distances as a measure of similarity. The spatial variability of water environment quality in the whole river basin was determined from CA, which divides a large number of objects into smaller number of homogenous groups on the basis of their internal correlations.

4.6. PRINCIPAL COMPONENT ANALYSIS / FACTOR ANALYSIS:

Factor analysis, which includes PCA is a very powerful technique applied to reduce the dimensionality of a dataset consisting of a large number of interrelated variables, while retaining as much as possible the variability presented in dataset. This reduction is achieved by transforming the dataset into a new set of variables called the principal components (PCs), which are orthogonal (non-correlated) and is arranged in decreasing order of importance. Mathematically, the PCs are computed from covariance or other cross-product matrix, which describes the dispersion of the multiple measured parameters to obtain Eigen values (Component variance values) and eigenvectors. Principal components are the linear combinations of the original variables and the eigenvectors. PCA can be used to reduce the variable numbers and explain the same amount of variance with fewer variables (principal components). Factor analysis attempts to explain the correlations between the observations in terms of the underlying factors, which are not directly observable. This study comprises application of multivariate statistical techniques to analyze water quality dataset obtained from the Mahanadi River in Odisha. Statistical calculations were performed using the MATLAB.

Table 4.7 NORMALIZED VALUES OF MONITORING STATIONS OF MAHANADI RIVER BASIN FROM THE YEAR 2000-2014

		CLASS A						CLASS B		CLASS C			CLASS D			CLASS E				
STATIONS	PARAMETERS	PH	DO	NO_3	TSS	TDS	TH	BOD	FE	TC	COD	ALKALINITY	NH_4-N	FREE NH_3	TKN	EC	SAR	CL_2	$S0_4^{2-}$	F
1	HIRAKUD	0.514	0.897	0.143	0.098	0.0018	0.01	0	0.185	0.011	0.0931	0.3053456	0.04444	0.1132	0.055	0.00427	0	0	0.00606	0.0549
2	SAMBALPUR	0.514	0.863	0.262	0.01	0	0.011	0.1366	0.155	0.078	0.2733	0.3638399	0.22222	0.2264	0.581	0.0049	0.0009	0.00026	0.00703	0.0503
3	SONEPUR(U/S)	0.595	0.94	0.066	0	0.0028	0.014	0.0275	0	0	0.1485	0.4987406	0	0.0377	0.059	0.00535	0.0023	0.00108	0.00408	0.0595
4	SONEPUR(D/S)	0.773	0.94	0.114	0.027	0.0039	0.016	0.2597	0.189	0.07	0.3561	0.7455919	0.24444	0.3774	0.263	0.00943	0.0029	0.00025	0.00642	0.1174
5	TIKARPADA	0.595	0.88	0.143	0.146	0.0044	0.012	0.0476	0.411	0.021	0.1528	0.4657151	0.04444	0.239	0.29	0.0068	0.0041	0.00024	0.00572	0.0259
6	NARSINGHPUR	0.622	0.931	0.066	0.036	0.0035	0.011	0.03	0.417	0.076	0.1974	0.5927792	0.08889	0.1635	0.263	0.00595	0.0014	0.00018	0.00553	0.0976
7	CUTTACK(U/S)	0.811	1	0	0.059	0.0031	0.01	0.0919	0.551	0.035	0.1737	0.2059894	0.46667	0.4623	0.052	0.00421	0.0031	0.00029	0.0107	0.1189
8	CUTTACK(D/S)	0.757	0.494	0.163	0.301	0.0037	0.014	0.5773	0.411	1	0.6934	0.4377274	0.44444	0.5597	0.342	0.00639	0.0042	0.0007	0.01003	0.0976
9	PARADEEP	1	0.459	0.365	1	1	1	0.2614	1	0.266	0.4276	1	0.13333	0.1101	1	1	1	1	1	0.5655
10	SUNDERGARH	0.405	0.991	0.097	0.492	0.0005	0	0.0406	0.658	0.02	0	0	0.06667	0.3931	0.476	0	0.0071	0.00011	0	0.0351
11	JHARSUGUDA	0.324	0.897	0.095	0.226	0.0011	0.002	0.0726	0.303	0.042	0.0323	0.2213826	0.08889	0	0	0.00075	0.0054	0.00019	0.001	0.0381
12	BRAJARAJNAGAR(U/S)	0.324	0.914	0.22	0.197	0.0009	0.003	0.048	0.324	0.014	0.0516	0.1754828	0.06667	0.0849	0.328	0.00167	0.0086	0.0002	0.00025	0.0335
13	BRAJARAJNAGAR(D/S)	0.405	0.721	0.235	0.395	0.0019	0.005	0.2655	0.22	0.067	0.1931	0.1754828	0.24444	0.1918	0.587	0.00226	0.0077	0.00045	0.00039	0.0747
14	BBSR(U/S)	0.378	0.797	0.154	0.274	0.0032	0.009	0.2491	0.518	0.167	0.2937	0.1449762	0.35556	0.2138	0.187	0.00466	0.0081	0.00074	0.00195	0.0091
15	BBSR(D/S)	0	0	1	0.483	0.0053	0.013	1	0.647	0.669	1	0.3638399	1	0.2484	0.475	0.01071	0.0164	0.00227	0.01637	0
16	CHOUDWAR	0.622	0.759	0.286	0.297	0.0063	0.023	0.1055	0.529	0.17	0.433	0.4783095	0.17778	1	0.098	0.00544	0.0013	0.00179	0.01184	1

CHAPTER 05

RESULTS AND DISCUSSION

5.1 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.

5.1.1 PH:

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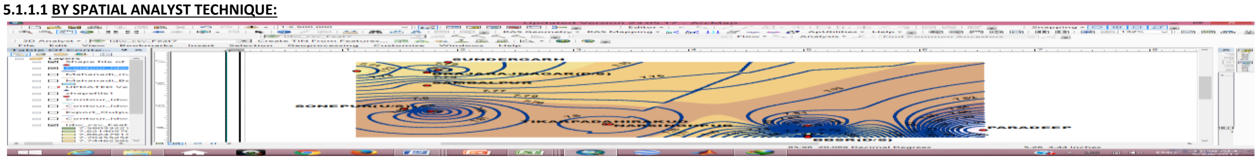

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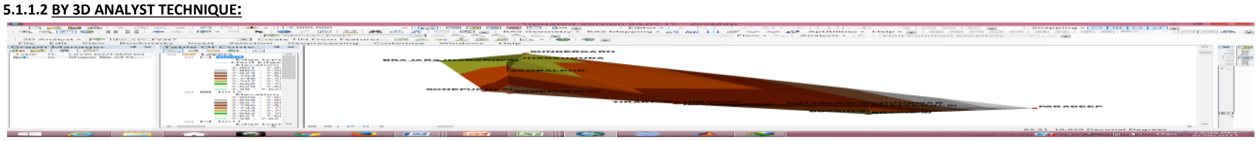

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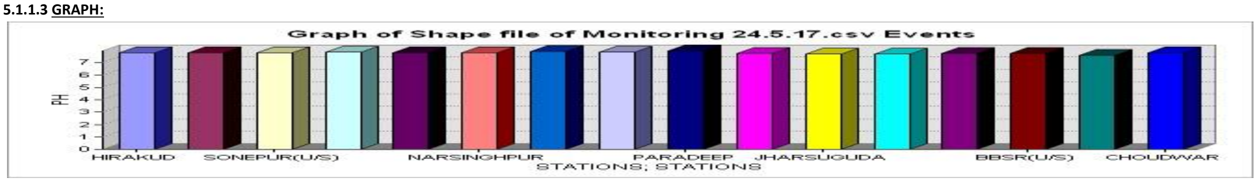

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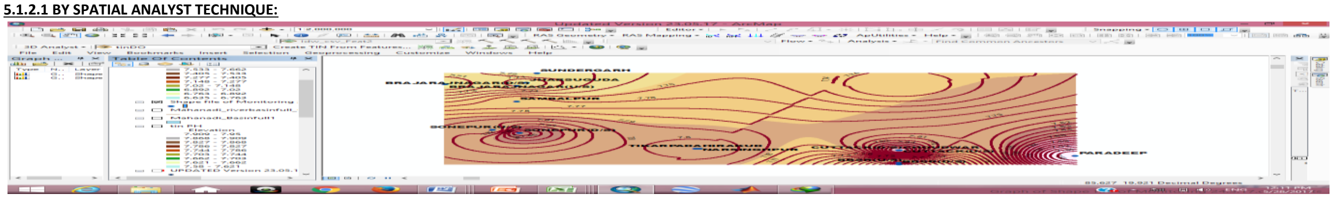

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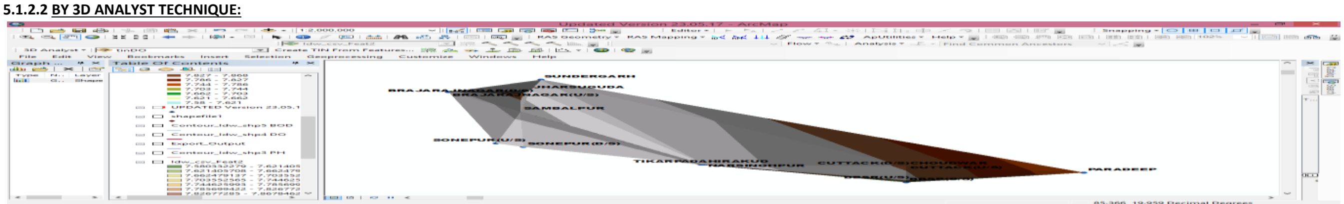

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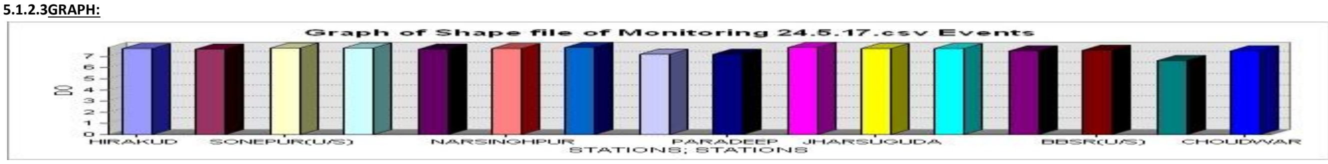

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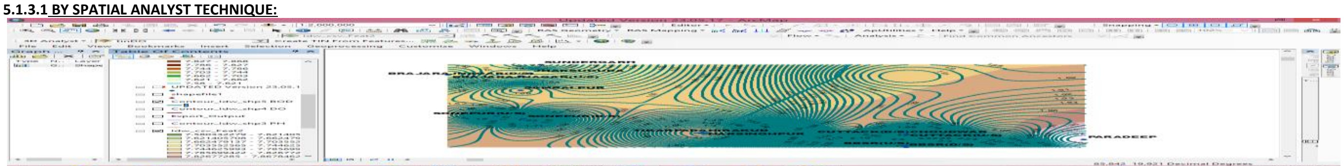

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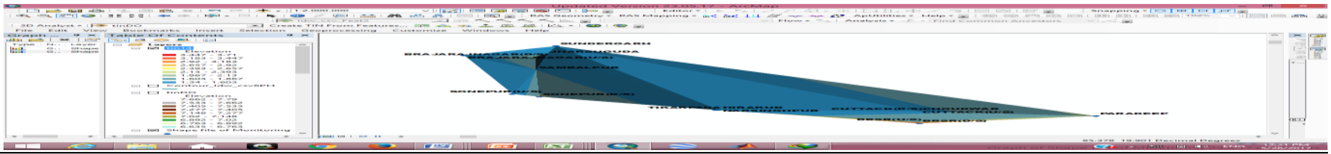

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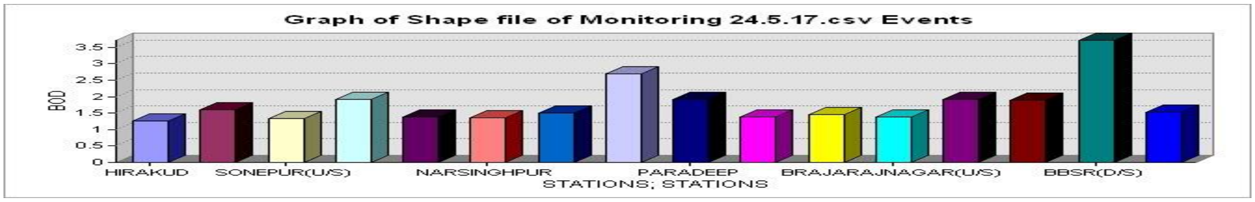

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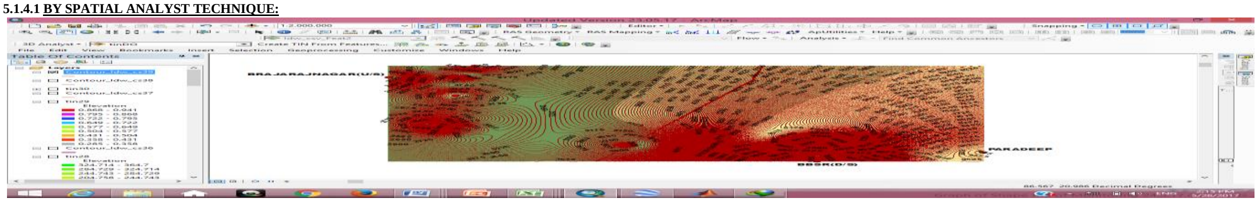

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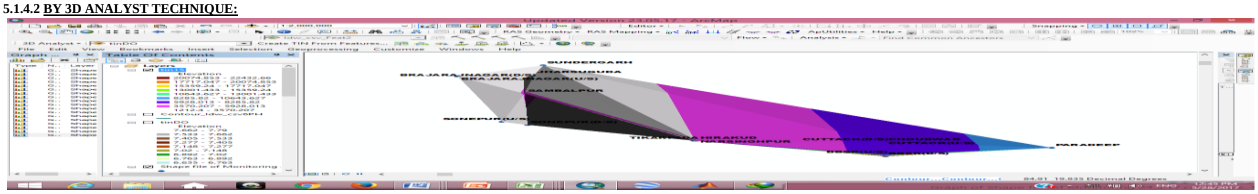

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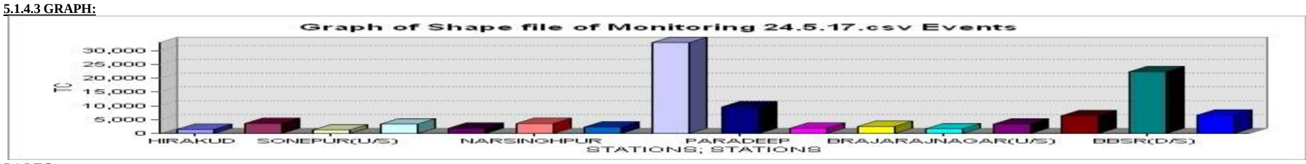

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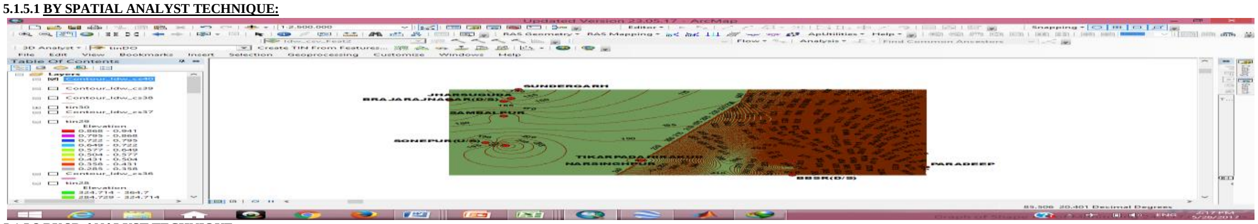

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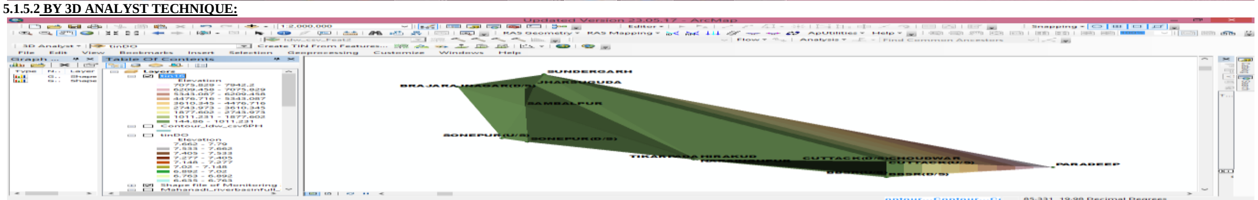

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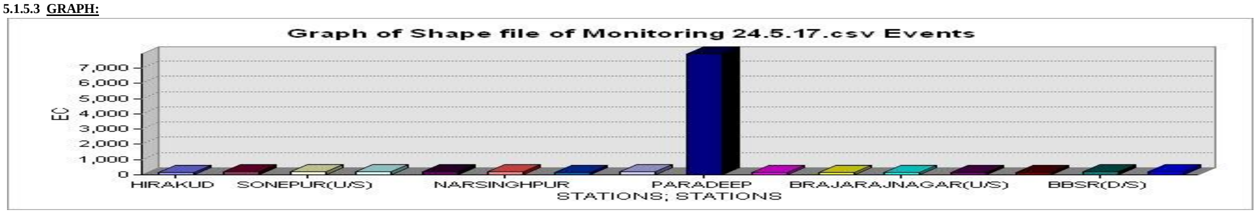

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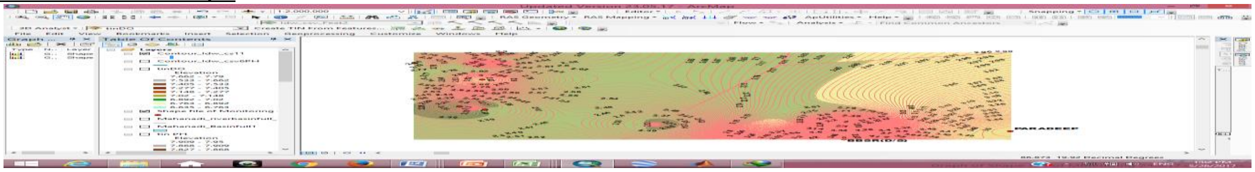

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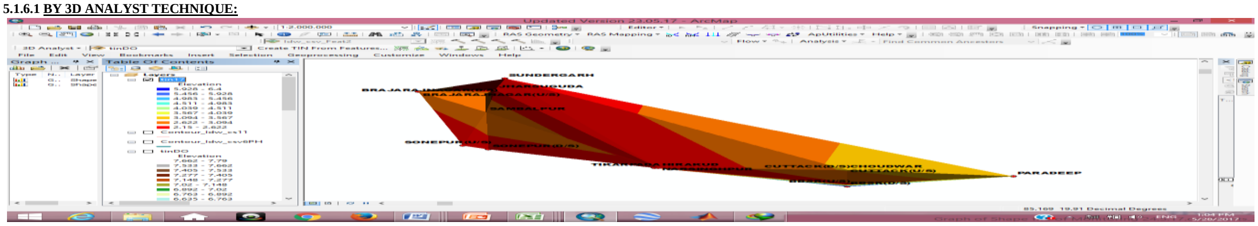

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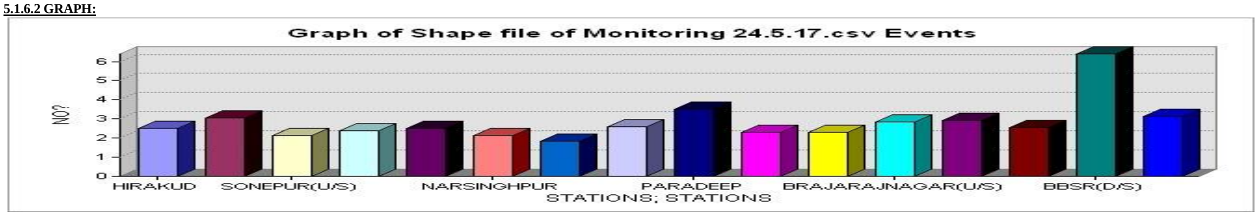

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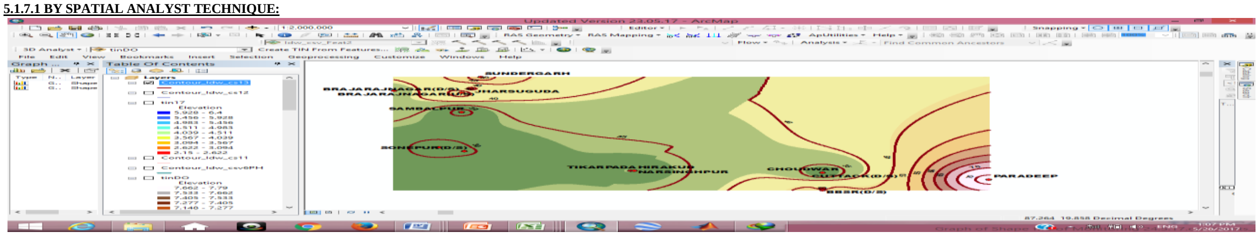

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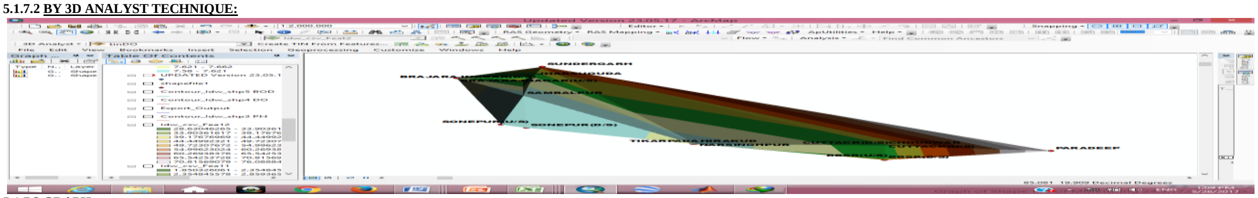

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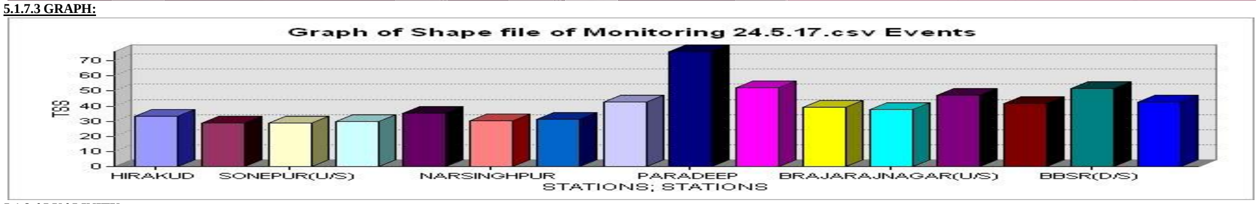

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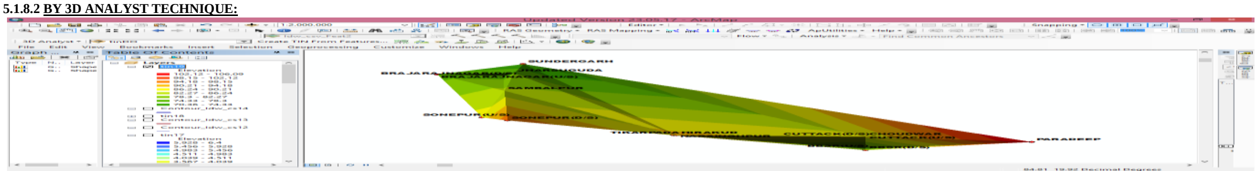

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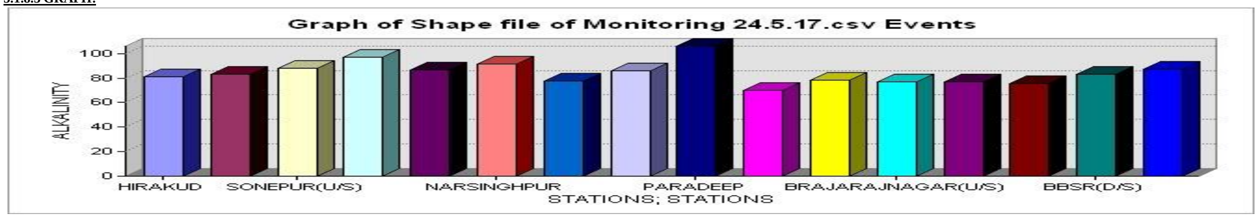

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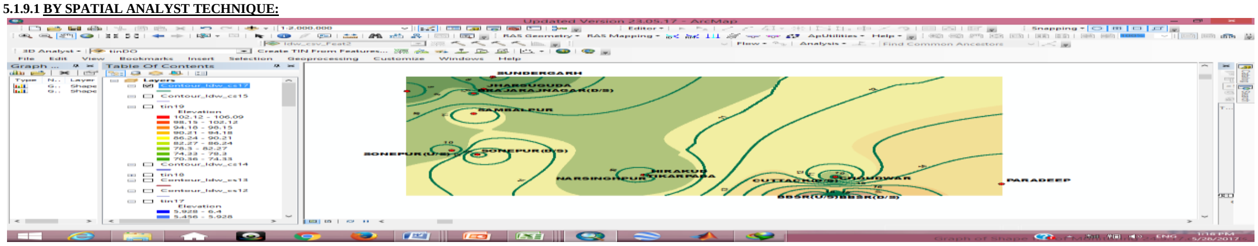

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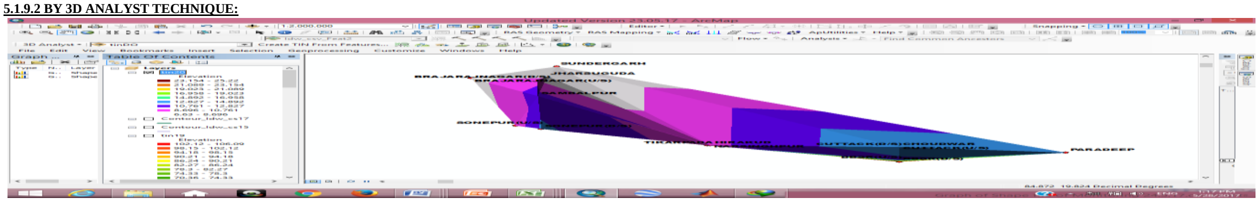

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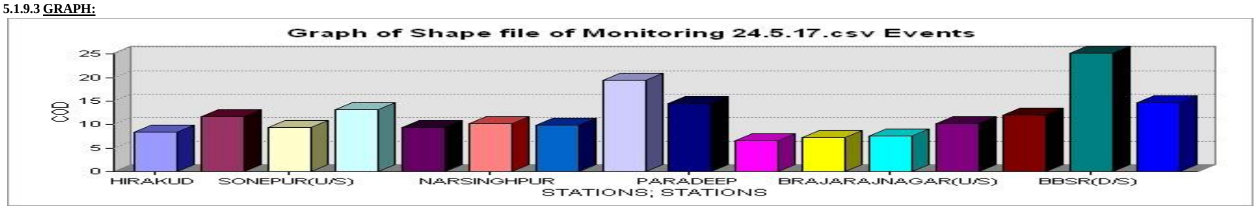

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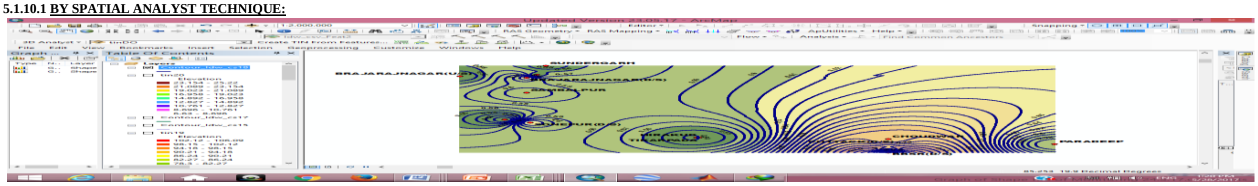

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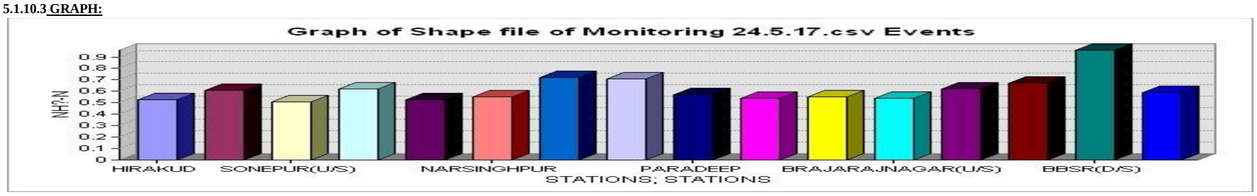
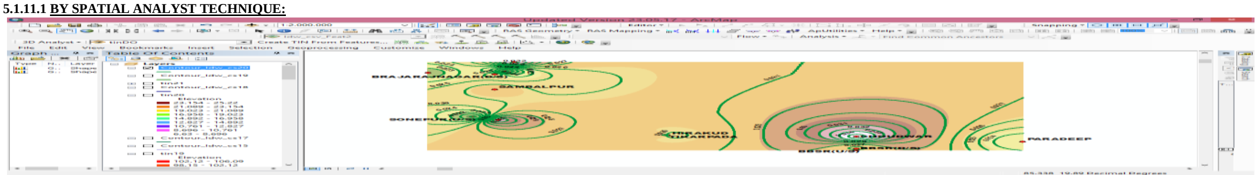
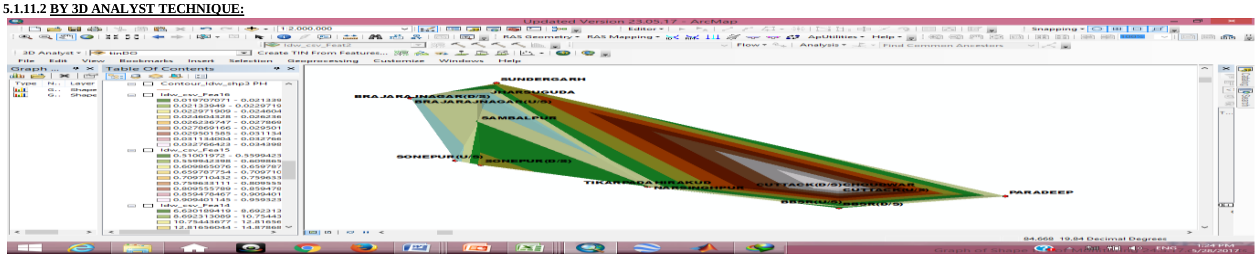


5.1.11 FREE NH_3:

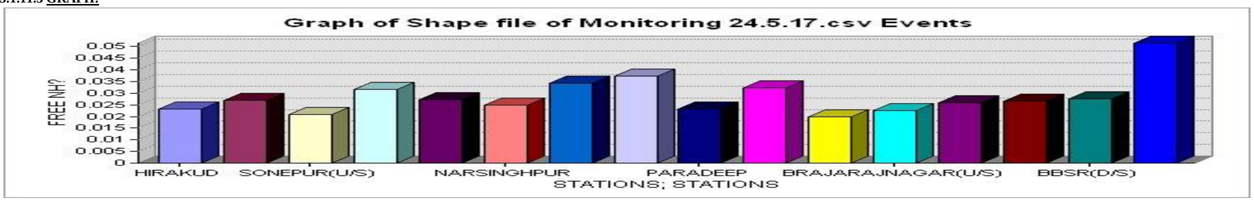
5.1.11.1 BY SPATIAL ANALYST TECHNIQUE:



5.1.11.2 **BY 3D ANALYST TECHNIQUE:**

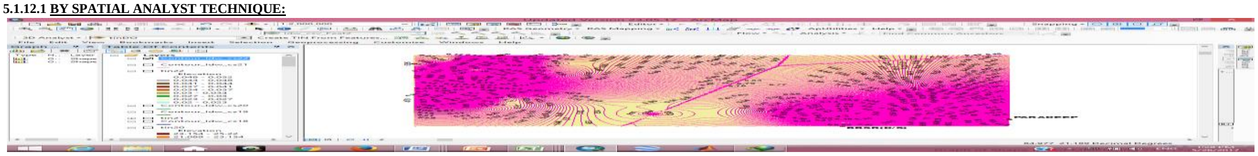


5.1.11.3 **GRAPH:**

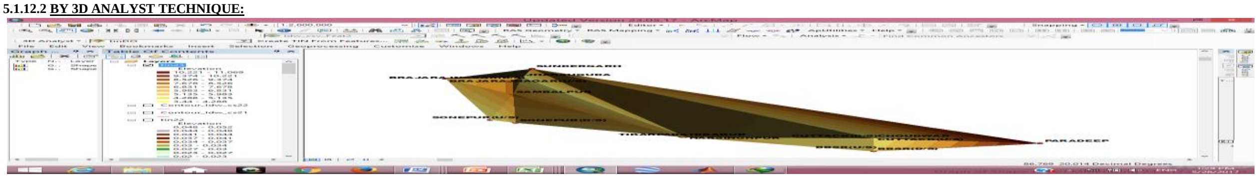


5.1.12 **TKN:**

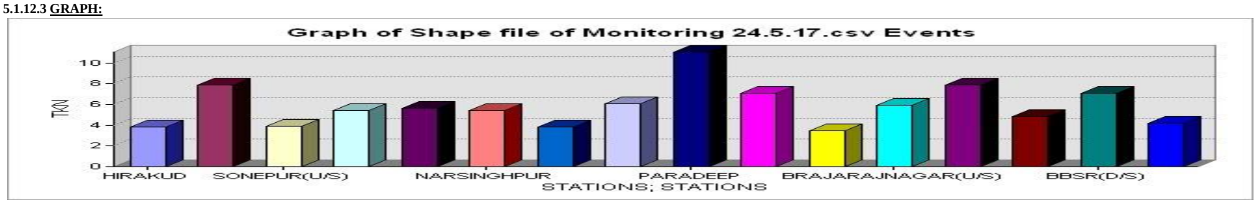
5.1.12.1 **BY SPATIAL ANALYST TECHNIQUE:**



5.1.12.2 **BY 3D ANALYST TECHNIQUE:**

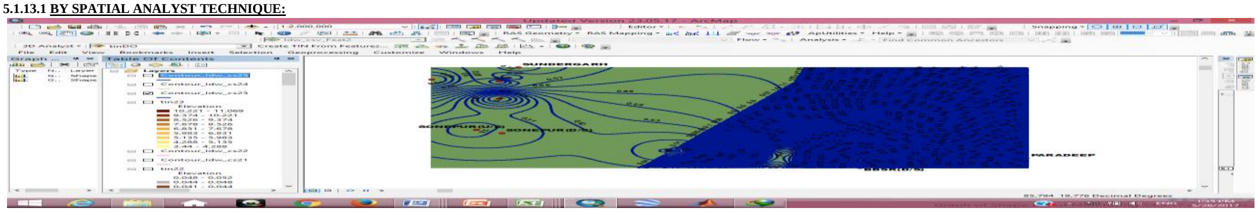


5.1.12.3 **GRAPH:**

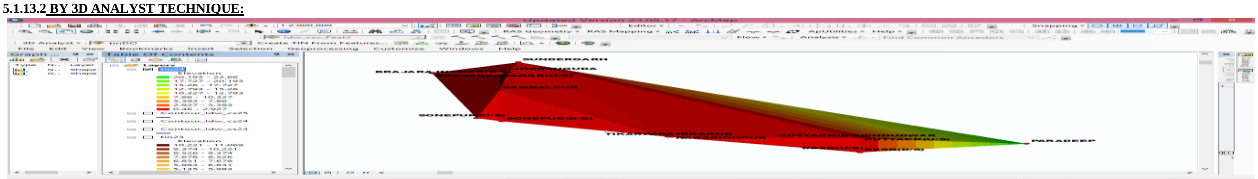


5.1.13 **SAR:**

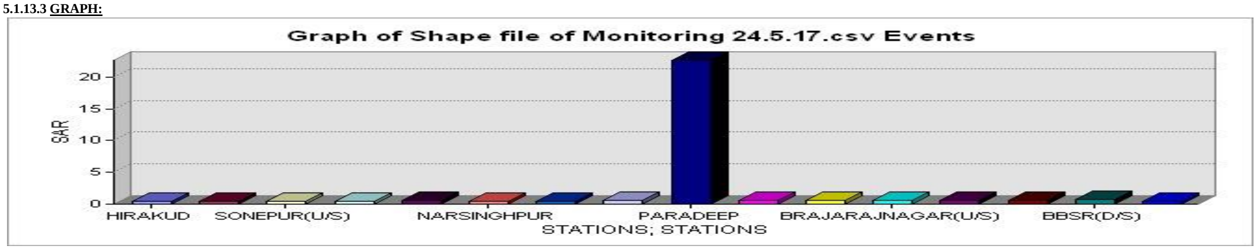
5.1.13.1 **BY SPATIAL ANALYST TECHNIQUE:**



5.1.13.2 **BY 3D ANALYST TECHNIQUE:**

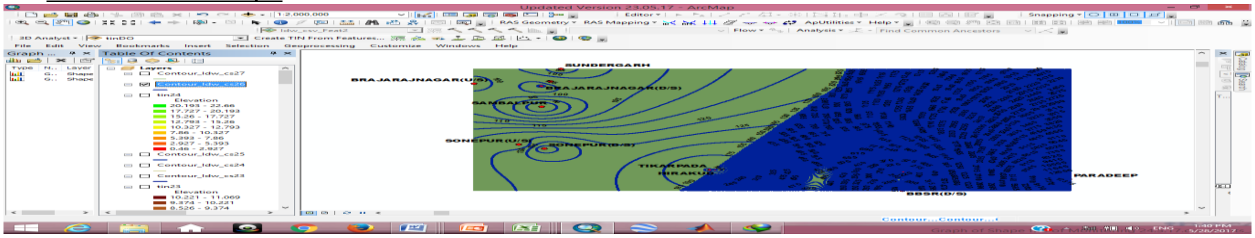


5.1.13.3 **GRAPH:**

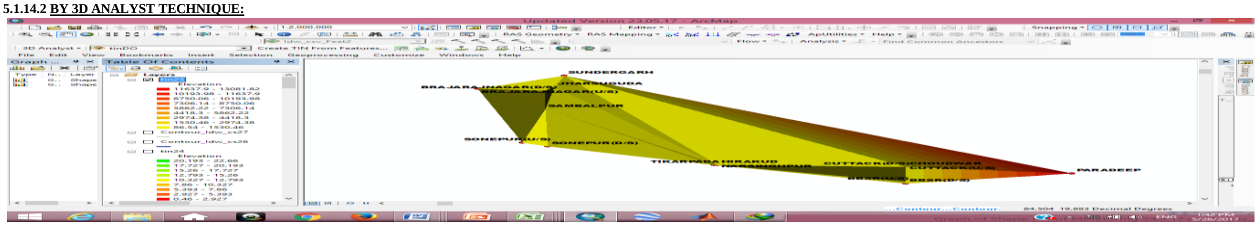


5.1.14 TDS:

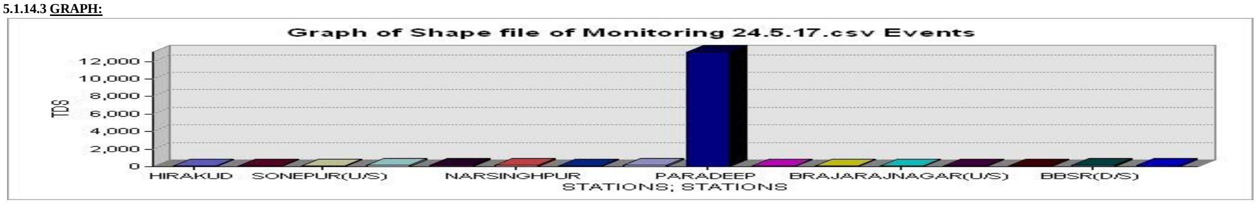
5.1.14.1 BY SPATIAL ANALYST TECHNIQUE:



5.1.14.2 BY 3D ANALYST TECHNIQUE:

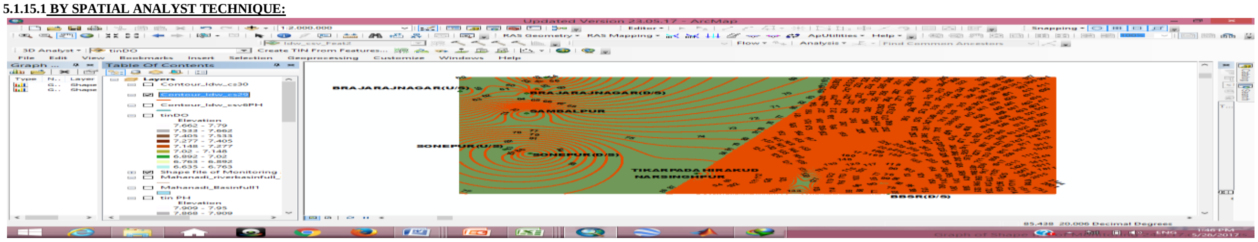


5.1.14.3 GRAPH:

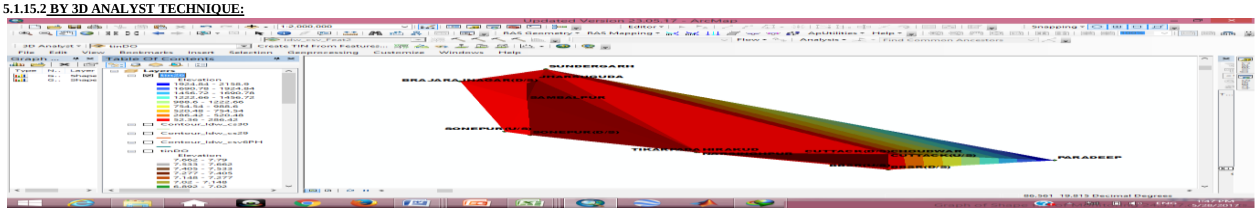


5.1.15 TH:

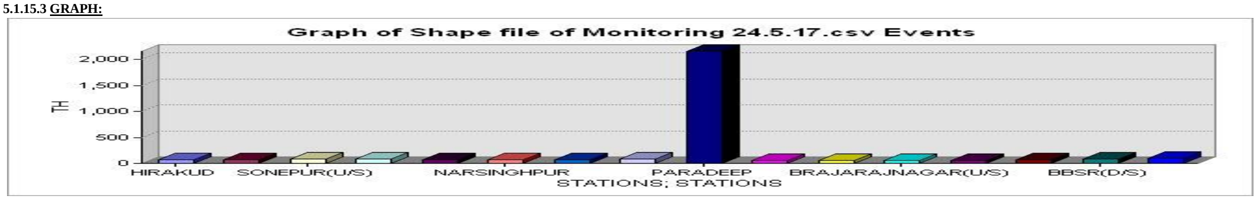
5.1.15.1 BY SPATIAL ANALYST TECHNIQUE:



5.1.15.2 BY 3D ANALYST TECHNIQUE:

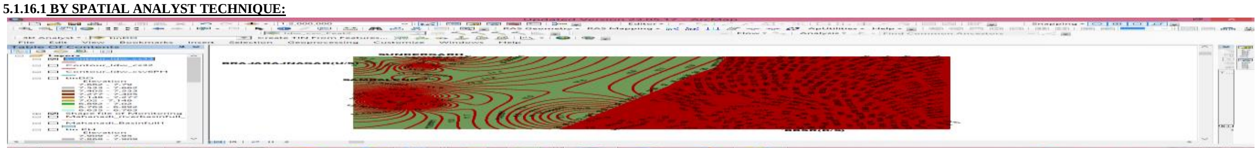


5.1.15.3 GRAPH:

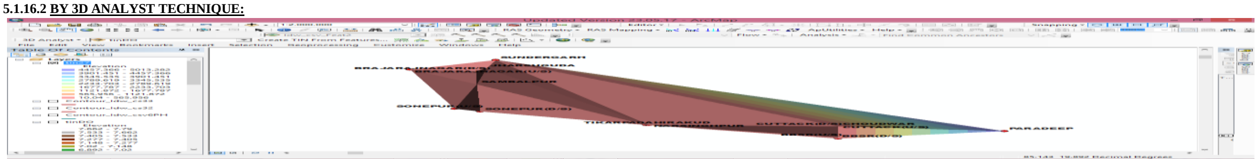


5.1.16 CHLORIDE:

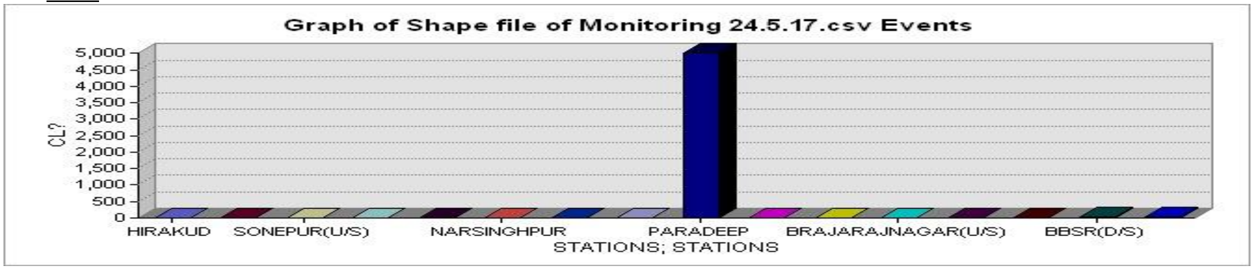
5.1.16.1 BY SPATIAL ANALYST TECHNIQUE:



5.1.16.2 BY 3D ANALYST TECHNIQUE:

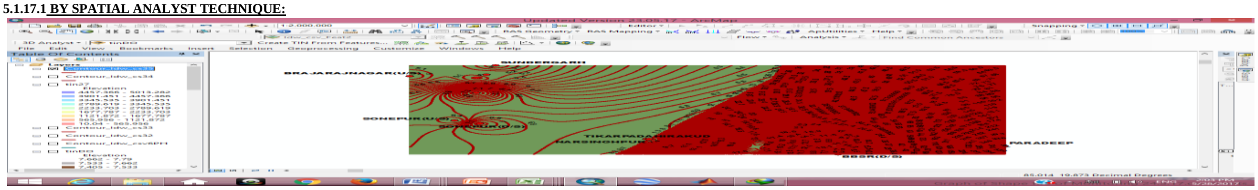


5.1.16.3 GRAPH:

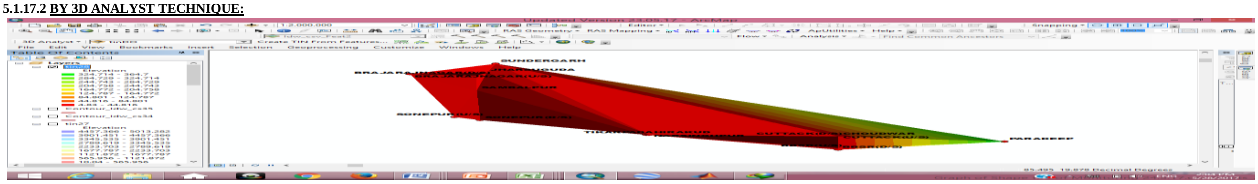


5.1.17 SULPHATE:

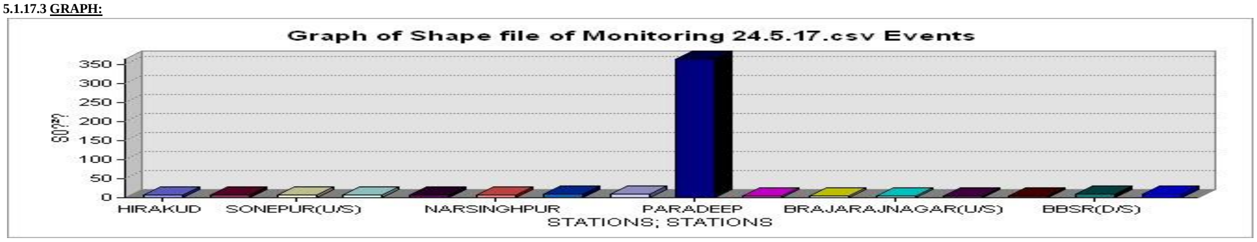
5.1.17.1 BY SPATIAL ANALYST TECHNIQUE:



5.1.17.2 BY 3D ANALYST TECHNIQUE:

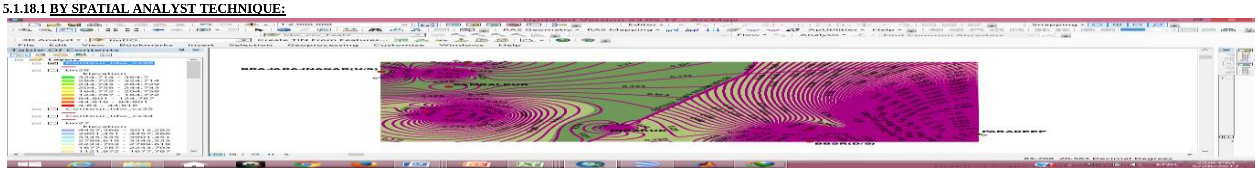


5.1.17.3 GRAPH:

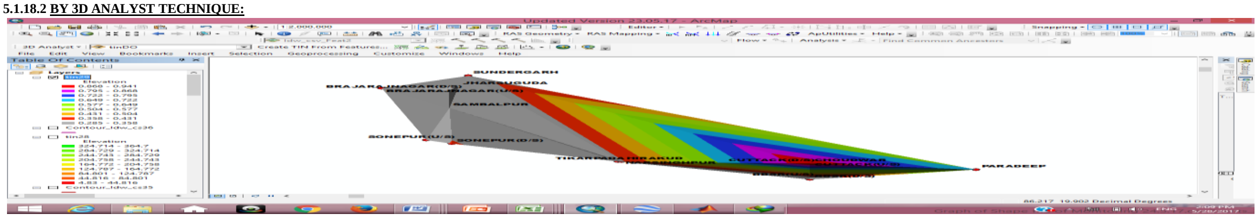


5.1.18 FLUORIDE:

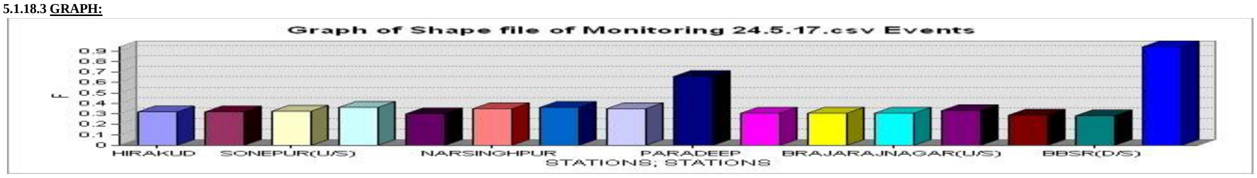
5.1.18.1 BY SPATIAL ANALYST TECHNIQUE:



5.1.18.2 BY 3D ANALYST TECHNIQUE:

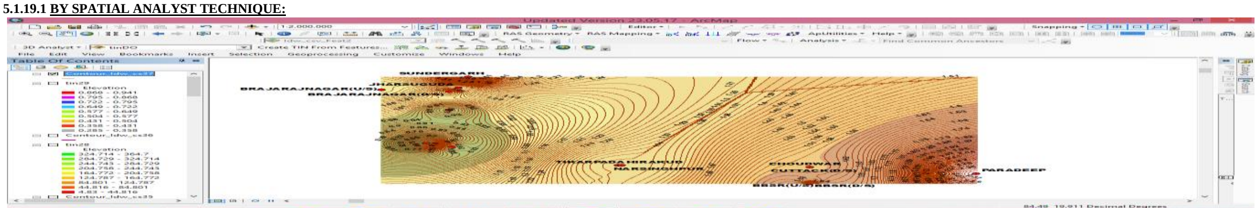


5.1.18.3 GRAPH:

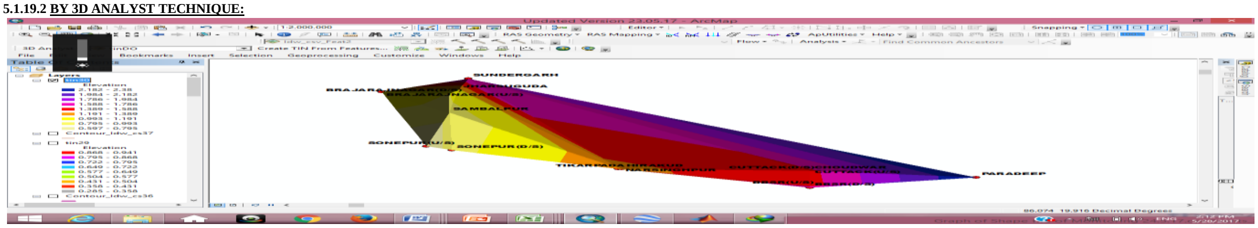


5.1.19 IRON:

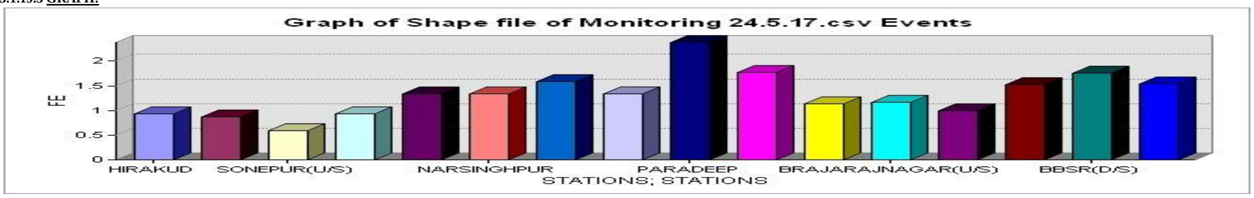
5.1.19.1 BY SPATIAL ANALYST TECHNIQUE:



5.1.19.2 **BY 3D ANALYST TECHNIQUE:**

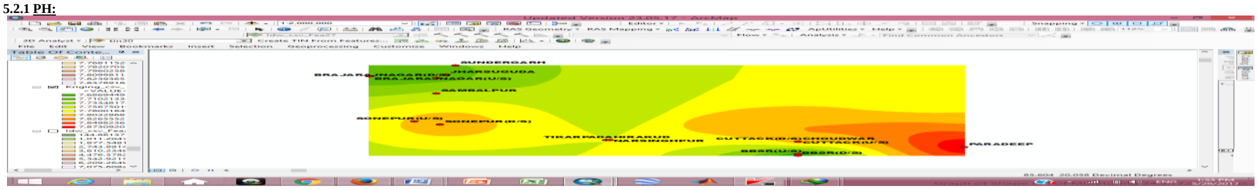


5.1.19.3 **GRAPH:**

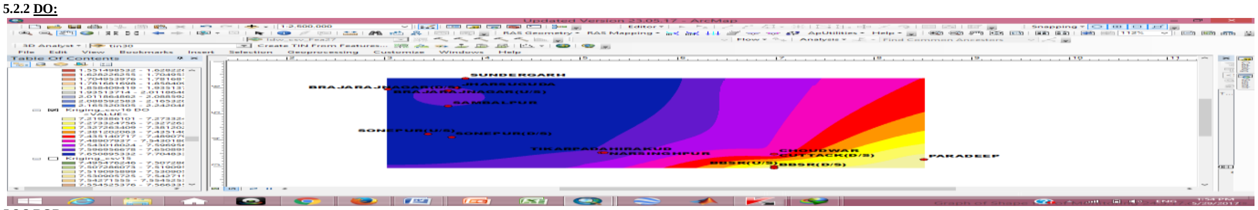


5.2. WATER QUALITY PARAMETERS MODELLING USING KRIGING TECHNIQUE BY GIS APPLICATION:

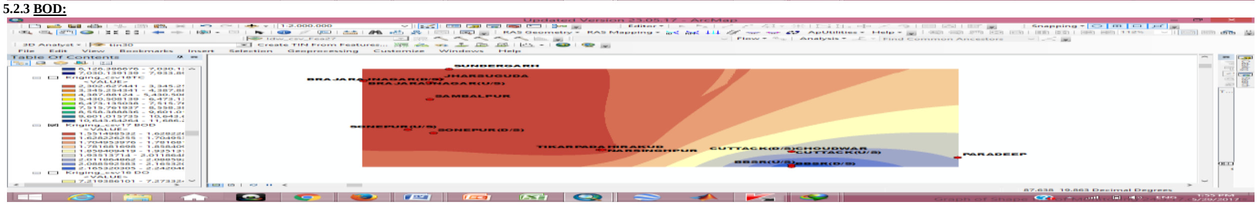
5.2.1 **PH:**



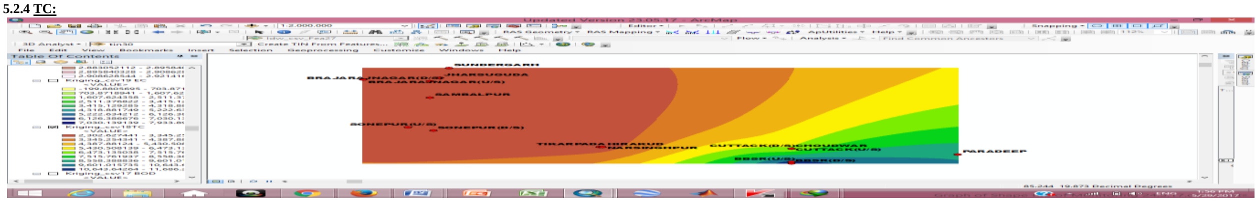
5.2.2 **DO:**



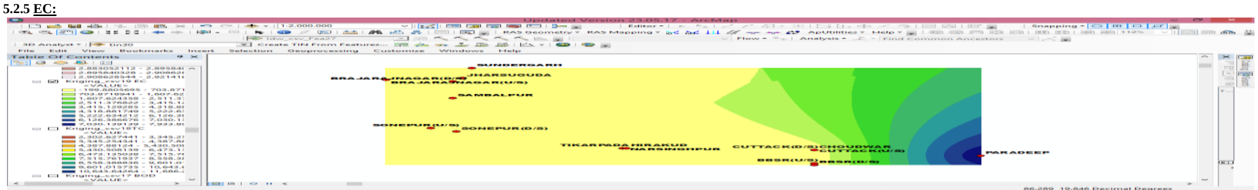
5.2.3 **BOD:**



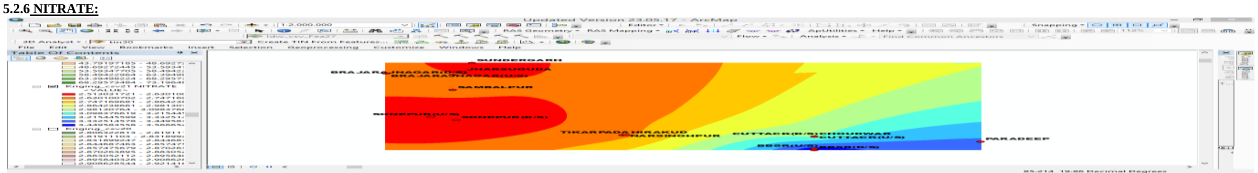
5.2.4 **TC:**



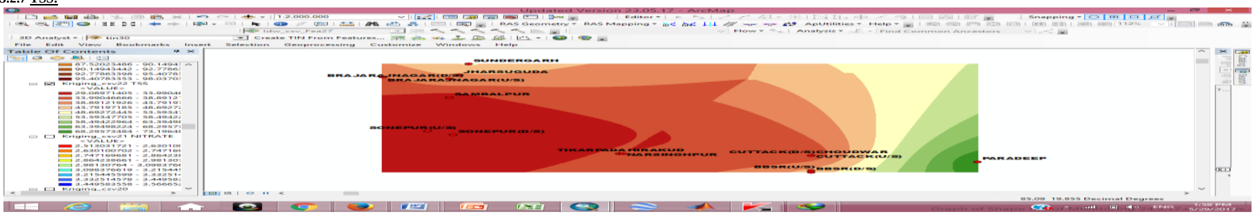
5.2.5 **EC:**



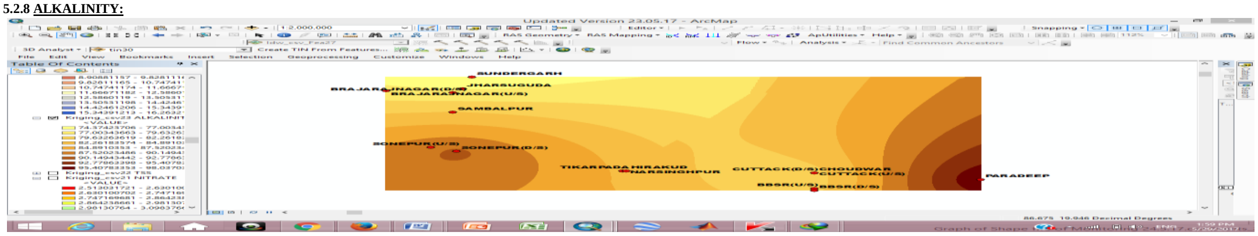
5.2.6 **NITRATE:**



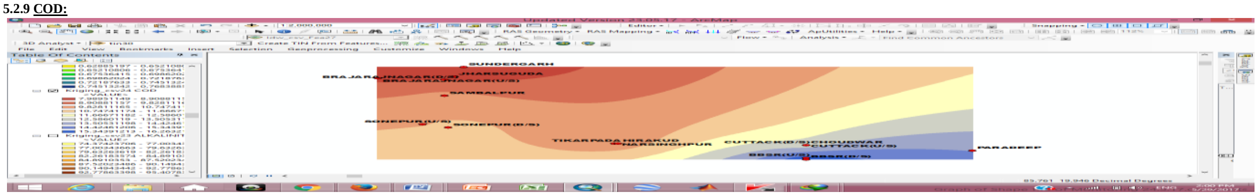
5.2.7 TSS:



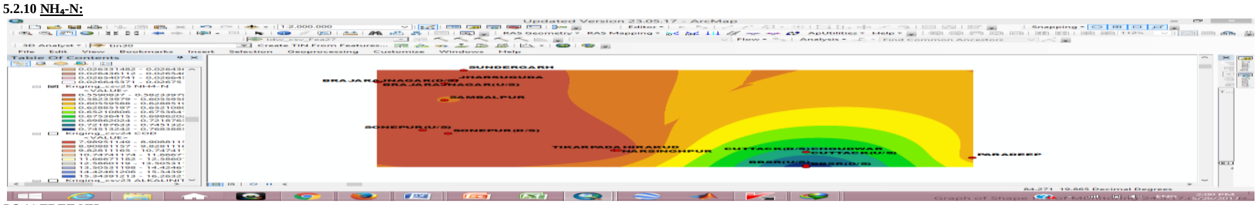
5.2.8 ALKALINITY:



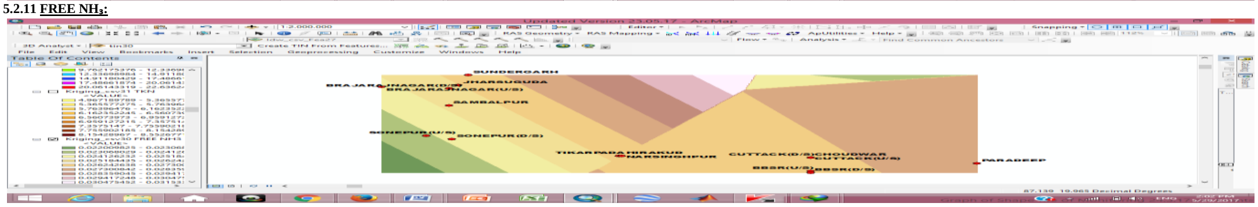
5.2.9 COD:



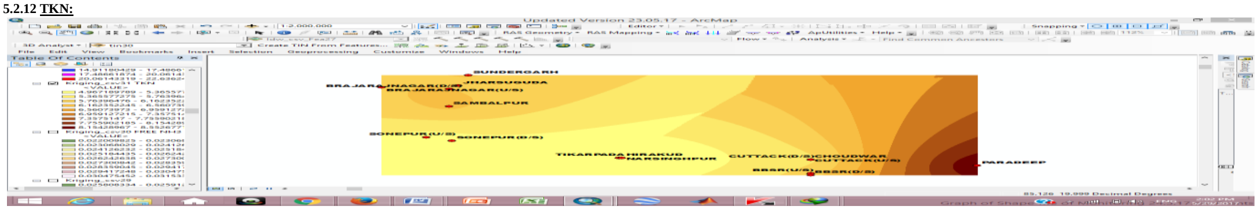
5.2.10 NH_4-N:



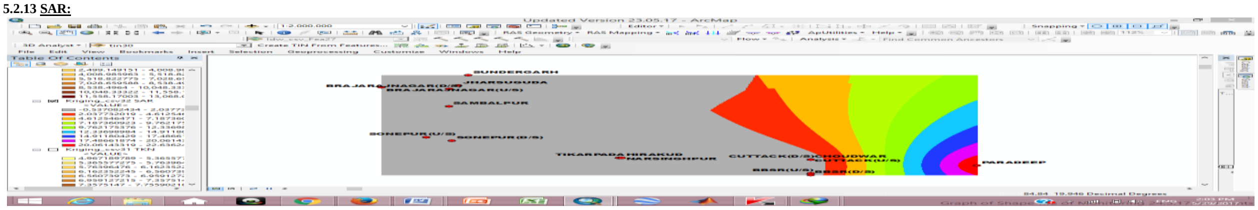
5.2.11 FREE NH_3:



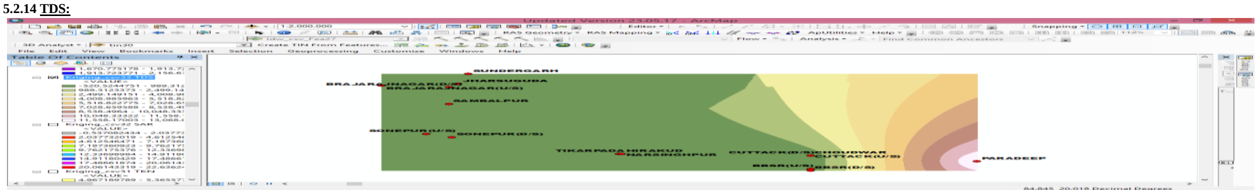
5.2.12 TKN:



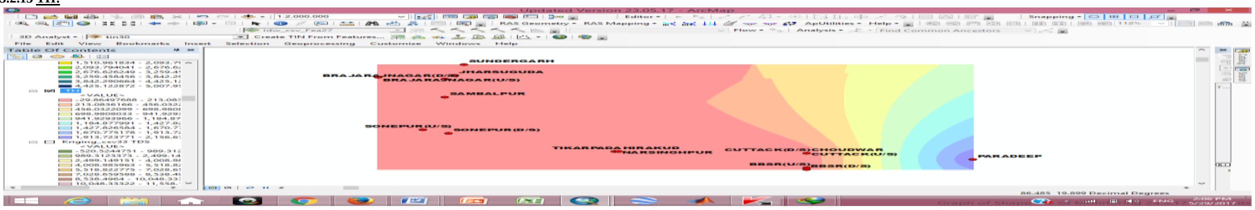
5.2.13 SAR:



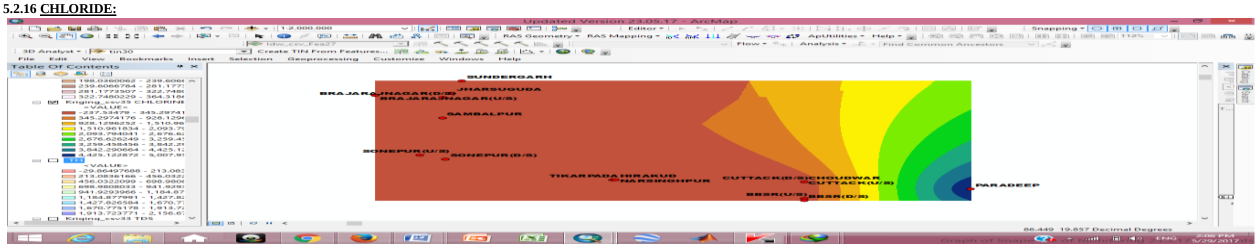
5.2.14 TDS:



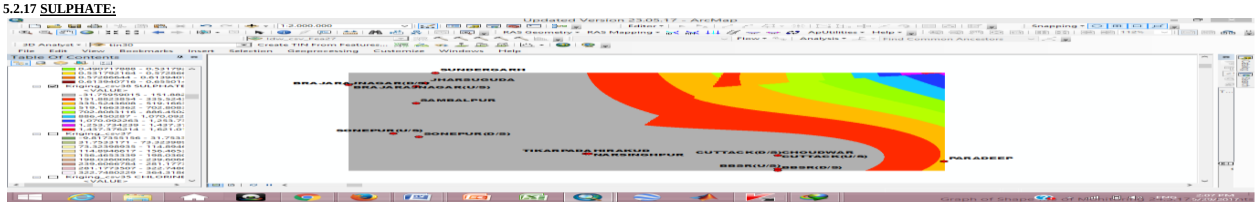
5.2.15 TH:



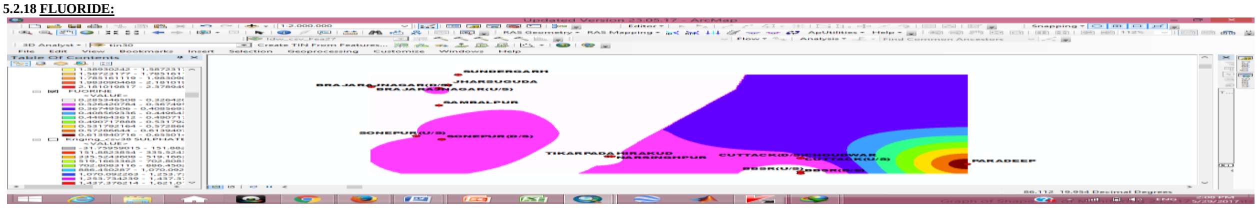
5.2.16 CHLORIDE:



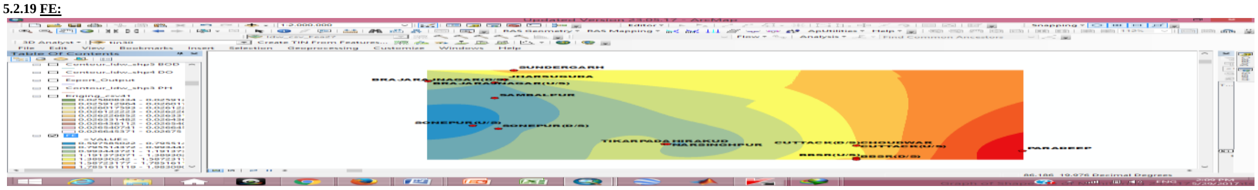
5.2.17 SULPHATE:



5.2.18 FLUORIDE:



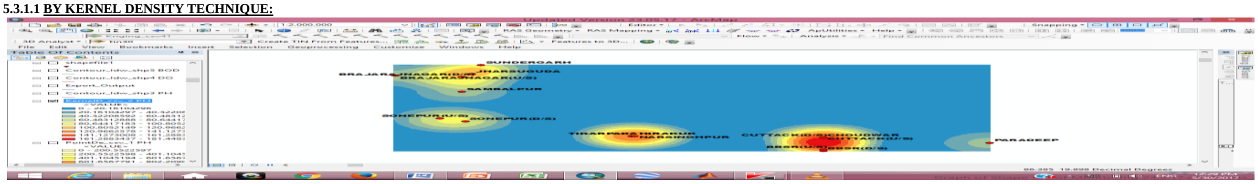
5.2.19 FE:



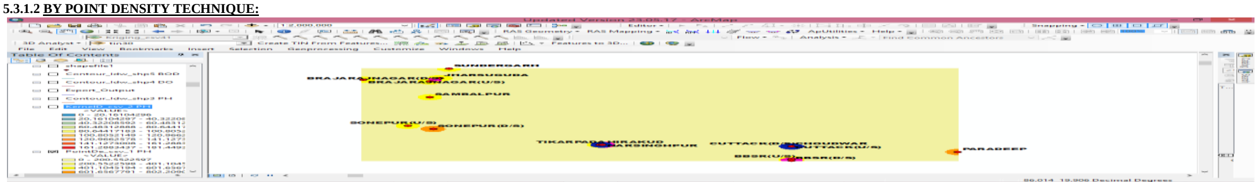
5.3 WATER QUALITY PARAMETERS MODELLING BY KERNEL AND POINT DENSITY USING GIS APPLICATION:

5.3.1 PH:

5.3.1.1 BY KERNEL DENSITY TECHNIQUE:



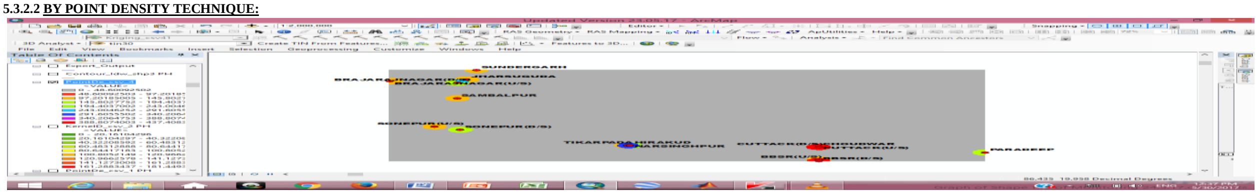
5.3.1.2 BY POINT DENSITY TECHNIQUE:



5.3.2 DO:

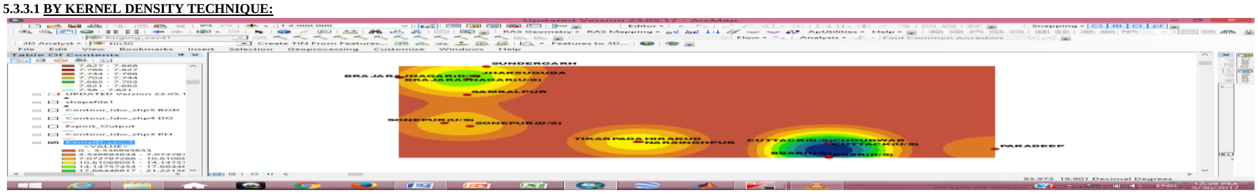
5.3.2.1 BY KERNEL DENSITY TECHNIQUE:

5.3.2.2 BY POINT DENSITY TECHNIQUE:

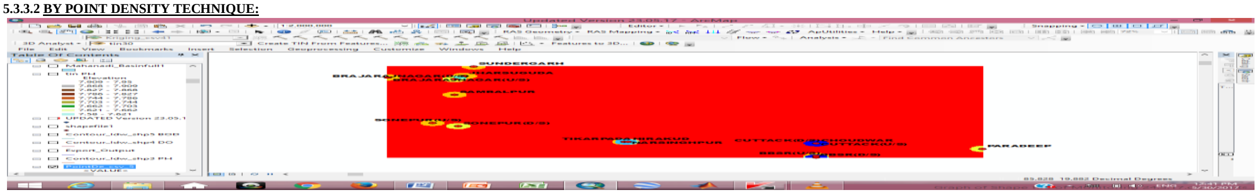


5.3.3 BOD:

5.3.3.1 BY KERNEL DENSITY TECHNIQUE:

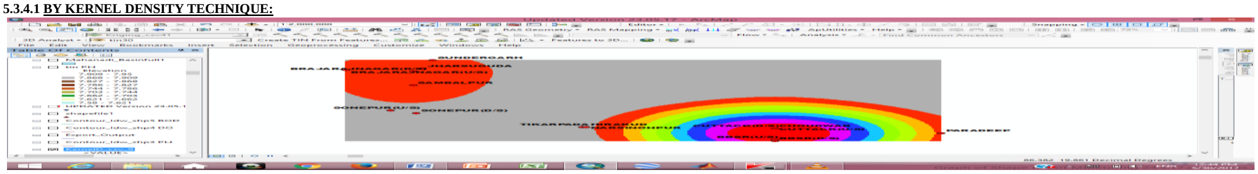


5.3.3.2 BY POINT DENSITY TECHNIQUE:

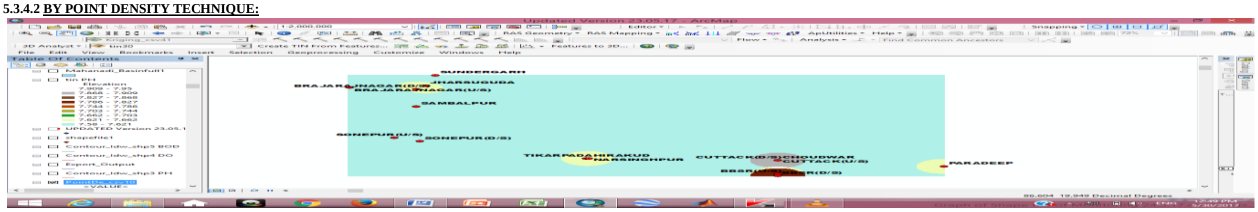


5.3.4 TC:

5.3.4.1 BY KERNEL DENSITY TECHNIQUE:

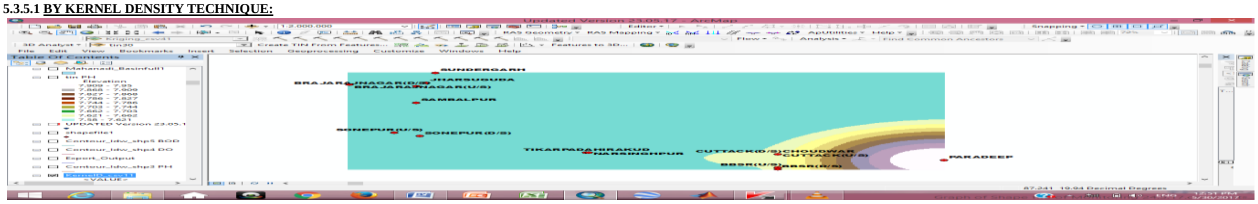


5.3.4.2 BY POINT DENSITY TECHNIQUE:

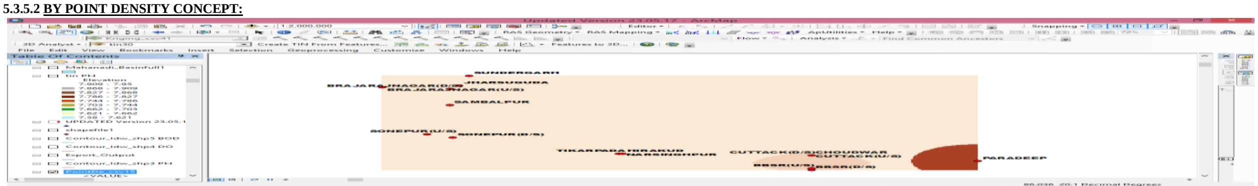


5.3.5 EC:

5.3.5.1 BY KERNEL DENSITY TECHNIQUE:

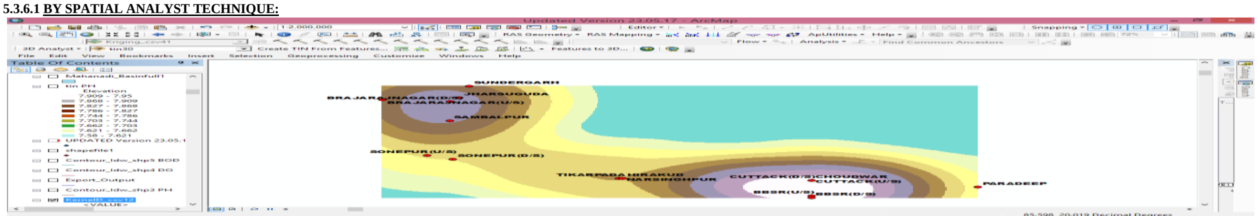


5.3.5.2 BY POINT DENSITY CONCEPT:

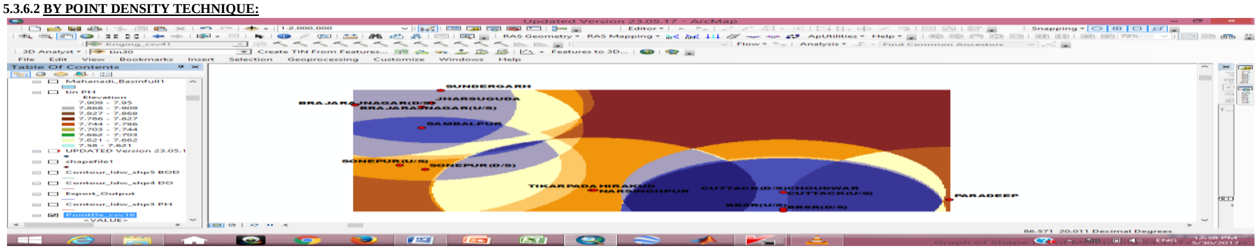


5.3.6 NITRATE:

5.3.6.1 BY SPATIAL ANALYST TECHNIQUE:

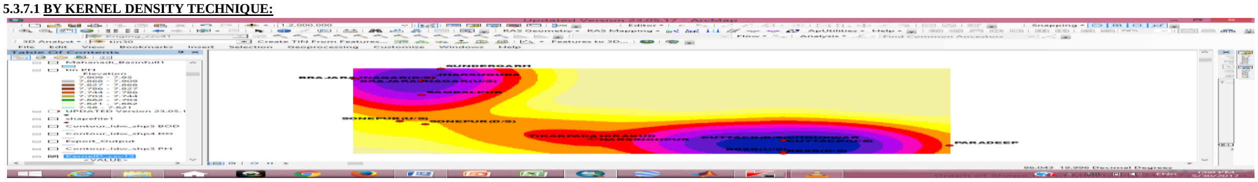


5.3.6.2 BY POINT DENSITY TECHNIQUE:

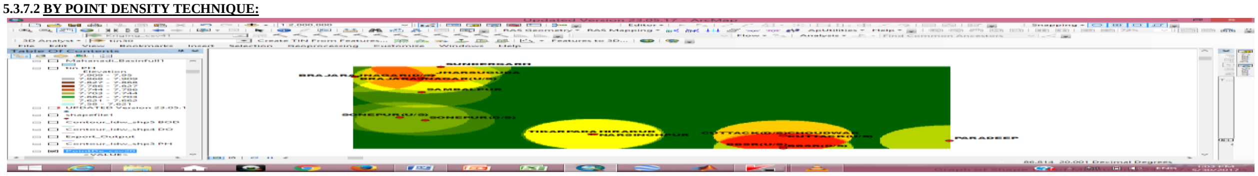


5.3.7 TSS:

5.3.7.1 BY KERNEL DENSITY TECHNIQUE:

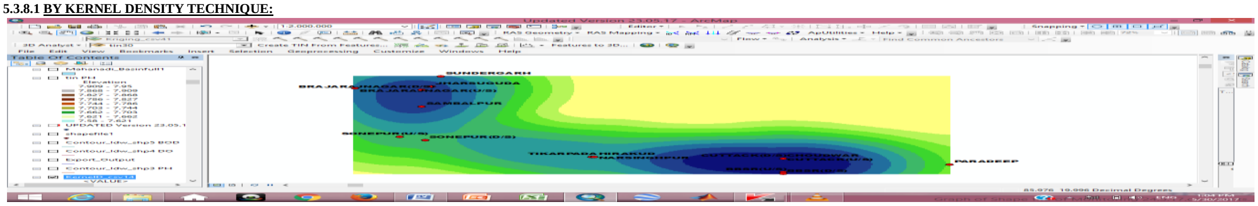


5.3.7.2 BY POINT DENSITY TECHNIQUE:

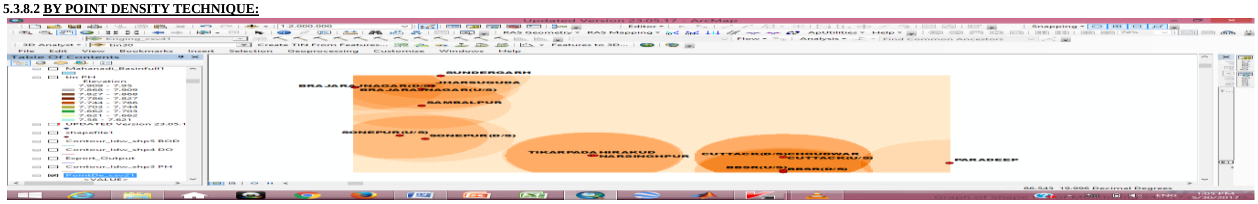


5.3.8 ALKALINITY:

5.3.8.1 BY KERNEL DENSITY TECHNIQUE:

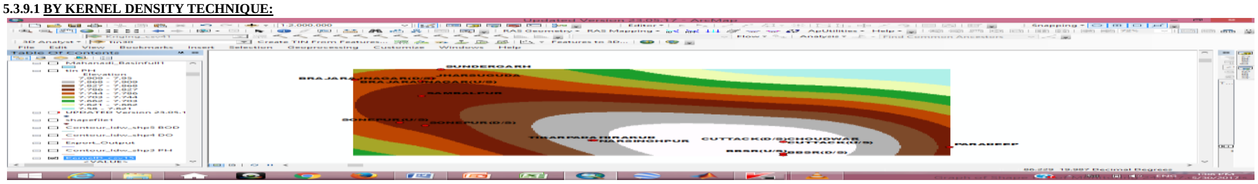


5.3.8.2 BY POINT DENSITY TECHNIQUE:

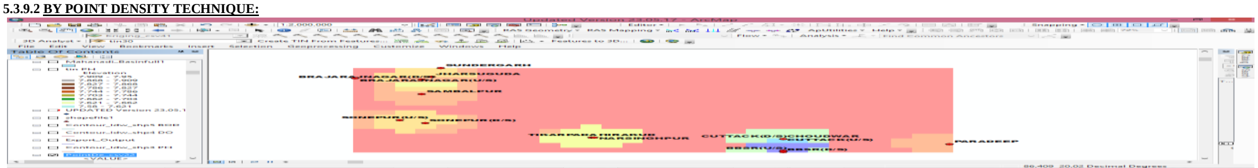


5.3.9 COD:

5.3.9.1 BY KERNEL DENSITY TECHNIQUE:

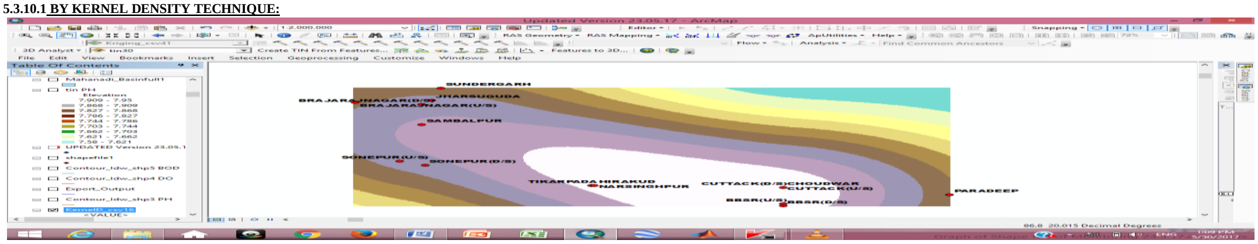


5.3.9.2 BY POINT DENSITY TECHNIQUE:

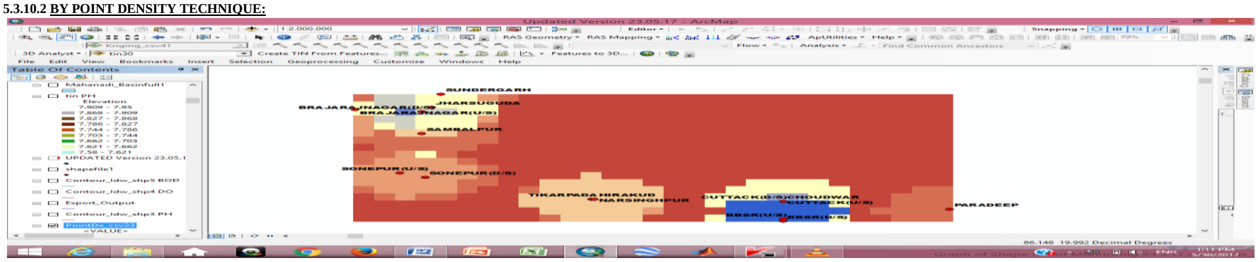


5.3.10 NH_4-N:

5.3.10.1 BY KERNEL DENSITY TECHNIQUE:

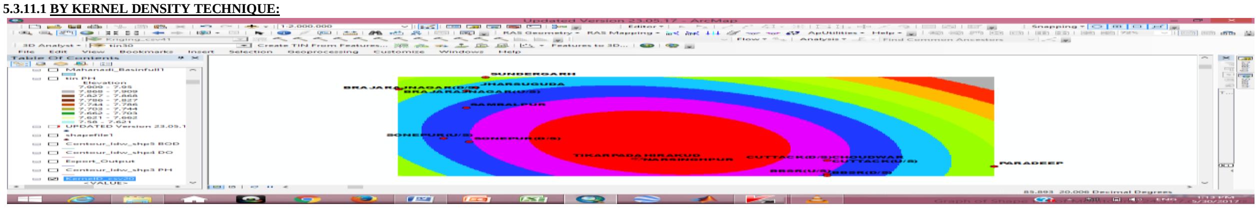


5.3.10.2 BY POINT DENSITY TECHNIQUE:

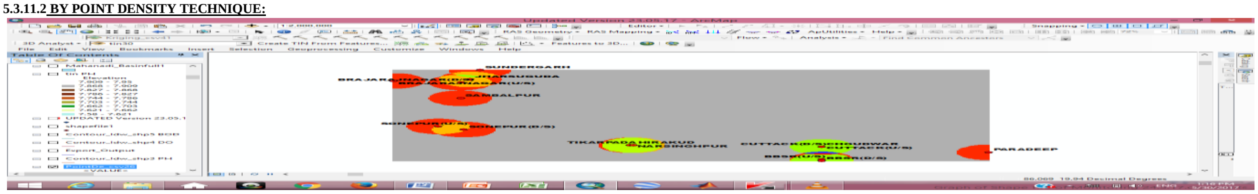


5.3.11 FREE AMMONIA:

5.3.11.1 BY KERNEL DENSITY TECHNIQUE:

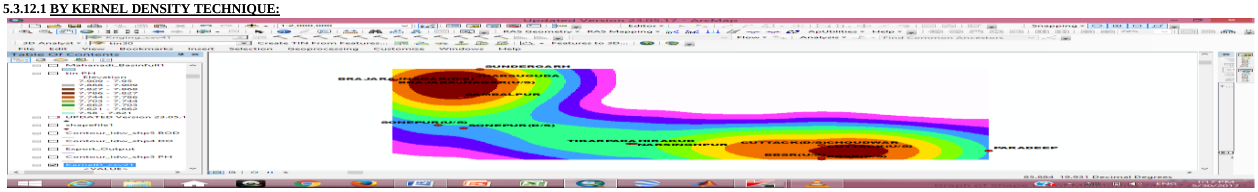


5.3.11.2 BY POINT DENSITY TECHNIQUE:

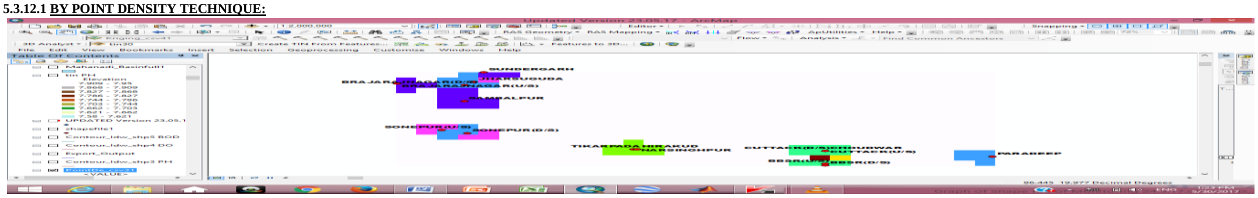


5.3.12 TKN:

5.3.12.1 BY KERNEL DENSITY TECHNIQUE:

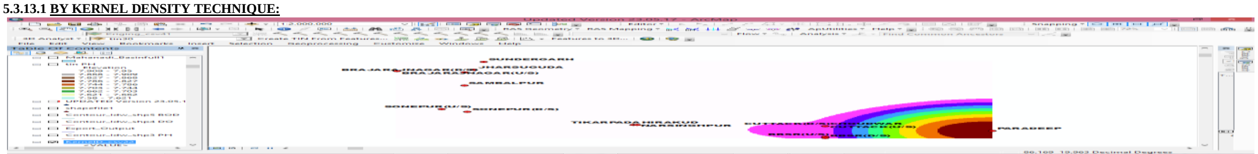


5.3.12.1 BY POINT DENSITY TECHNIQUE:



5.3.13 SAR:

5.3.13.1 BY KERNEL DENSITY TECHNIQUE:



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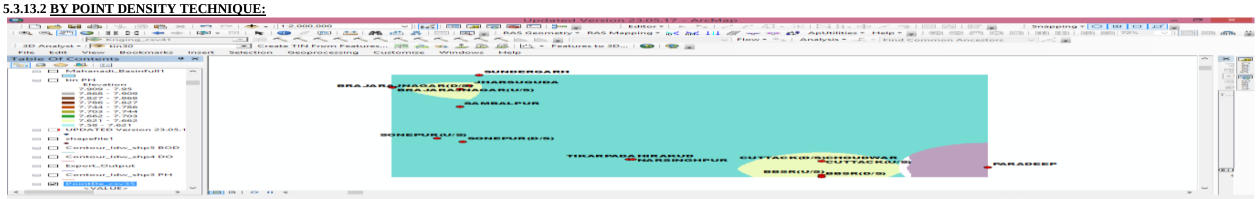
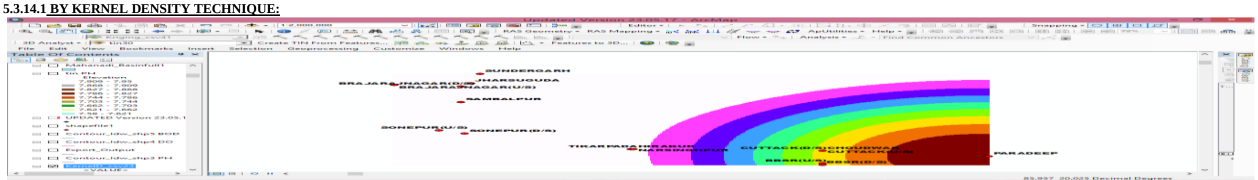
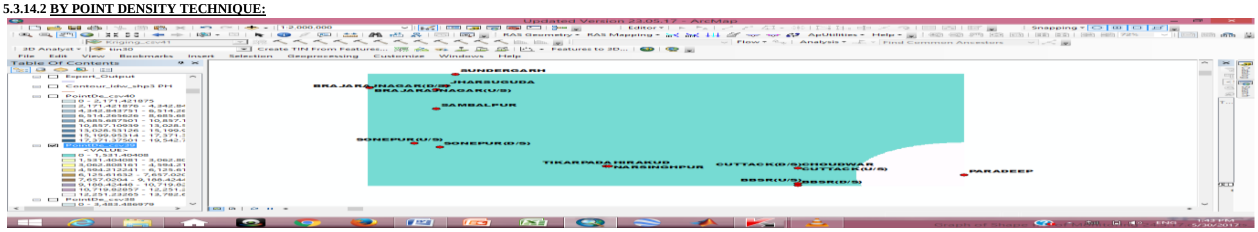


5.3.14 TDS:

5.3.14.1 BY KERNEL DENSITY TECHNIQUE:

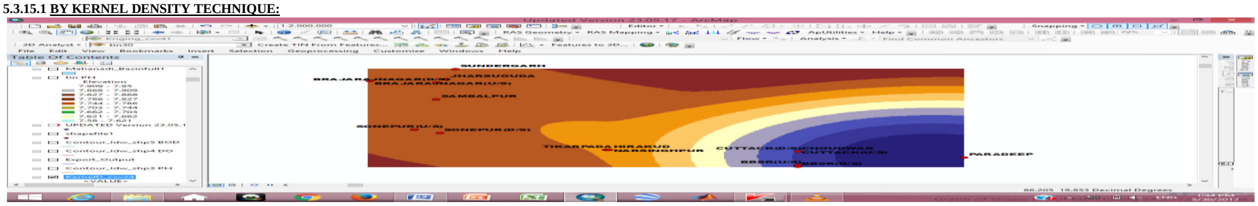


5.3.14.2 **BY POINT DENSITY TECHNIQUE:**

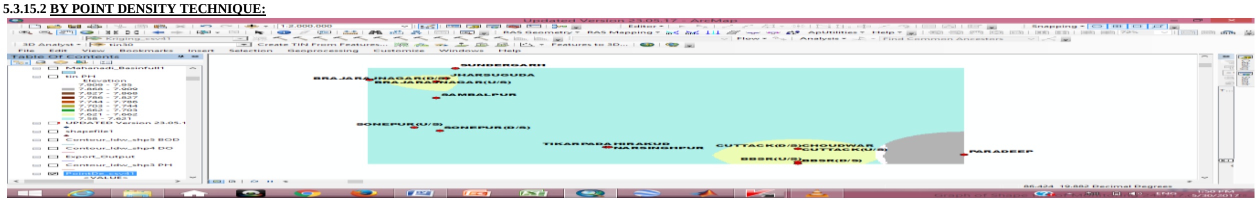


5.3.15 **TH:**

5.3.15.1 **BY KERNEL DENSITY TECHNIQUE:**

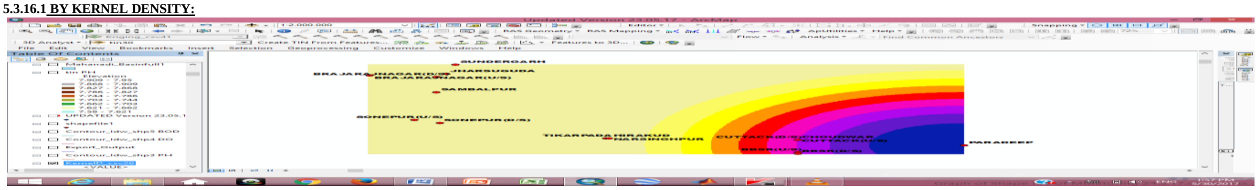


5.3.15.2 **BY POINT DENSITY TECHNIQUE:**

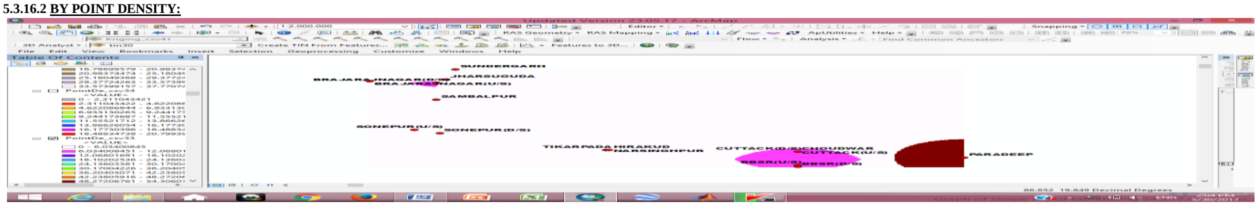


5.3.16 **CHLORIDE:**

5.3.16.1 **BY KERNEL DENSITY:**

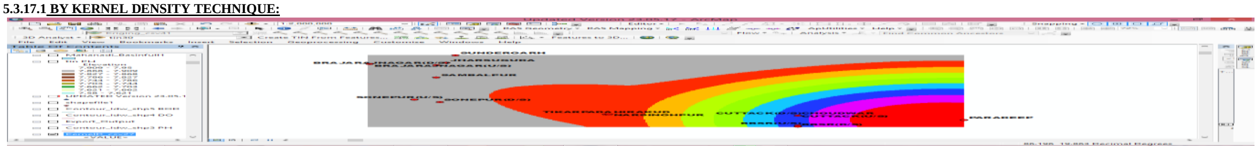


5.3.16.2 **BY POINT DENSITY:**

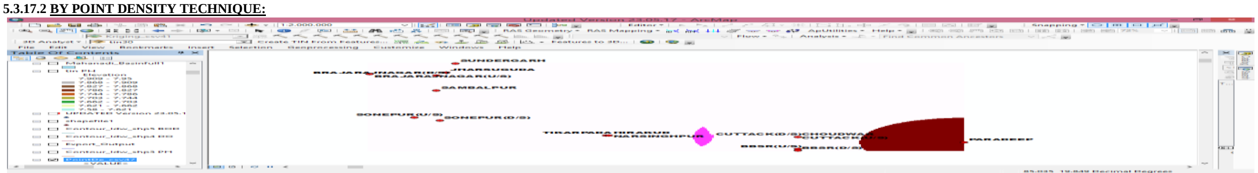


5.3.17 **SULPHATE:**

5.3.17.1 **BY KERNEL DENSITY TECHNIQUE:**

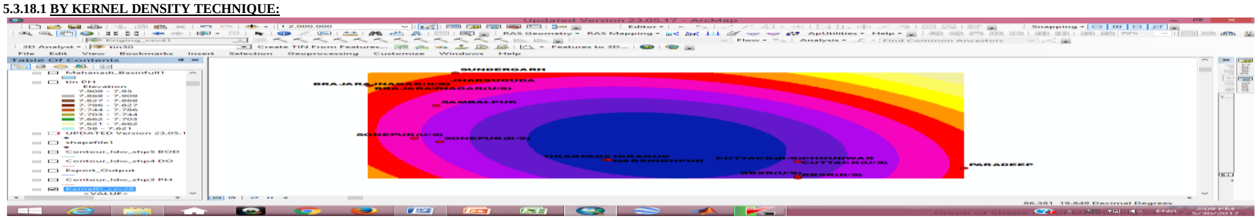


5.3.17.2 **BY POINT DENSITY TECHNIQUE:**

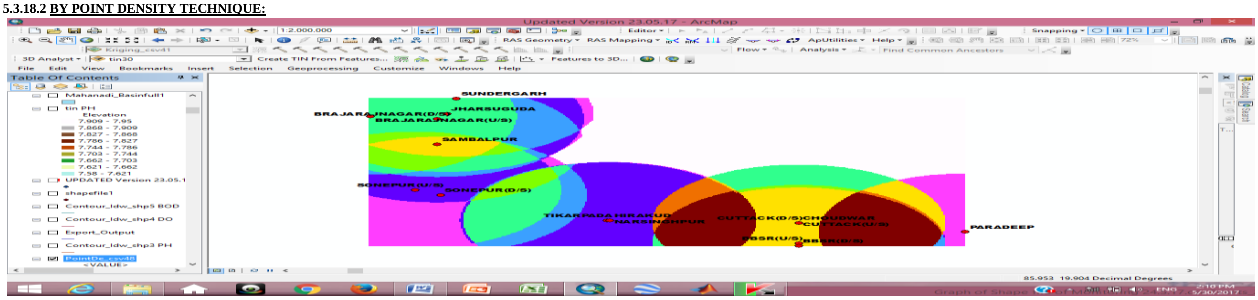


5.3.18 **FLUORIDE:**

5.3.18.1 **BY KERNEL DENSITY TECHNIQUE:**

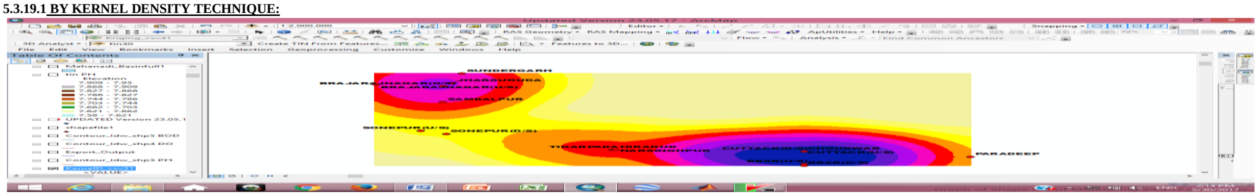


5.3.18.2 BY POINT DENSITY TECHNIQUE:

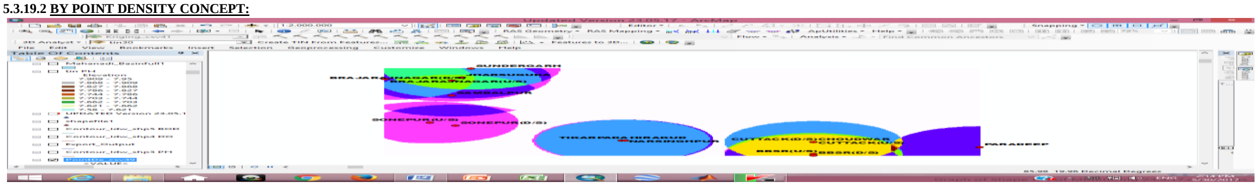


5.3.19 FE:

5.3.19.1 BY KERNEL DENSITY TECHNIQUE:



5.3.19.2 BY POINT DENSITY CONCEPT:

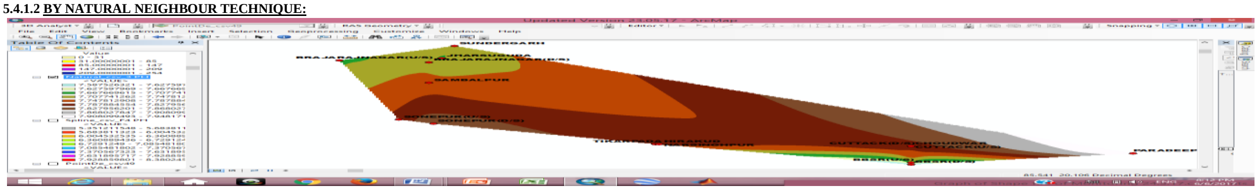


5.4 QUALITY PARAMETERS MODELLING USING SPLINE, NATURAL NEIGHBOUR AND TOPO TO RASTER USING GIS APPLICATION:

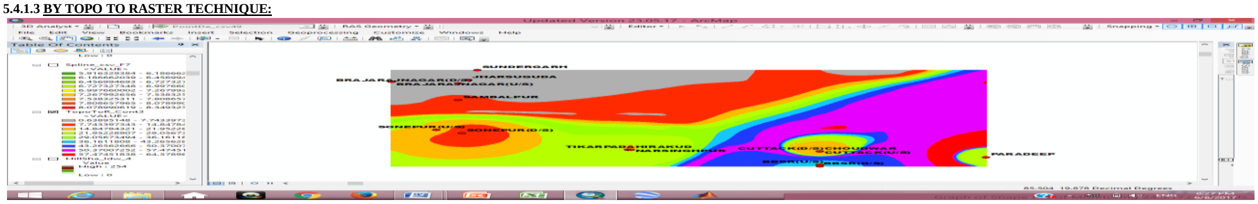
5.4.1 PH:

5.4.1.1 BY SPLINE TECHNIQUE:

5.4.1.2 BY NATURAL NEIGHBOUR TECHNIQUE:

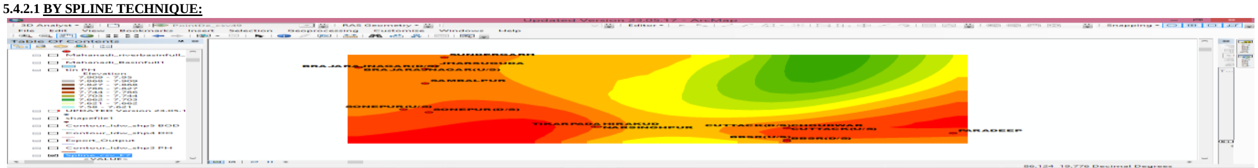


5.4.1.3 BY TOPO TO RASTER TECHNIQUE:



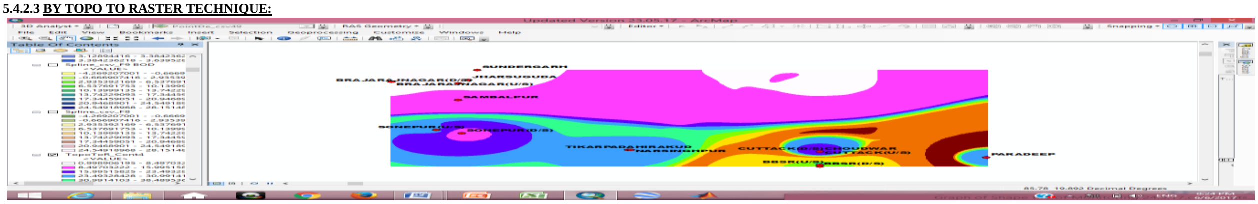
5.4.2 DO:

5.4.2.1 BY SPLINE TECHNIQUE:



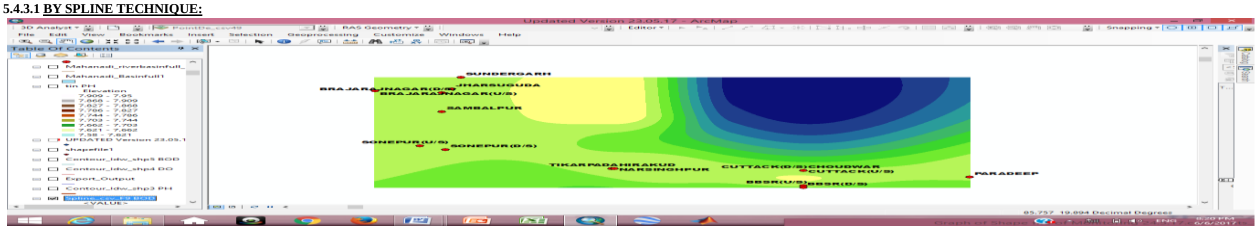
5.4.2.2 BY NATURAL NEIGHBOUR TECHNIQUE:

5.4.2.3 **BY TOPO TO RASTER TECHNIQUE:**

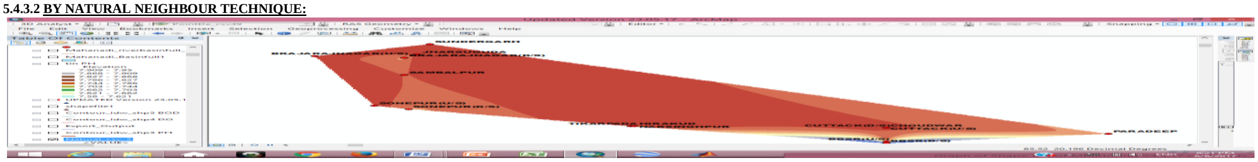


5.4.3 **BOD:**

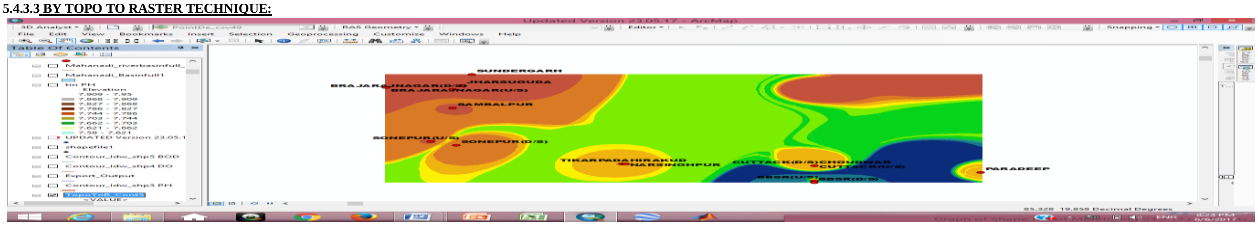
5.4.3.1 **BY SPLINE TECHNIQUE:**



5.4.3.2 **BY NATURAL NEIGHBOUR TECHNIQUE:**

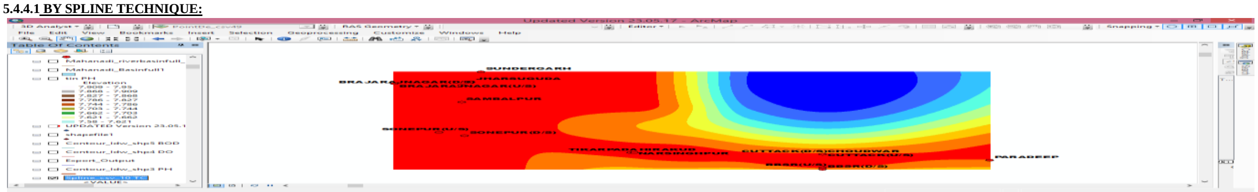


5.4.3.3 **BY TOPO TO RASTER TECHNIQUE:**

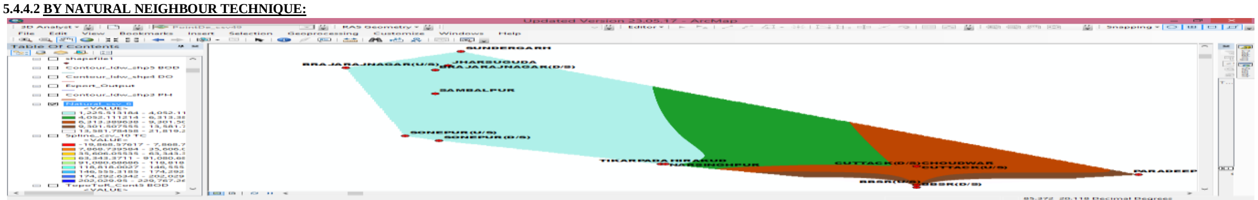


5.4.4 **TC:**

5.4.4.1 **BY SPLINE TECHNIQUE:**



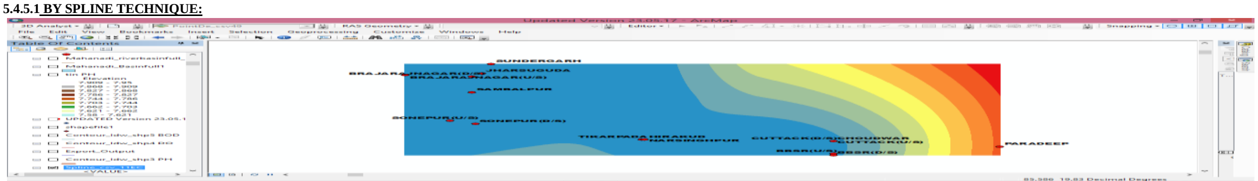
5.4.4.2 **BY NATURAL NEIGHBOUR TECHNIQUE:**



5.4.4.3 **BY TOPO TO RASTER TECHNIQUE:**

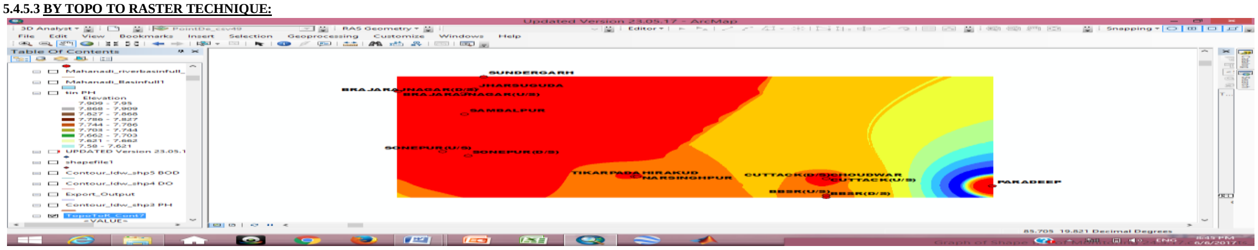
5.4.5 **EC:**

5.4.5.1 **BY SPLINE TECHNIQUE:**



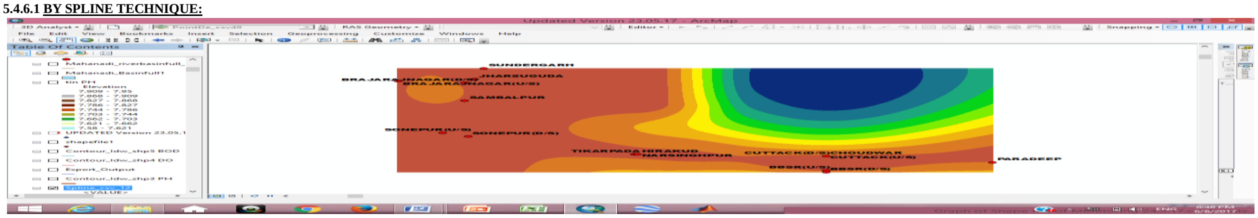
5.4.5.2 BY NATURAL NEIGHBOUR TECHNIQUE:

5.4.5.3 BY TOPO TO RASTER TECHNIQUE:

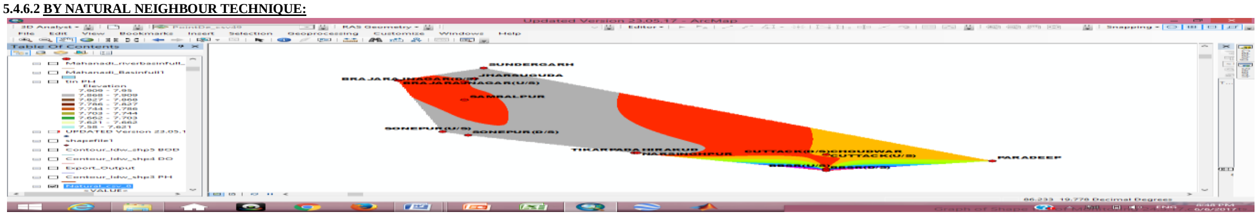


5.4.6 NITRATE:

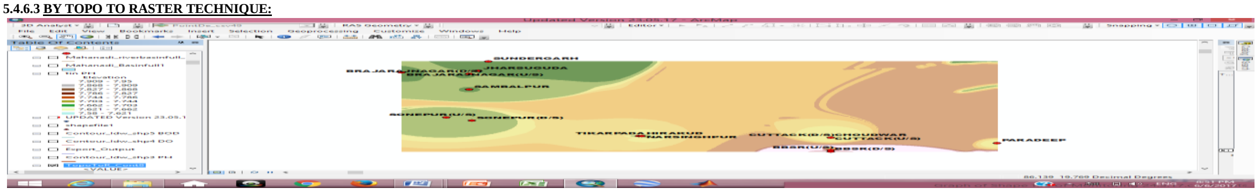
5.4.6.1 BY SPLINE TECHNIQUE:



5.4.6.2 BY NATURAL NEIGHBOUR TECHNIQUE:

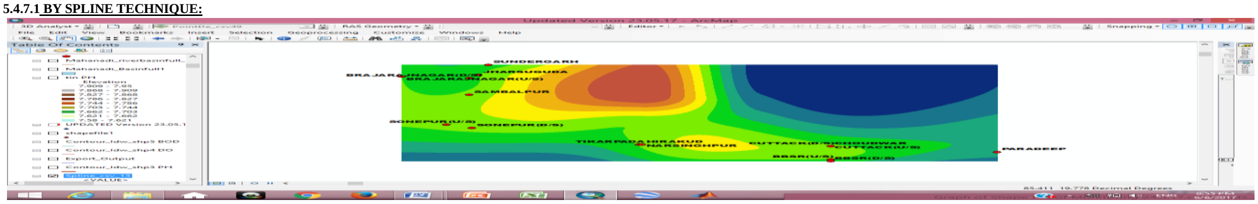


5.4.6.3 BY TOPO TO RASTER TECHNIQUE:

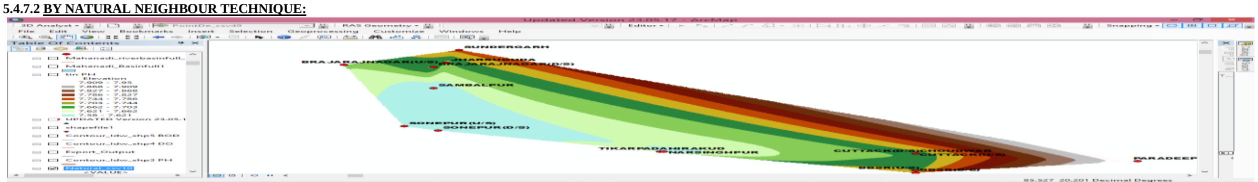


5.4.7 TSS:

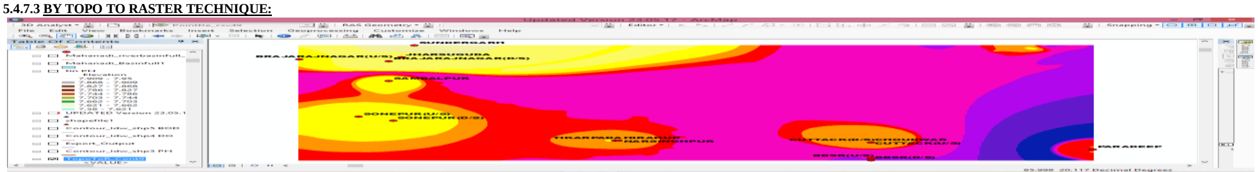
5.4.7.1 BY SPLINE TECHNIQUE:



5.4.7.2 BY NATURAL NEIGHBOUR TECHNIQUE:

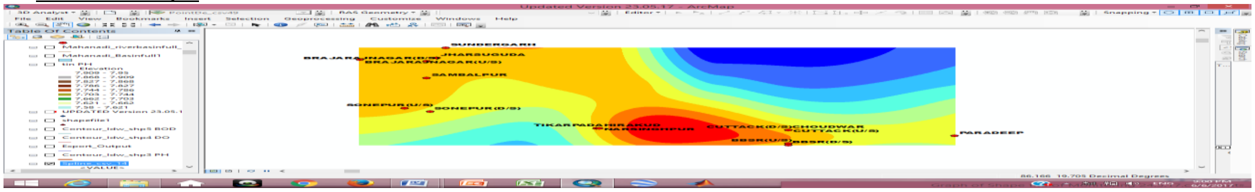


5.4.7.3 BY TOPO TO RASTER TECHNIQUE:



5.4.8 ALKALINITY:

5.4.8.1 BY SPLINE TECHNIQUE:



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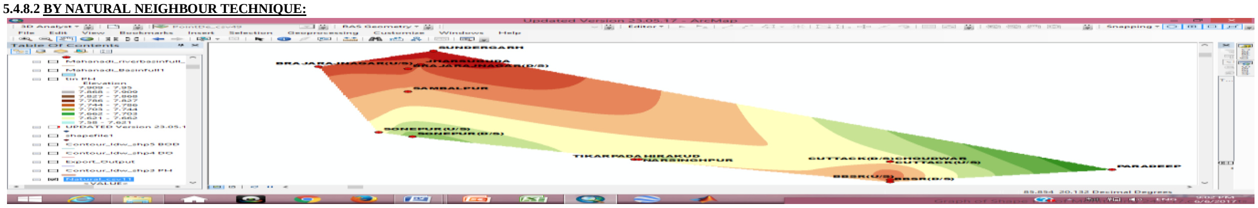
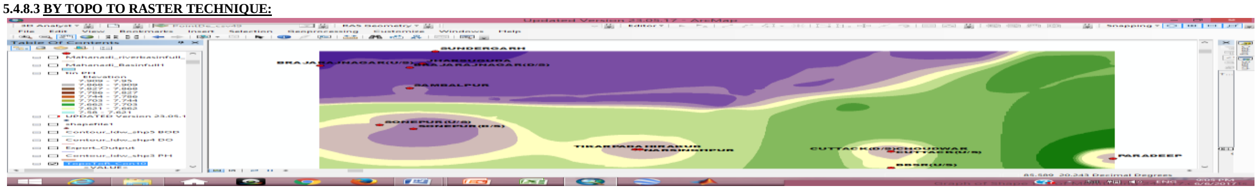
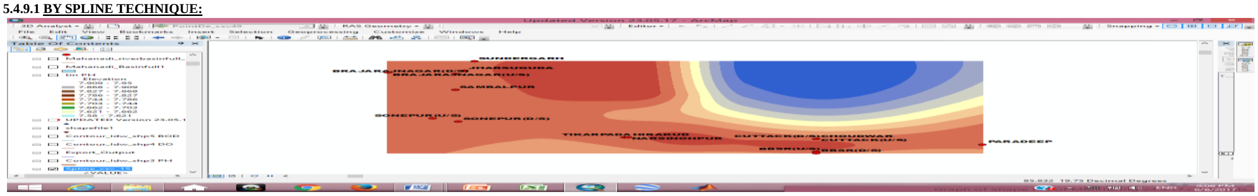


5.4.8.3 BY TOPO TO RASTER TECHNIQUE:



5.4.9 COD:

5.4.9.1 BY SPLINE TECHNIQUE:



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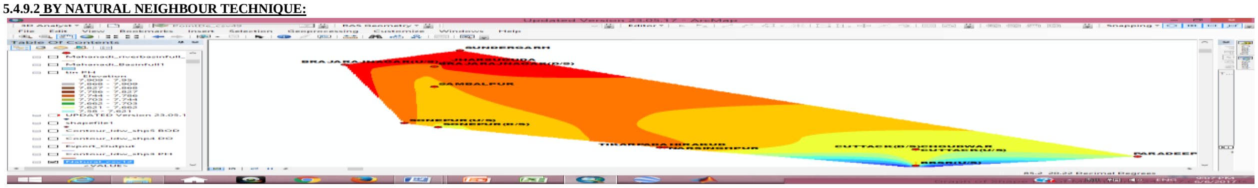
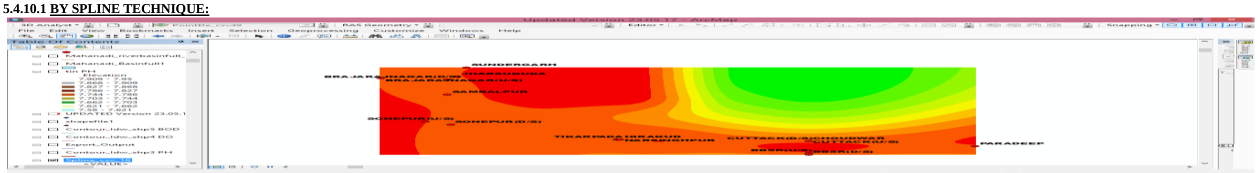


5.4.9.3 BY TOPO TO RASTER TECHNIQUE:

5.4.10 NH_4-N:

5.4.10.1 BY SPLINE TECHNIQUE:



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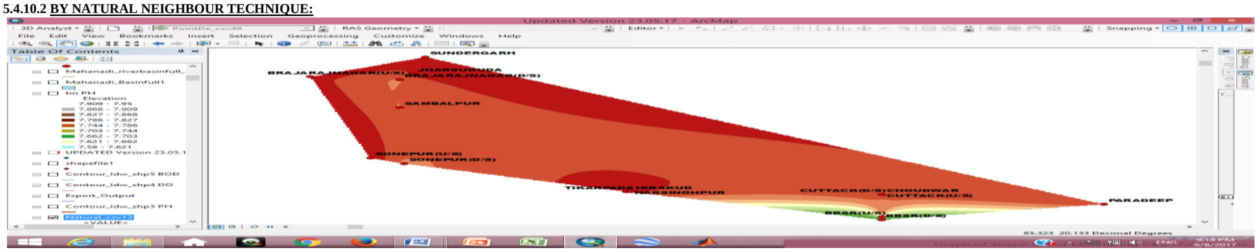
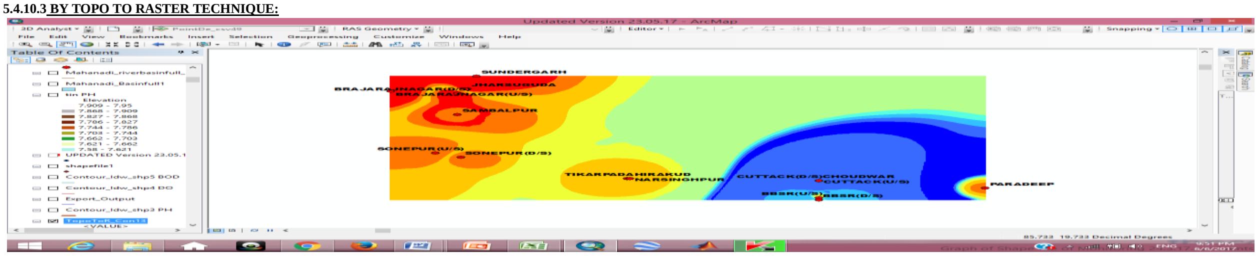
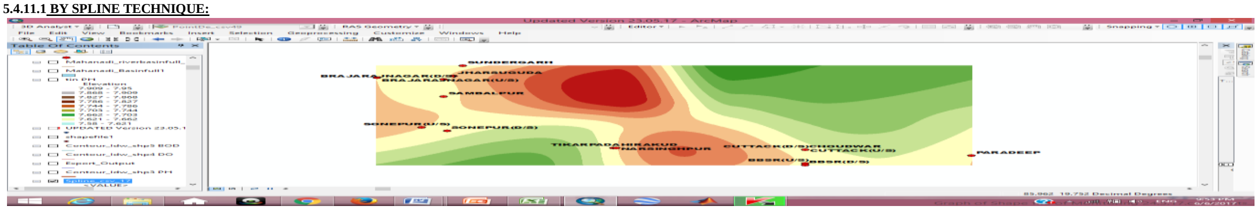


5.4.10.3 BY TOPO TO RASTER TECHNIQUE:



5.4.11 FREE NH_3:

5.4.11.1 BY SPLINE TECHNIQUE:



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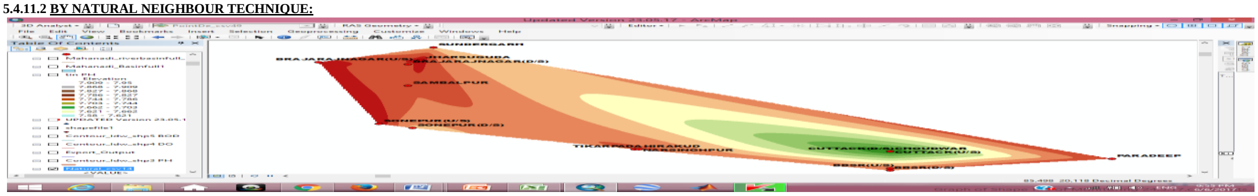
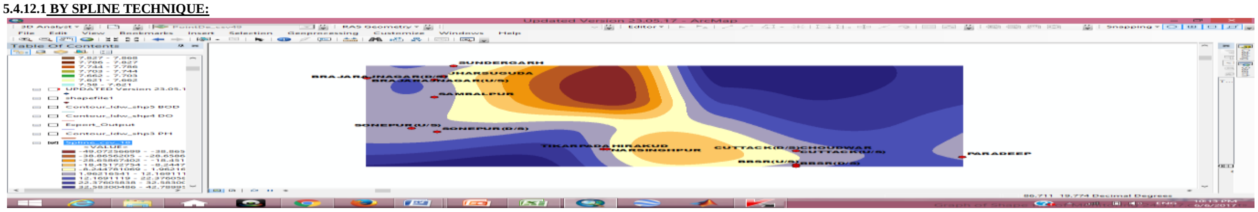


5.4.11.3 BY TOPO TO RASTER TECHNIQUE:

5.4.12 TKN:

5.4.12.1 BY SPLINE TECHNIQUE:



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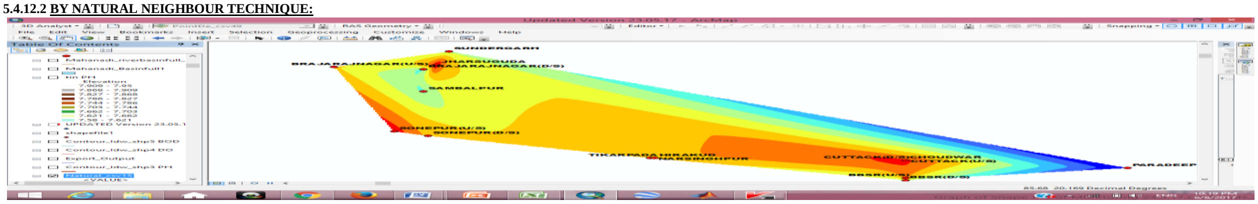
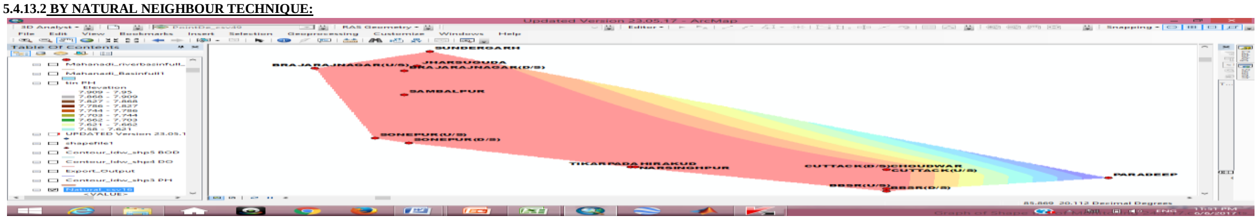


5.4.12.3 BY TOPO TO RASTER TECHNIQUE:

5.4.13 SAR:

5.4.13.1 BY SPLINE TECHNIQUE:

5.4.13.2 BY NATURAL NEIGHBOUR TECHNIQUE:

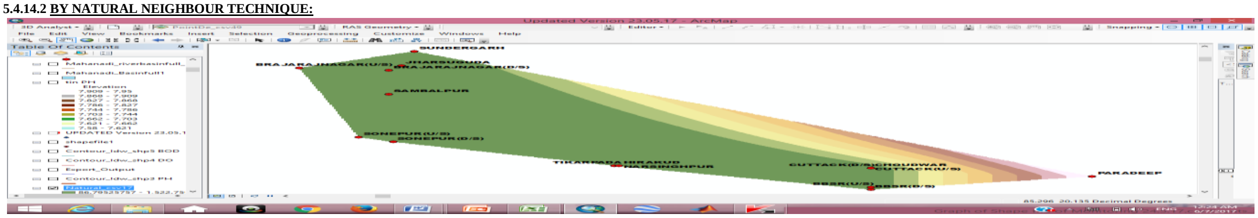


5.4.13.3 BY TOPO TO RASTER TECHNIQUE:

5.4.14 TDS:

5.4.14.1 BY SPLINE TECHNIQUE:

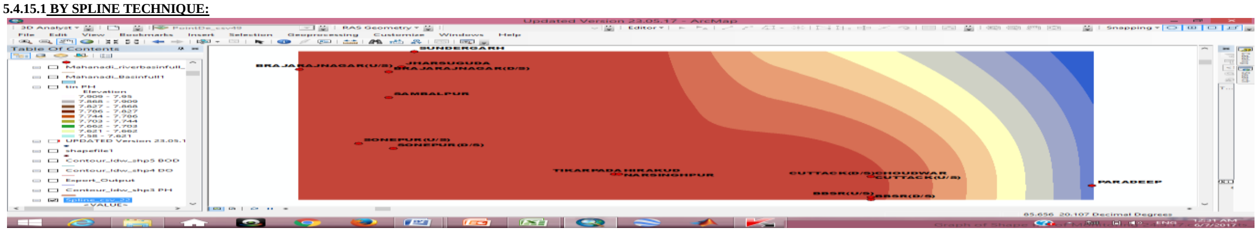
5.4.14.2 BY NATURAL NEIGHBOUR TECHNIQUE:



5.4.14.3 BY TOPO TO RASTER TECHNIQUE:

5.4.15 TH:

5.4.15.1 BY SPLINE TECHNIQUE:

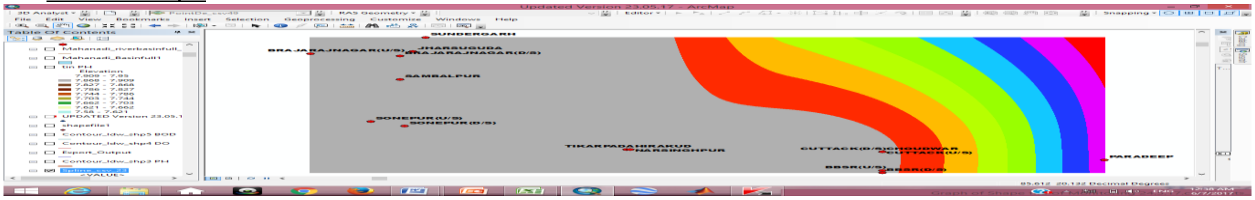


5.4.15.2 BY NATURAL NEIGHBOUR TECHNIQUE:

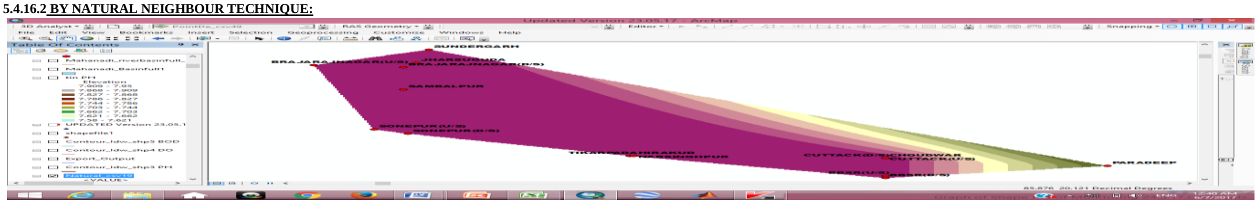
5.4.15.3 BY TOPO TO RASTER TECHNIQUE:

5.4.16 CHLORINE:

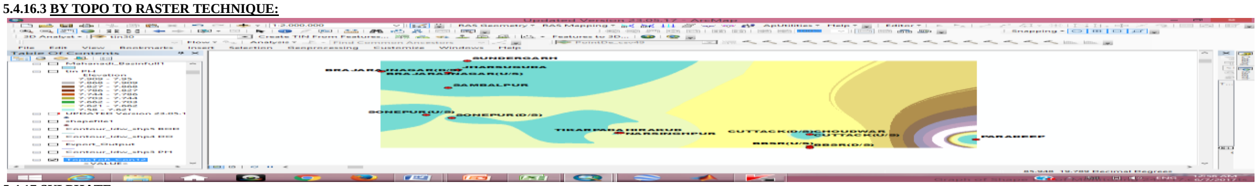
5.4.16.1 BY SPLINE TECHNIQUE:



5.4.16.2 BY NATURAL NEIGHBOUR TECHNIQUE:

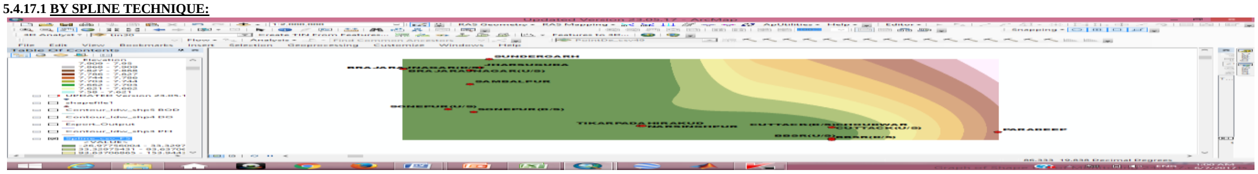


5.4.16.3 BY TOPO TO RASTER TECHNIQUE:

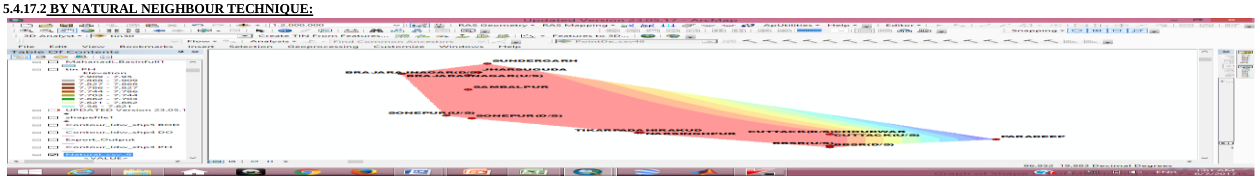


5.4.17 SULPHATE:

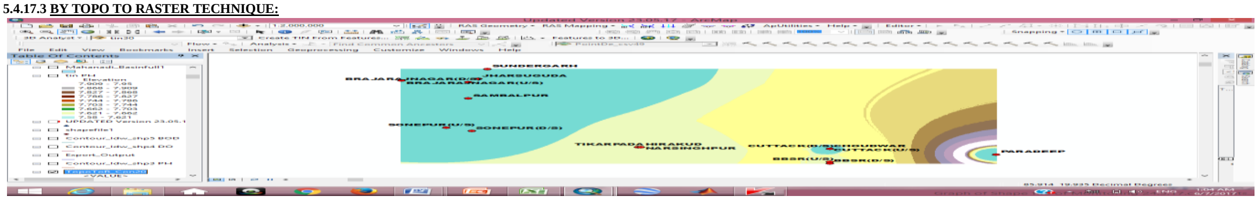
5.4.17.1 BY SPLINE TECHNIQUE:



5.4.17.2 BY NATURAL NEIGHBOUR TECHNIQUE:

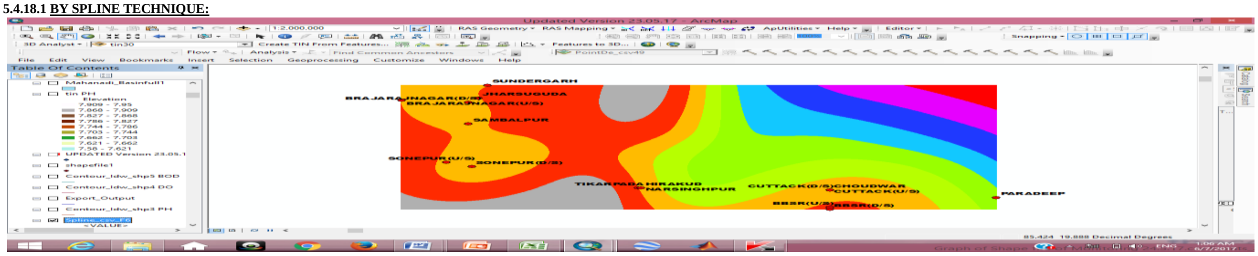


5.4.17.3 BY TOPO TO RASTER TECHNIQUE:



5.4.18 FLUORIDE:

5.4.18.1 BY SPLINE TECHNIQUE:



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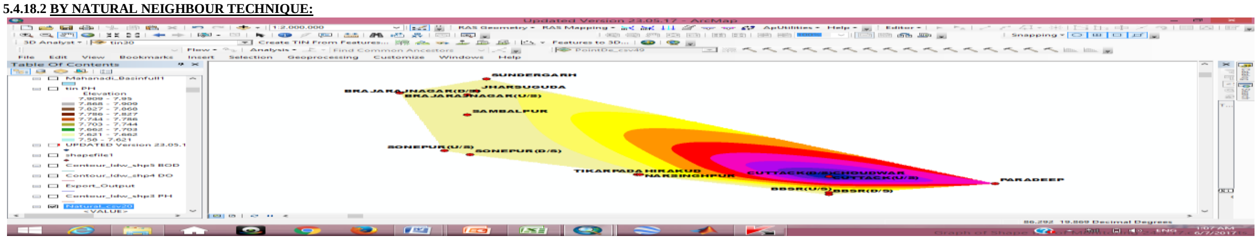

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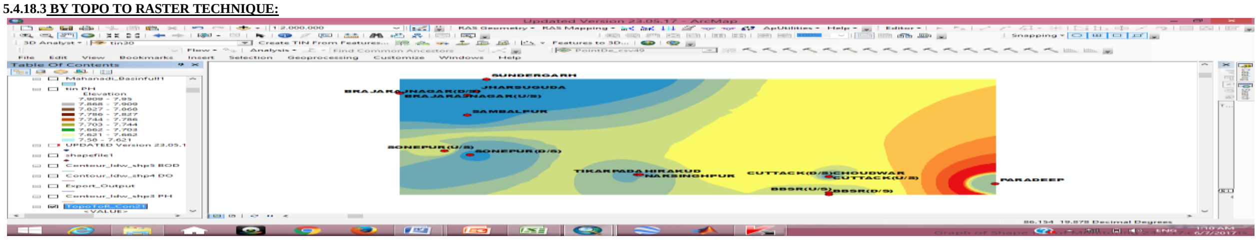
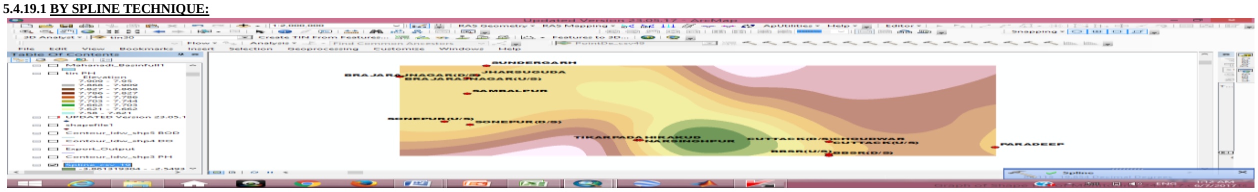
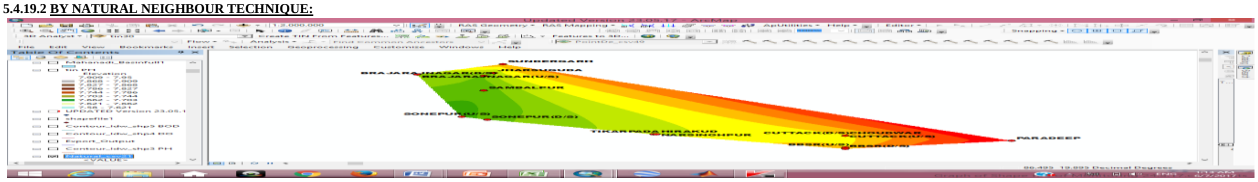


5.4.19 IRON:

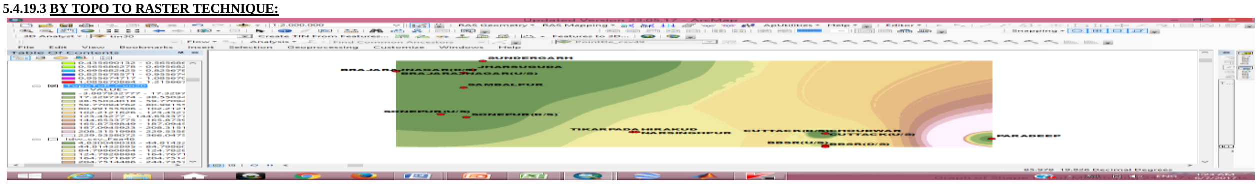
5.4.19.1 BY SPLINE TECHNIQUE:



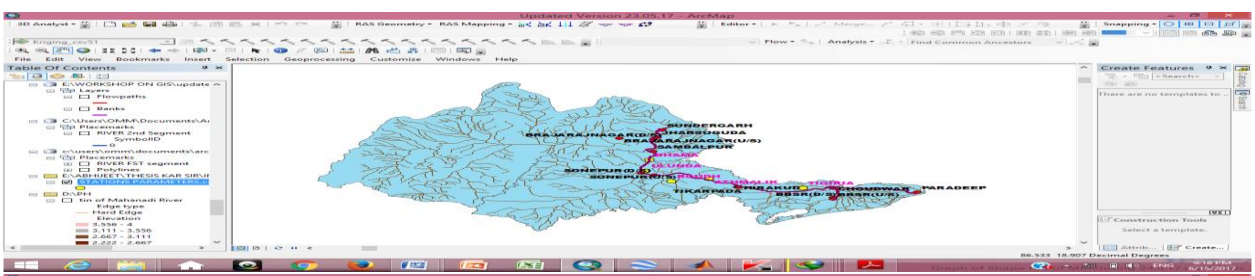
5.4.19.2 BY NATURAL NEIGHBOUR TECHNIQUE:

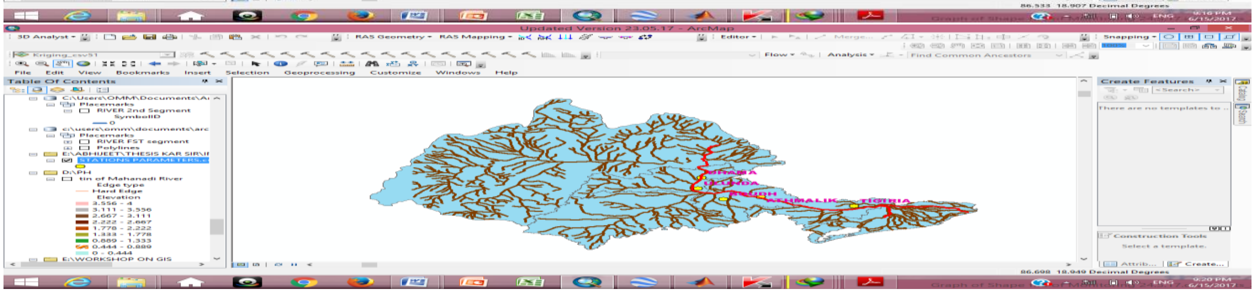


5.4.19.3 BY TOPO TO RASTER TECHNIQUE:



5.5 PLOTTING OF INTERPOLATED STATIONS (DHAMA, ULUNDA, BOUDH, ATHMALIK, TIGIRIA) USING GIS APPLICATION:

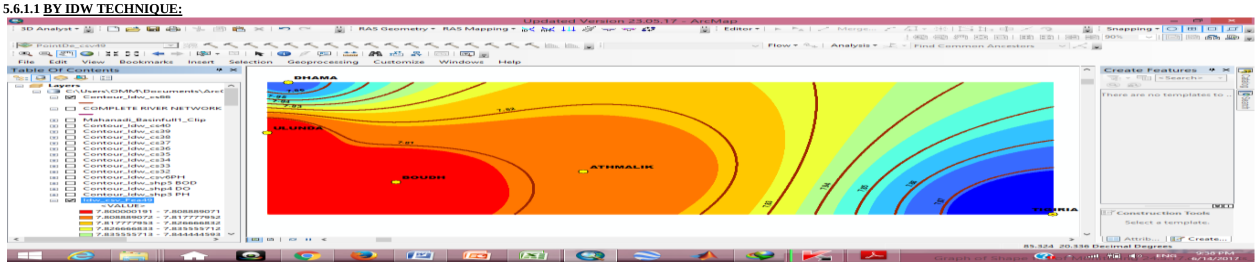




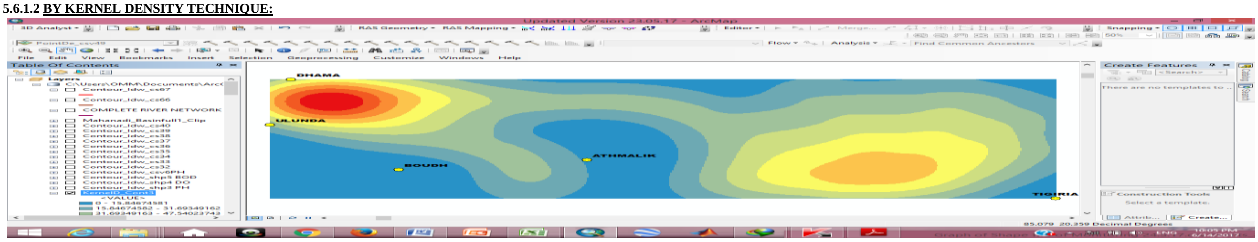
5.6 WATER QUALITY ANALYSIS OF INTERPOLATED STATIONS USING GIS APPLICATION

5.6.1 PH:

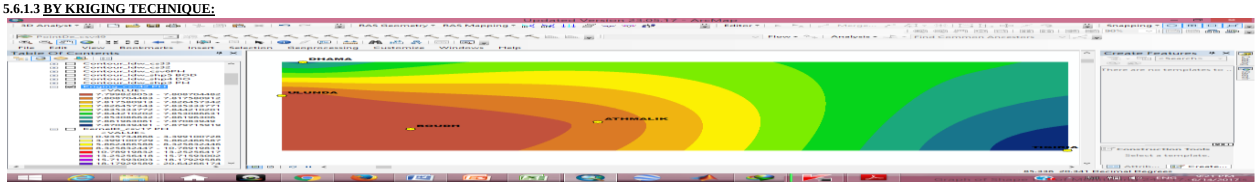
5.6.1.1 BY IDW TECHNIQUE:



5.6.1.2 BY KERNEL DENSITY TECHNIQUE:

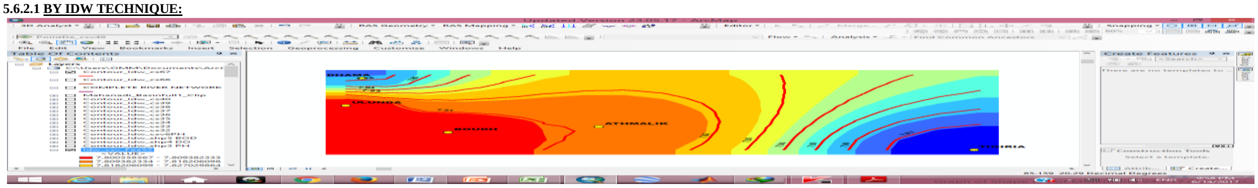


5.6.1.3 BY KRIGING TECHNIQUE:

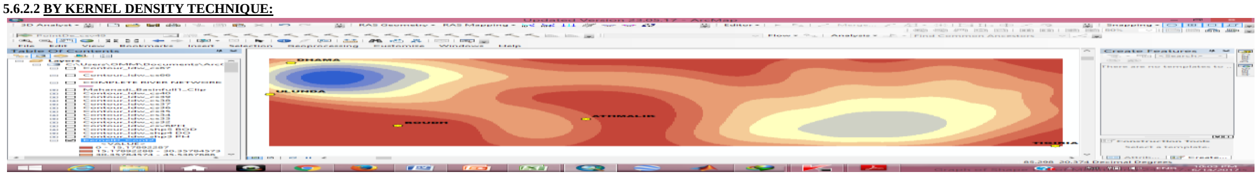


5.6.2 DO:

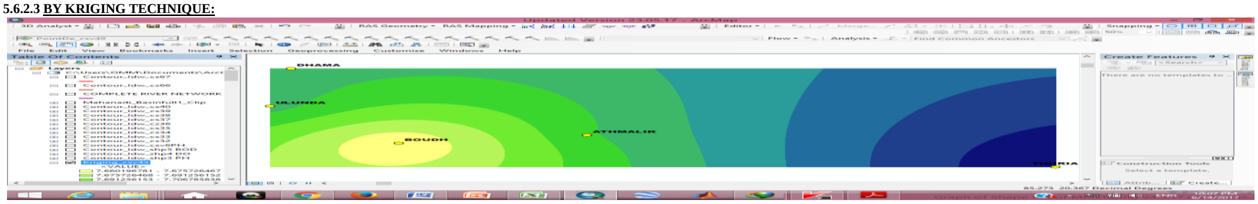
5.6.2.1 BY IDW TECHNIQUE:



5.6.2.2 BY KERNEL DENSITY TECHNIQUE:

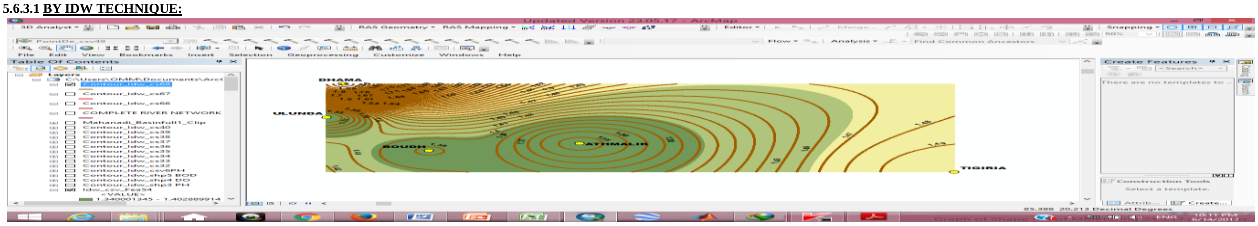


5.6.2.3 BY KRIGING TECHNIQUE:



5.6.3 BOD:

5.6.3.1 BY IDW TECHNIQUE:



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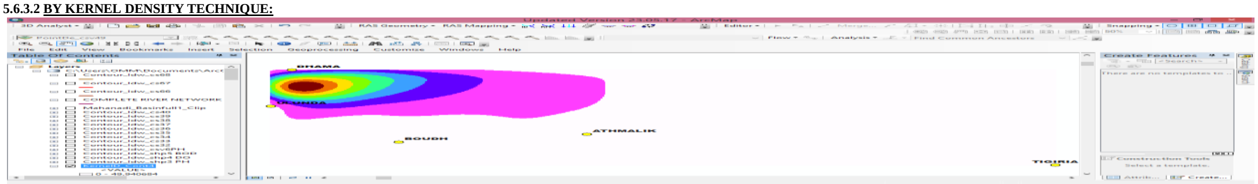

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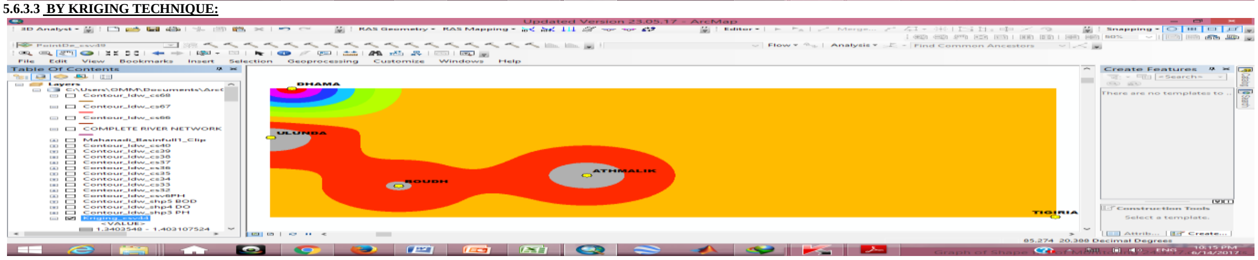
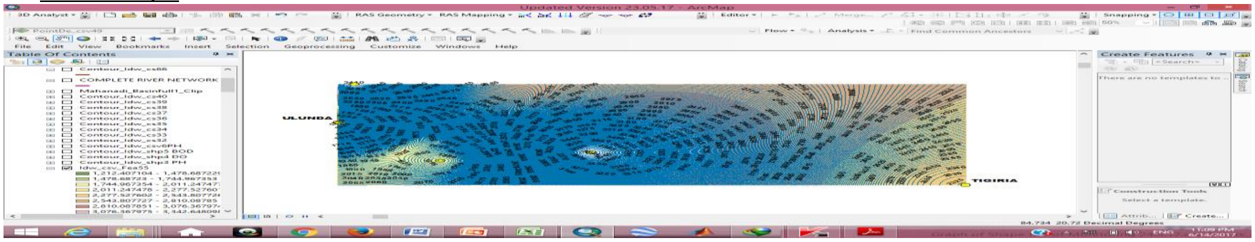


5.6.4 TC:

5.6.4.1 BY IDW TECHNIQUE:



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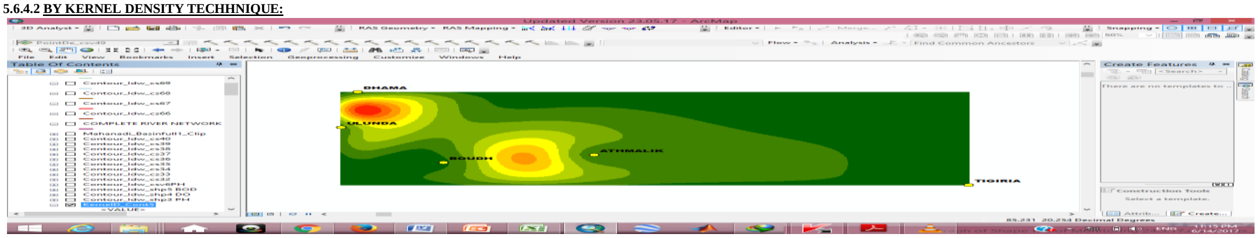
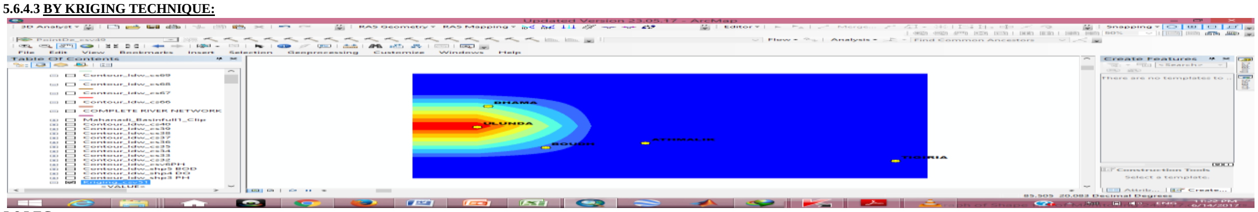


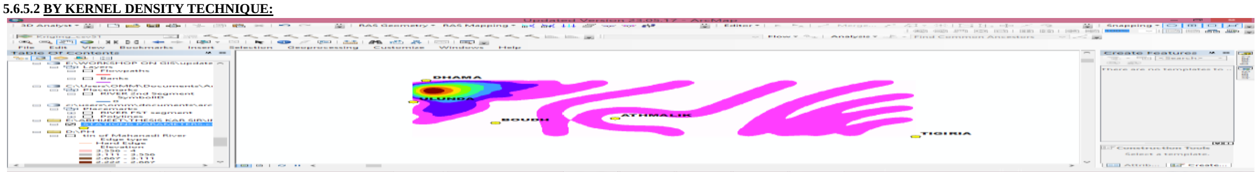
5.6.4.3 BY KRIGING TECHNIQUE:



5.6.5 EC:

5.6.5.1 BY IDW TECHNIQUE:

5.6.5.2 BY KERNEL DENSITY TECHNIQUE:



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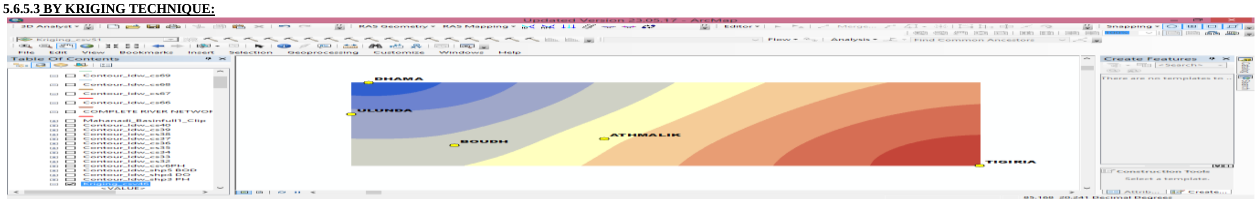

5.6.6 NITRATE:

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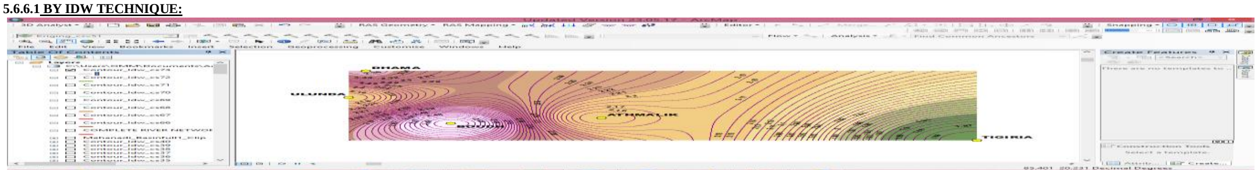
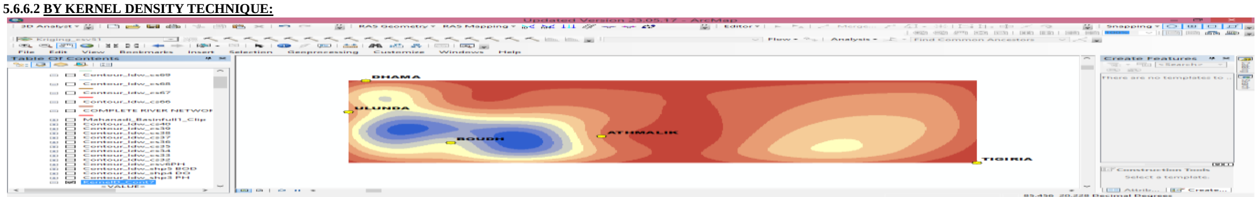


5.6.6.2 BY KERNEL DENSITY TECHNIQUE:



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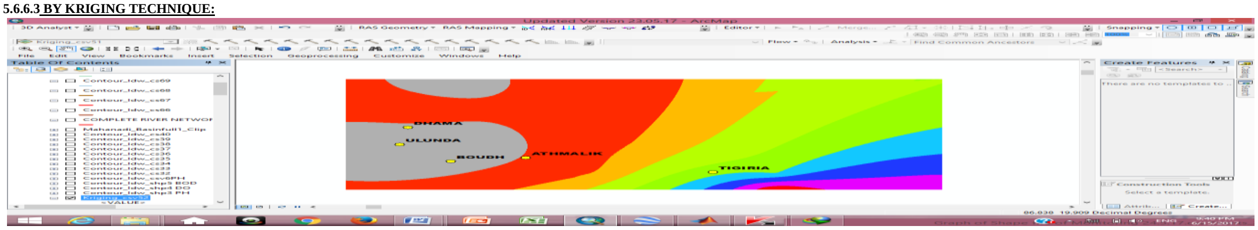
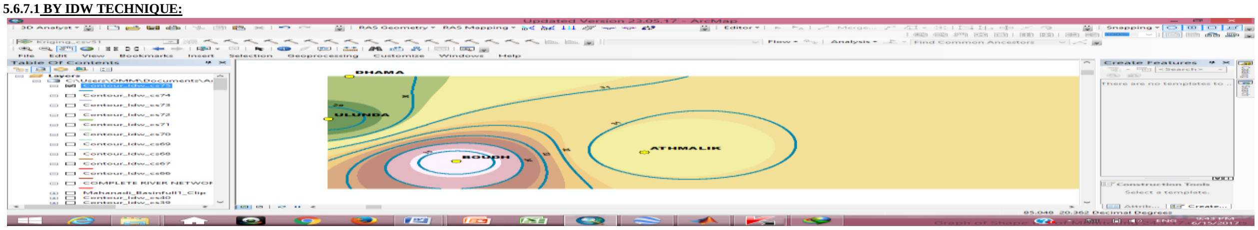


5.6.7 TSS:

5.6.7.1 BY IDW TECHNIQUE:

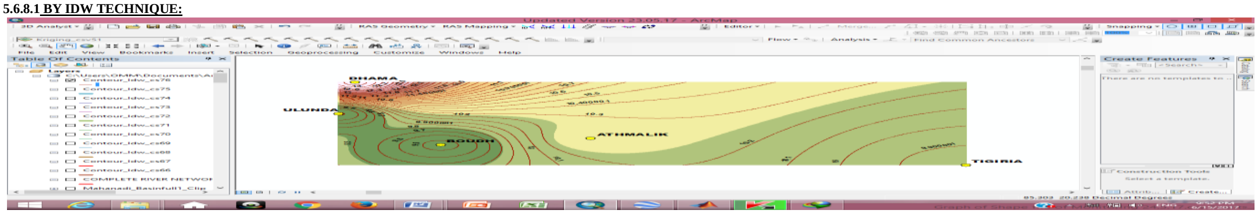


5.6.7.2 BY KERNEL DENSITY TECHNIQUE:

5.6.7.3 BY KRIGING TECHNIQUE:

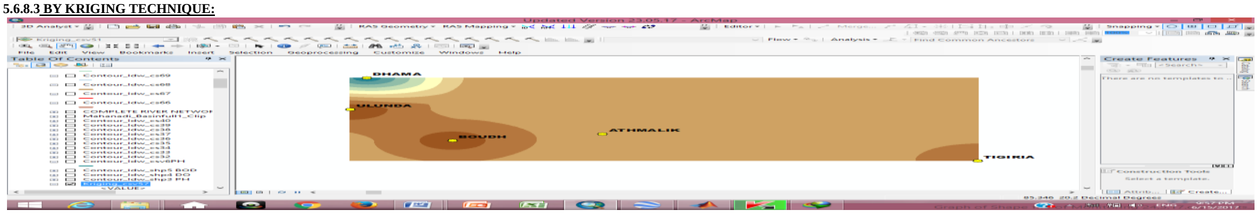
5.6.8 COD:

5.6.8.1 BY IDW TECHNIQUE:



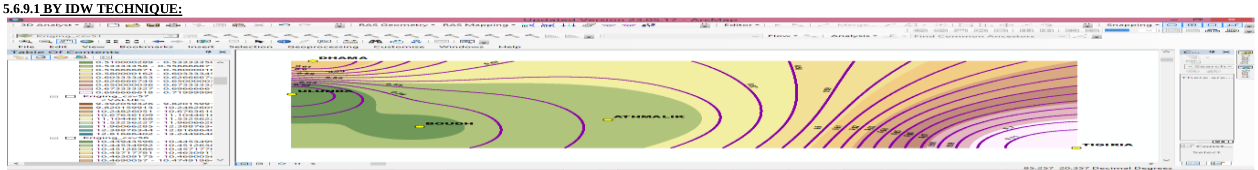
5.6.8.2 BY KERNEL DENSITY TECHNIQUE:

5.6.8.3 BY KRIGING TECHNIQUE:



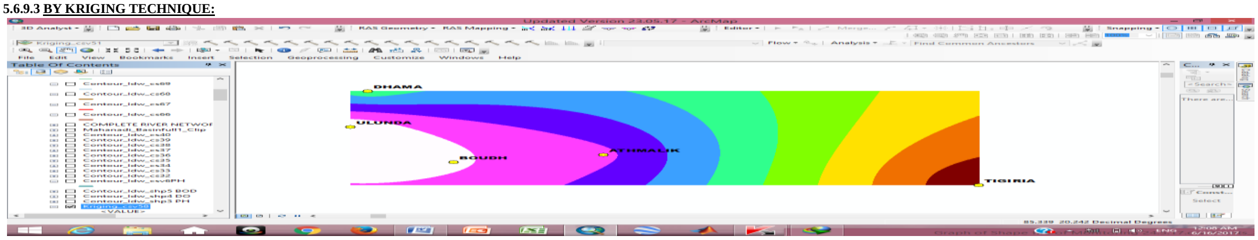
5.6.9 NH_4-N:

5.6.9.1 BY IDW TECHNIQUE:



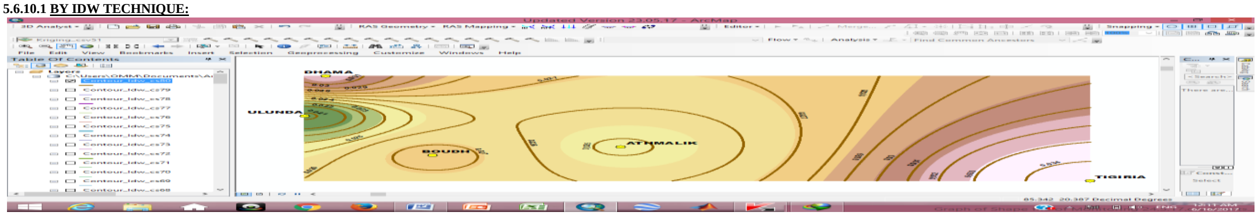
5.6.9.2 **BY KERNEL DENSITY TECHNIQUE:**

5.6.9.3 **BY KRIGING TECHNIQUE:**



5.6.10 **FREE NH_3:**

5.6.10.1 **BY IDW TECHNIQUE:**



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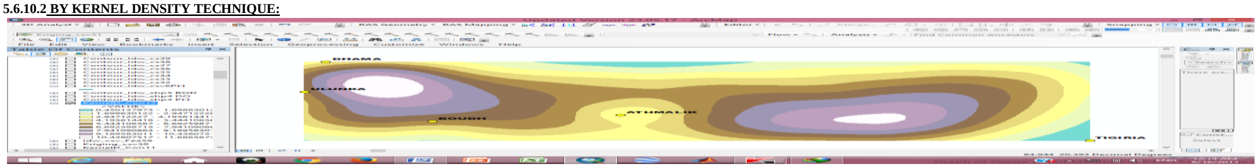

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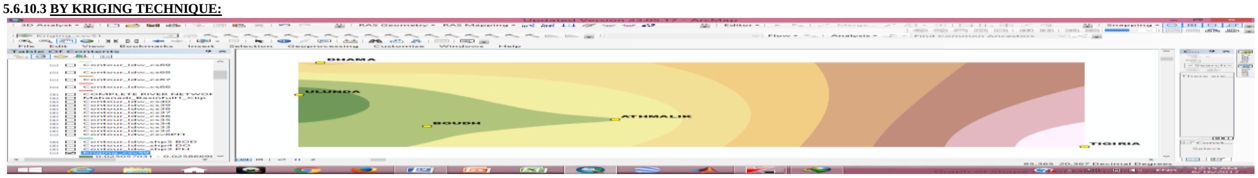
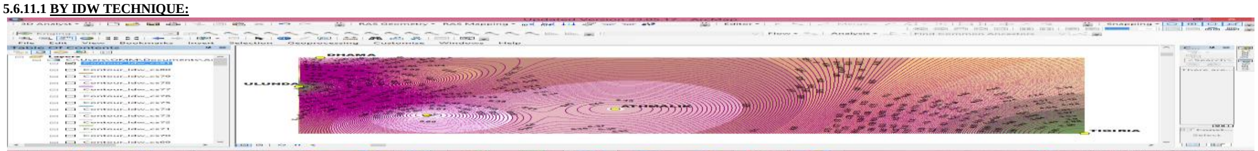


5.6.11 **TKN:**

5.6.11.1 **BY IDW TECHNIQUE:**



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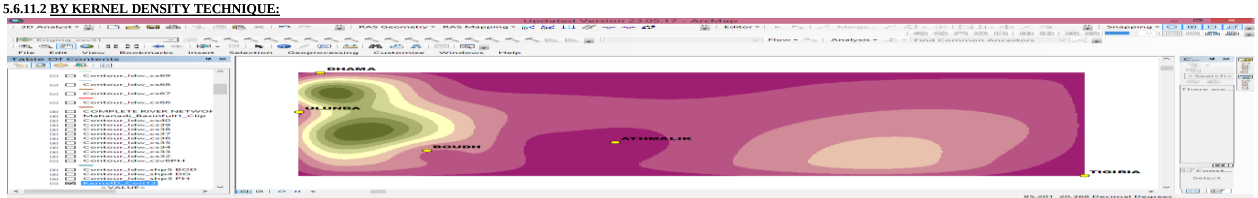

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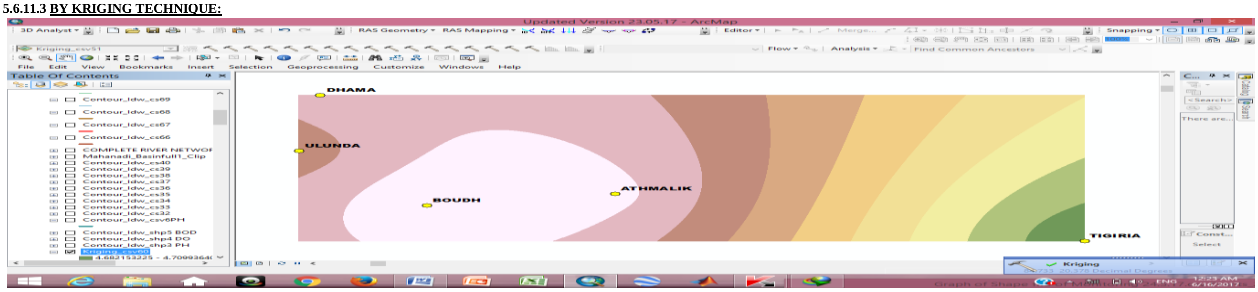
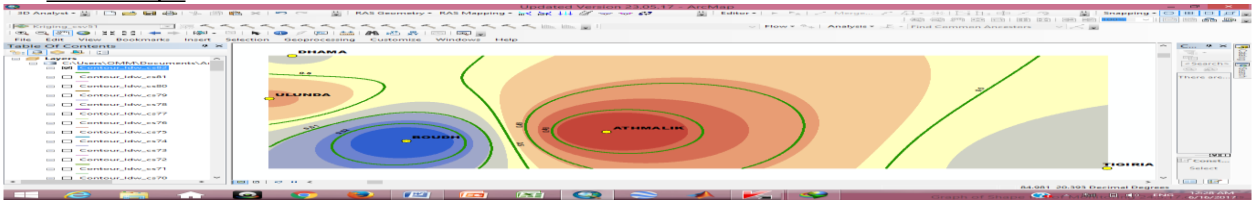


5.6.12 SAR:

5.6.12.1 BY IDW TECHNIQUE:



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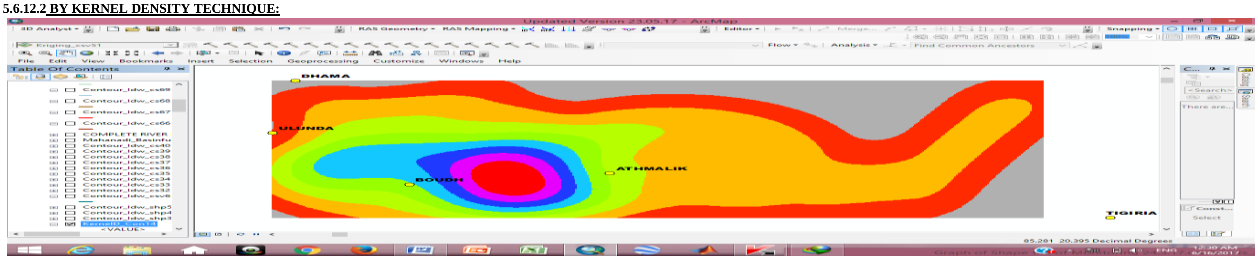

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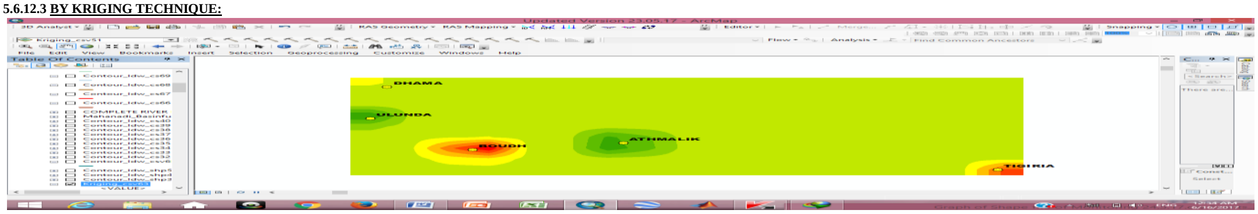
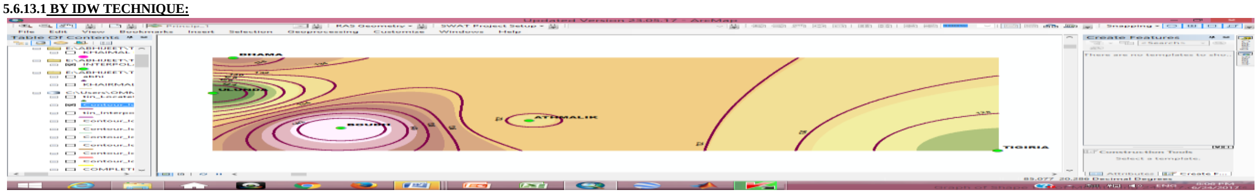


5.6.13 TDS:

5.6.13.1 BY IDW TECHNIQUE:



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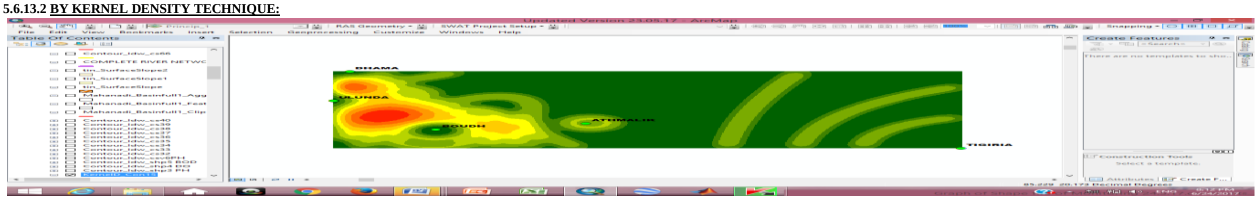

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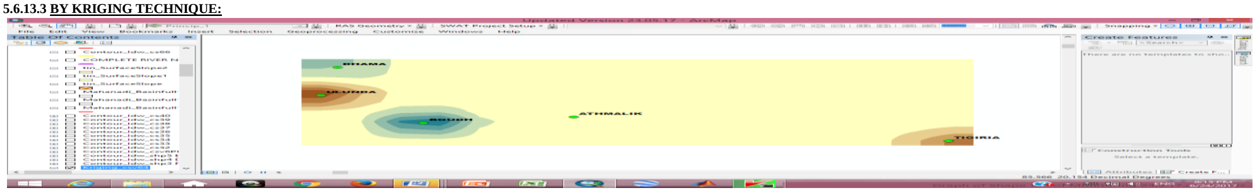
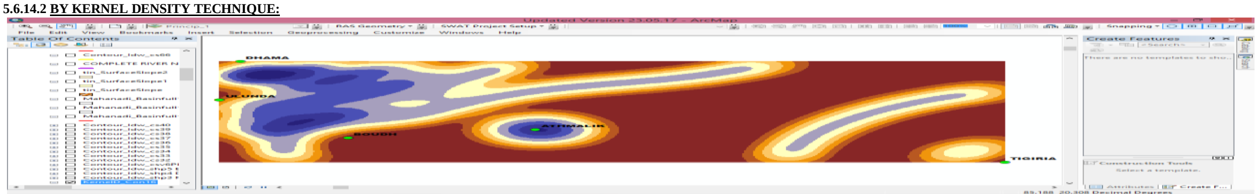


5.6.14 TH:

5.6.14.1 BY IDW TECHNIQUE:

5.6.14.2 BY KERNEL DENSITY TECHNIQUE:



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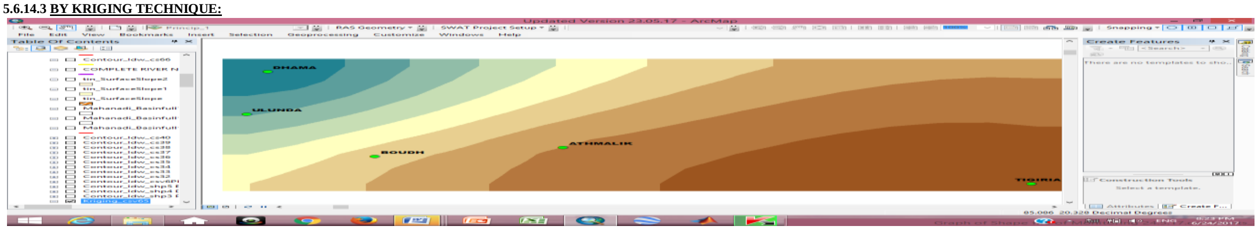
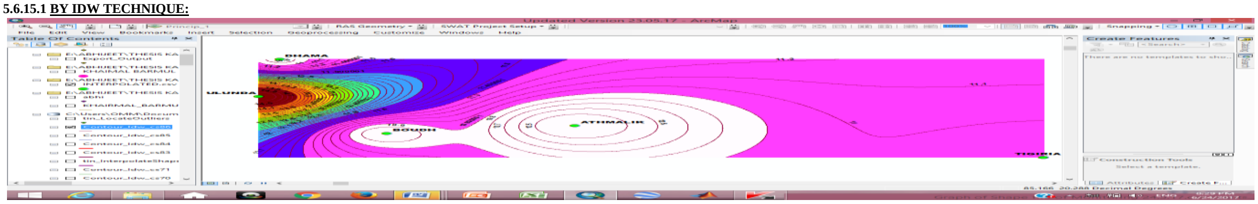


5.6.15 **CHLORIDE:**

5.6.15.1 **BY IDW TECHNIQUE:**



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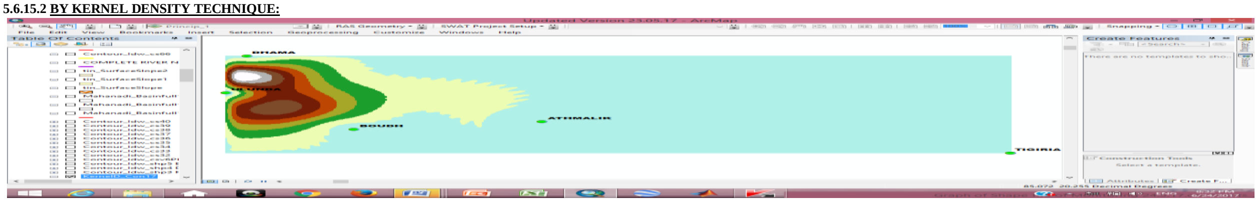

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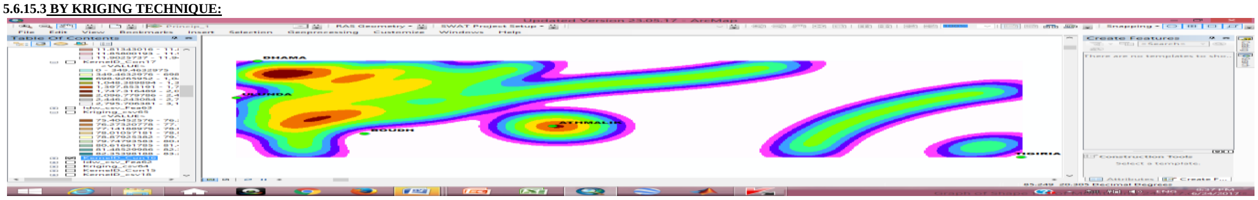
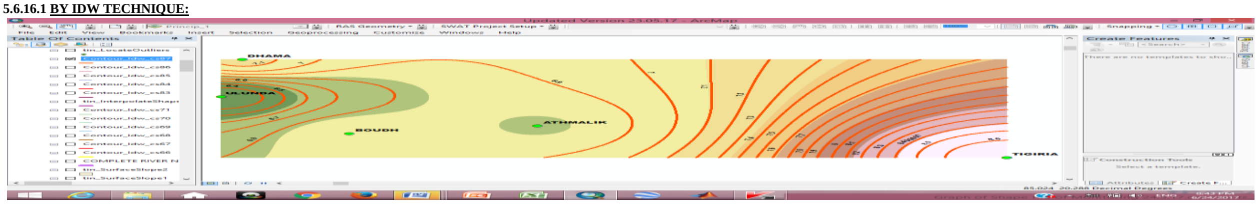
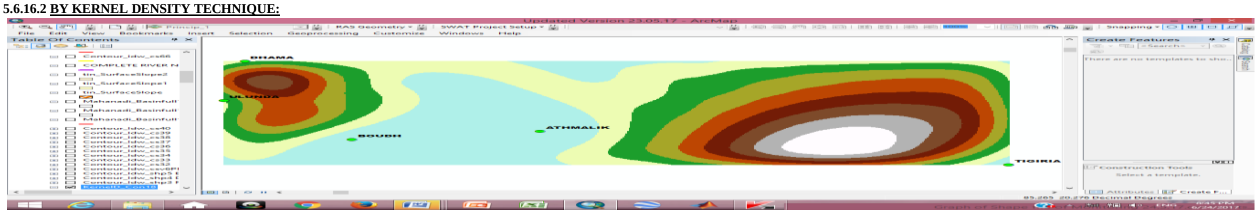


5.6.16 **SULPHATE:**

5.6.16.1 **BY IDW TECHNIQUE:**



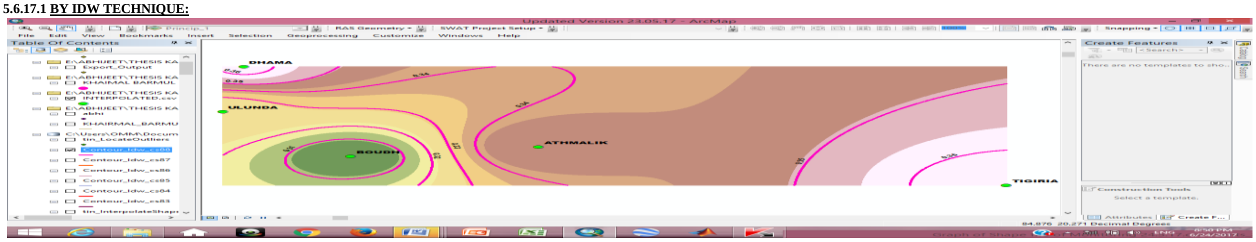
5.6.16.2 **BY KERNEL DENSITY TECHNIQUE:**



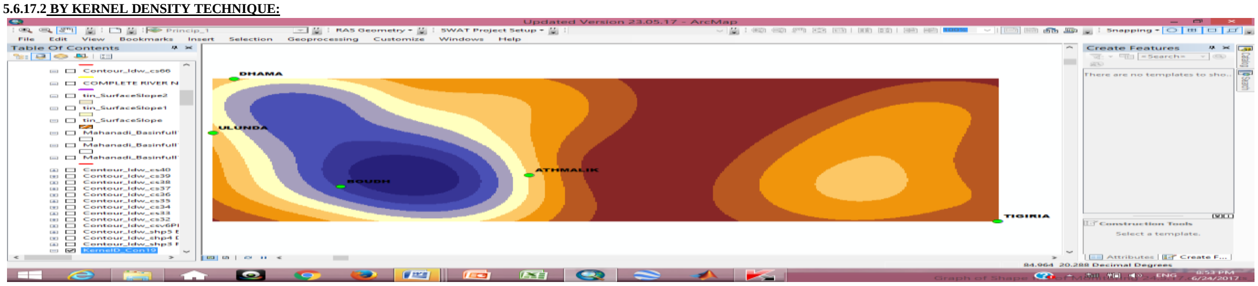
5..6.16.3 **BY KRIGING TECHNIQUE:**

5.6.17 **FLUORIDE:**

5.6.17.1 **BY IDW TECHNIQUE:**



5.6.17.2 BY KERNEL DENSITY TECHNIQUE:



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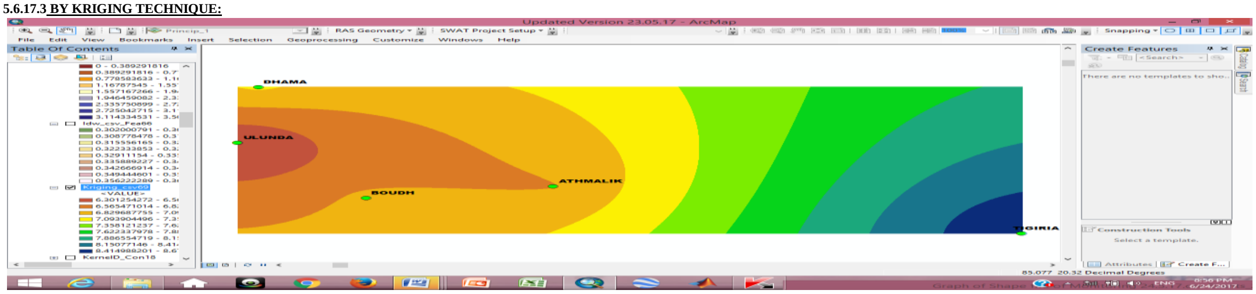
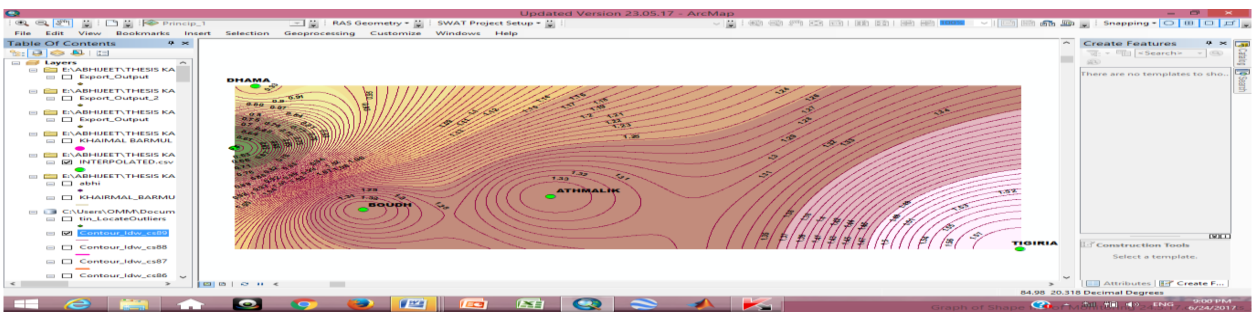
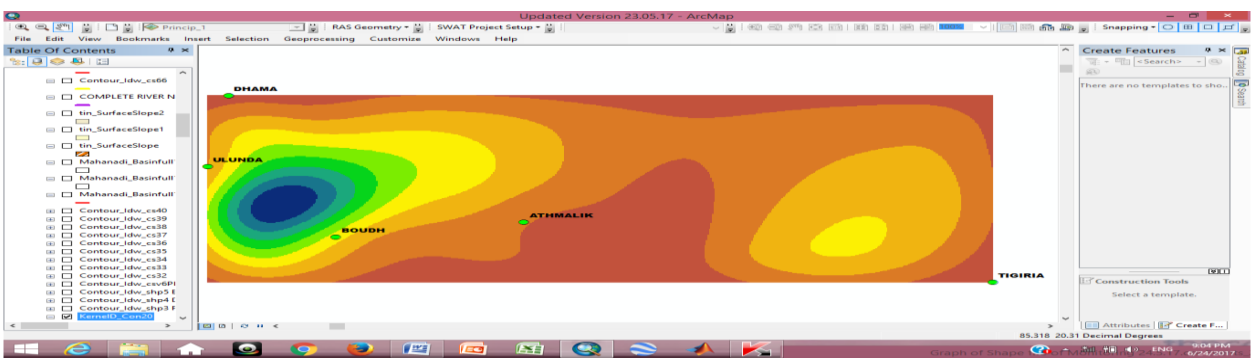


5.6.18 FE:

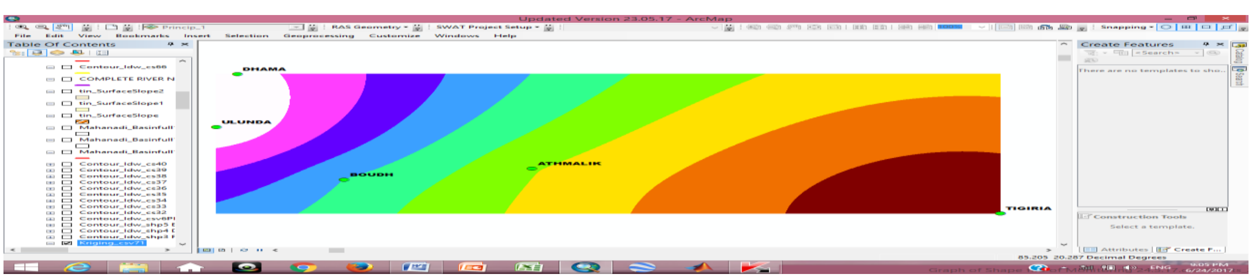
5.6.18.1 BY IDW TECHNIQUE:



5.6.18.2 BY KERNEL DENSITY TECHNIQUE:



5.6.18.3 BY KRIGING TECHNIQUE:



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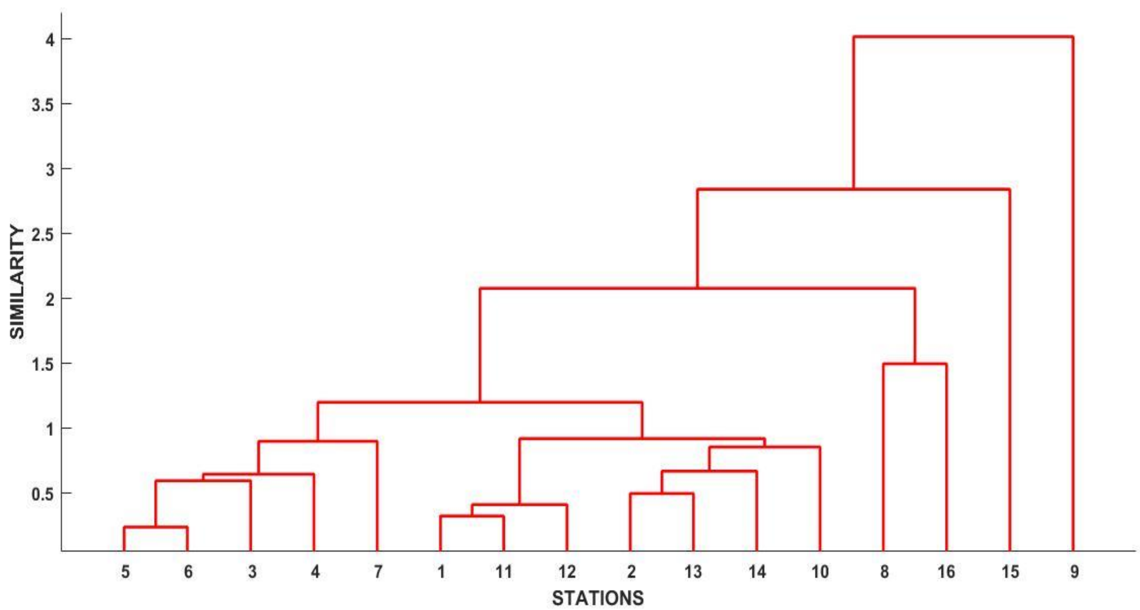
5.7 CLUSTERING AND PRINCIPAL COMPONENT ANALYSIS

In this study, sampling sites classification was performed by the use of cluster analysis. The relationships among the stations 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 effected by land use and industrial structure. The physicochemical parameters like pH, dissolved oxygen (DO), Biochemical oxygen demand (BOD), Total Colliform (TC), Electrical Conductivity (EC), Nitrate(NO_3), Total Suspended Solids(TSS), Alkalinity, Chemical Oxygen Demand (COD), NH_4-N, FREE NH_3, Total Kjeldahl nitrogen (TKN), Sodium Absorption Ratio(SAR), Total Dissolved Solids(TDS), Total Hardness(TH), Chloride(Cl^-) , Sulphate (SO_4^{2-}), Fluoride(F^-) and Iron(Fe) were used as variables and showed a sequence in their association, displaying the information as degree of contamination. Based on the result of the cluster analysis, the 16 monitoring stations are grouped into three different clusters namely less polluted (LP) sites, moderately polluted (MP) and highly polluted (HP) sites, depending on the similarity of their water quality characteristics. Grouped stations under each cluster are depicted in Ward's minimum variance dendrogram.

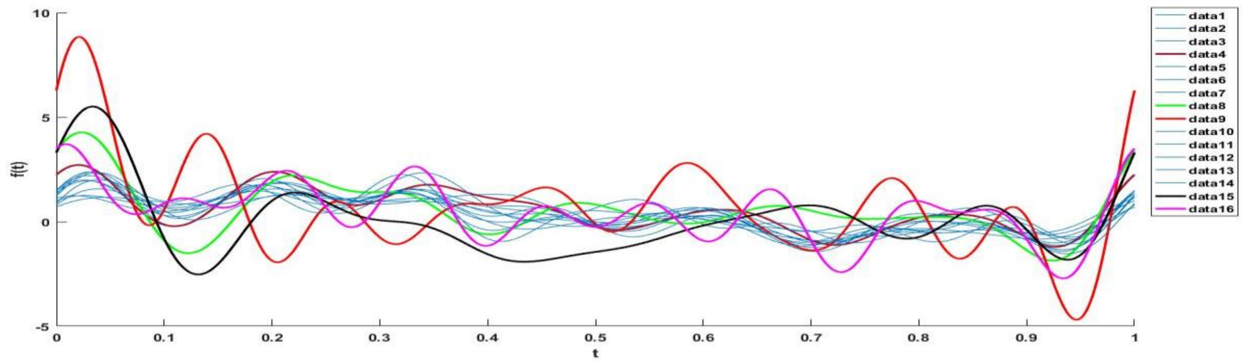
5.7.1 AGGLOMERATIVE HIERARCHICAL CLUSTER ANALYSIS (AHC)

(WARD'S MINIMUM VARIANCE DENDROGRAM)



(Dendrogram showing clustering of monitoring sites according to surface water quality characteristics of the Mahanadi river basin)

ANDREWS PLOT

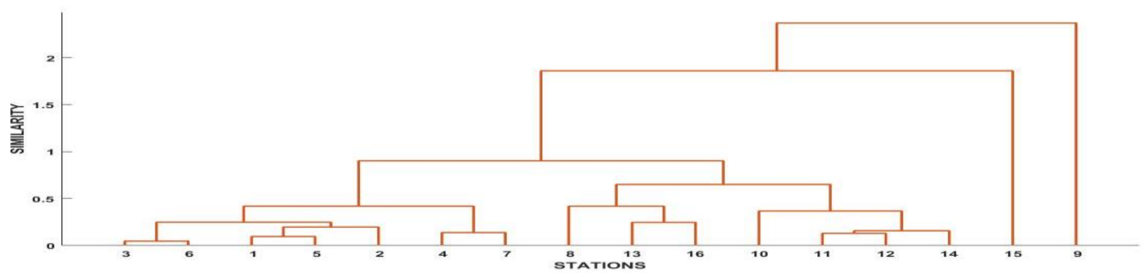


The bold lines showing the red, black, pink and green depicts the stations Cuttack D/s, Bhubaneswar D/s, Paradeep and Choudwar which are heavily polluted due to the parameters TC, TKN, EC and nitrate.

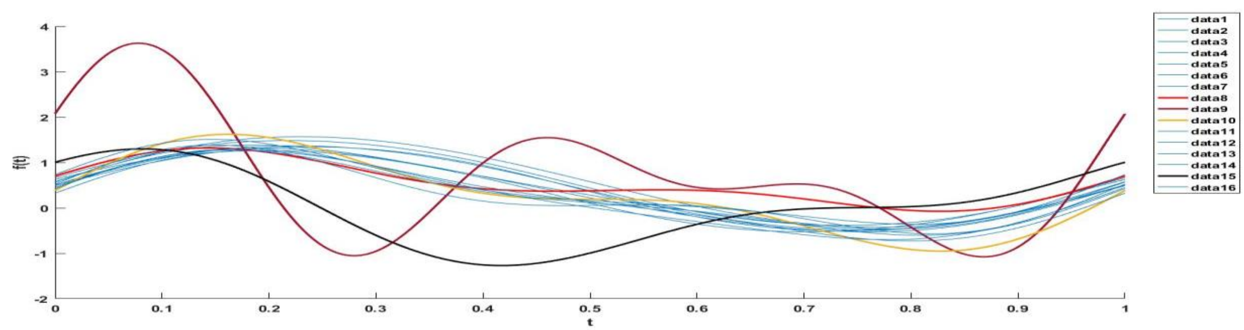
Similarly, adopting the same procedure, the Andrews plot and Dendrograms have been developed for the remaining classes A, B, C, D and E as mentioned below.

CLASS A

DENDROGRAM:

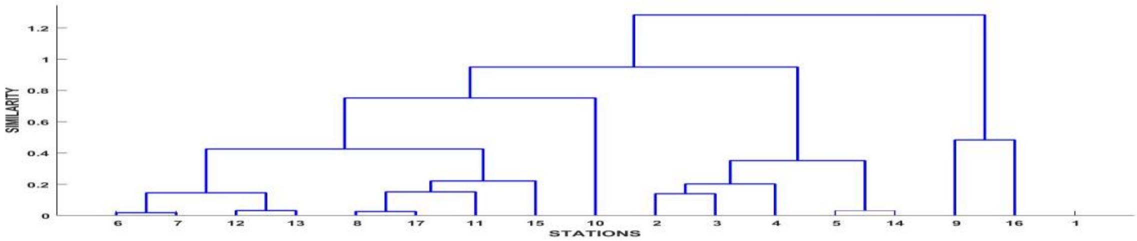


ANDREWS PLOT:

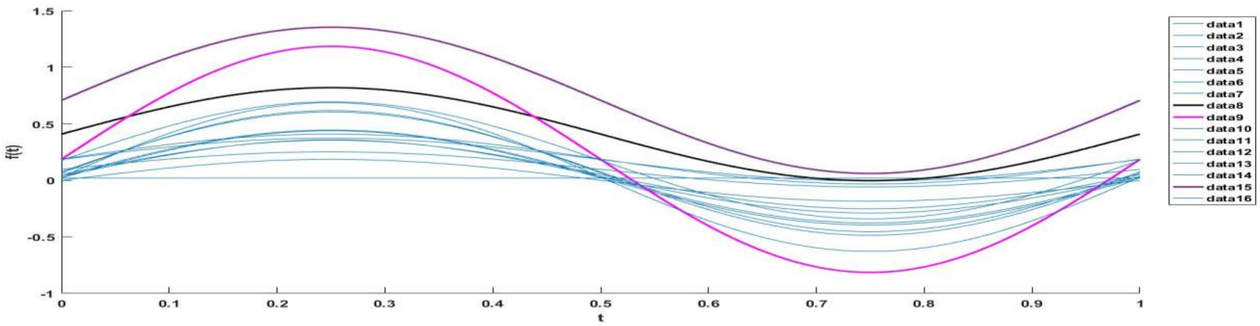


5.7.1.2 CLASS B

DENDROGRAM:

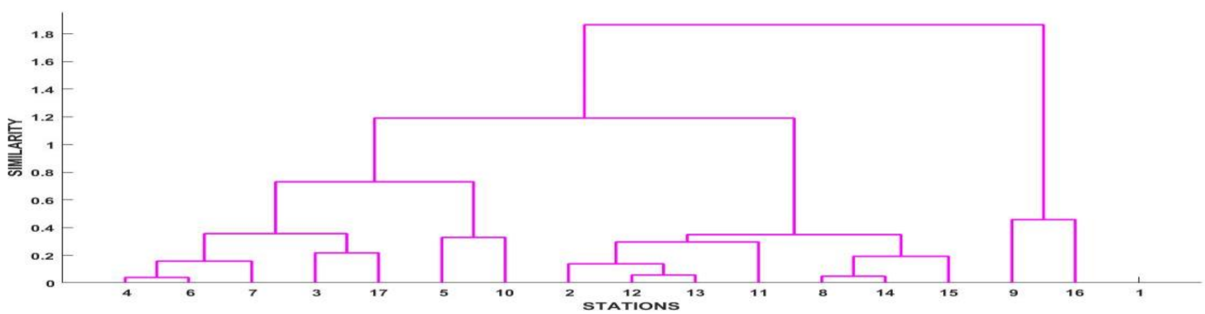


ANDREWS PLOT:

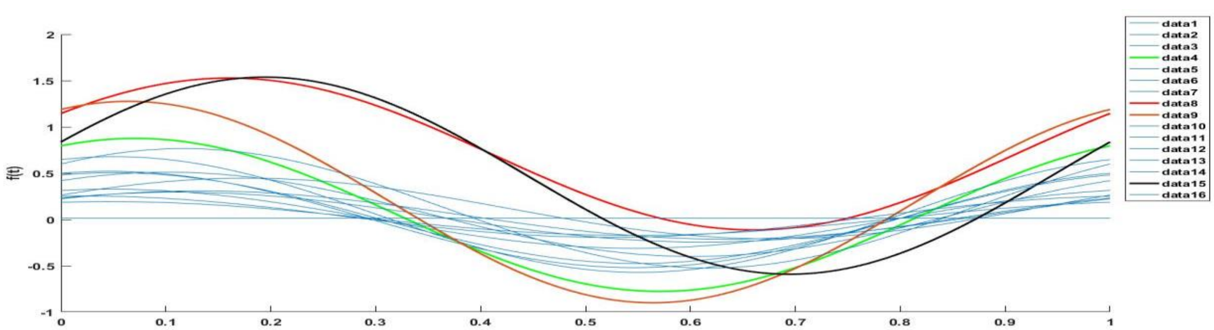


5.7.1.3 CLASS C

DENDROGRAM:

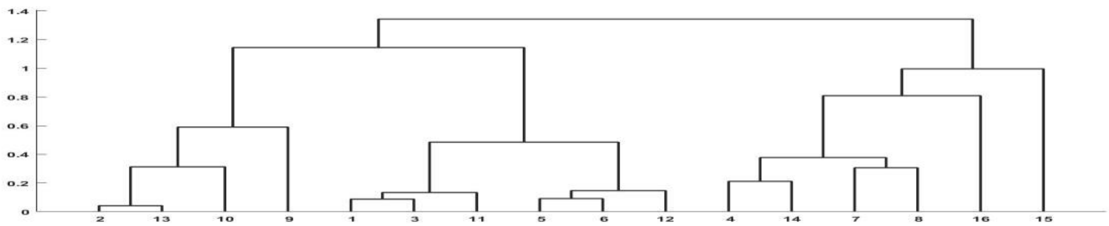


ANDREWS PLOT:

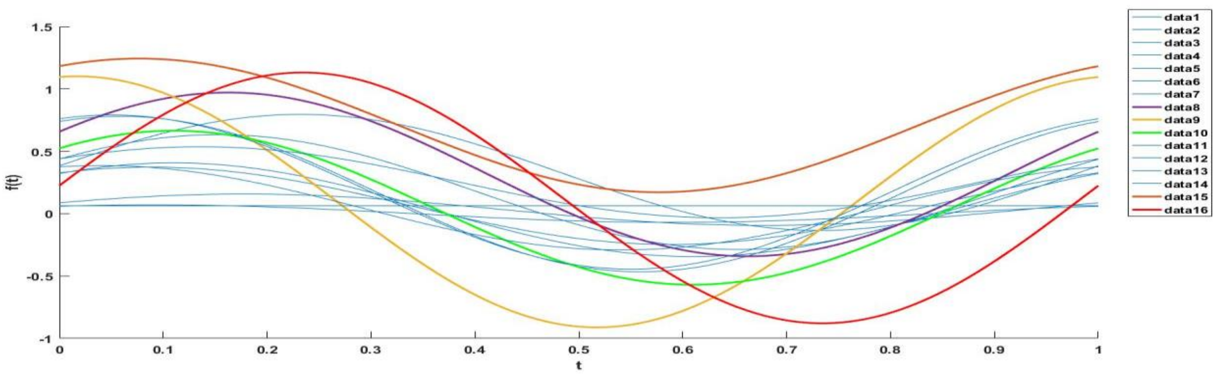


5.7.1.4 CLASS D

DENDROGRAM:

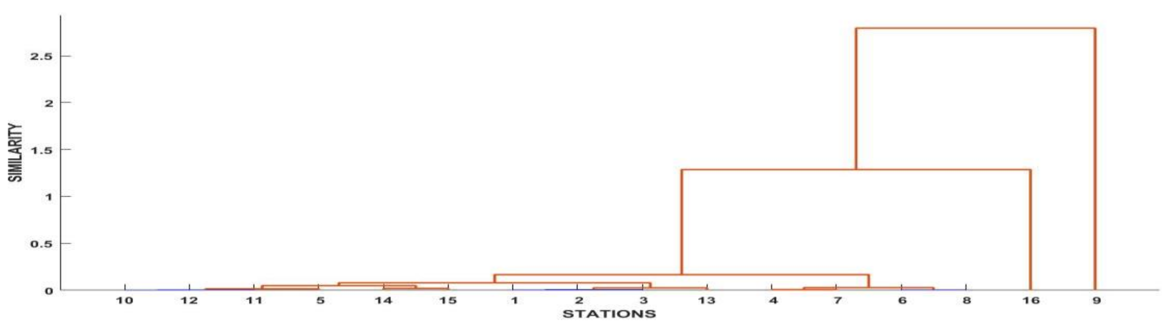


ANDREWS PLOT:

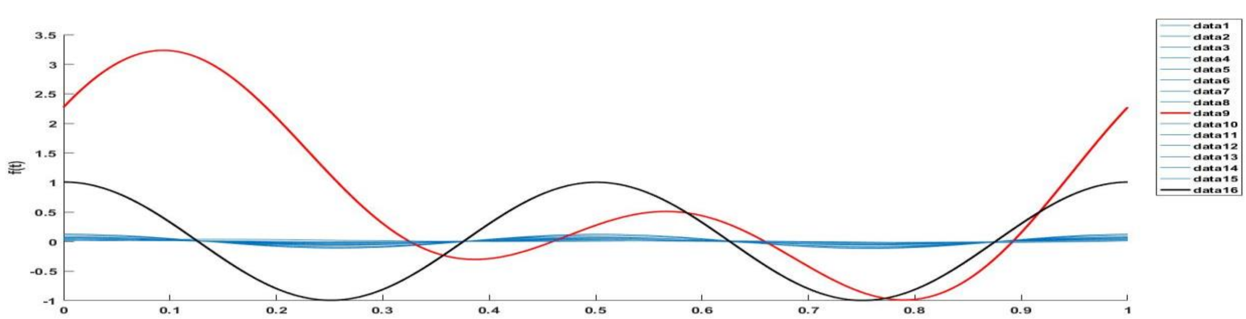


5.7.1.5 CLASS E

DENDROGRAM:



ANDREWS PLOT:



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5.7.2 **<u>CLUSTER- I (3-4-5-6-7):</u>** Monitoring sites, mainly located in between the Sonepur upstream to Cuttack (U/s) including Sonepur (D/s), Tikarpada and Narasinghpur namely (stations 3-4-5-6-7) are clustered in this group. The impact of human beings activities on the riverine ecosystem is relatively low. Although the mining and the direct discharge of domestic water contaminated the river water system, cluster I corresponds to less polluted (LP) site, because the inclusion of sampling location suggests the self purification and assimilative capacity of the river are strong.

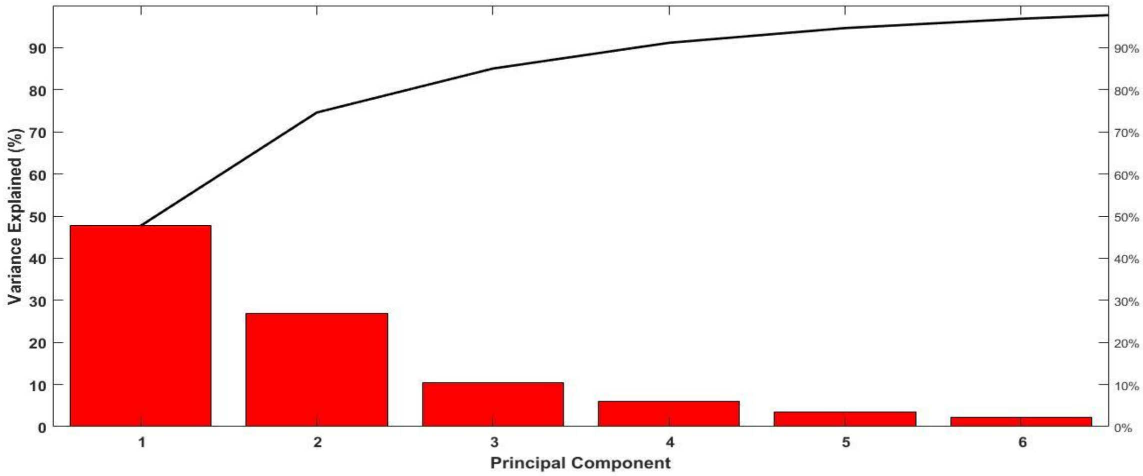
5.7.3 **<u>CLUSTER- II (1-2-10-11-12-13-14):</u>** This cluster sites mainly located in between Hirakud to Bhubaneswar (U/s) city. These sites are classified as moderately polluted (MP). From Hirakud further downstream of Sambalpur to Sonepur D/s (about 78 km, along the river course), the river travels through a region with no major urban settlement or waste water outfall. Sonepur is the confluence 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. Although Sonepur is a district head quarter, the deterioration of water quality at Sonepur D/s is not as much as expected. This is primarily because Sonepur D/s on the Mahanadi is actually the downstream of its confluence with Tel, which has significant annual average flow with very low pollution load. From Sonepur D/s to Tikarpada does not have any industry or urban settlement on its banks and also there is no major wastewater outfall. From Tikarpada to Narasinghpur (about 60 km), the river flows completely undisturbed.

5.7.4 **<u>CLUSTER- III (8-16 & 9-15</u>**<u>):</u> This cluster mainly includes Cuttack (D/s) (8), Paradeep (9) and Bbsr (D/s) (15) and Choudwar (16).These sites are classified as highly polluted (HP). During its course from Brajarajnagar to Bbsr (D/s) the river enter into deltatic region characterized by high population density and intense agricultural activities and large industries like paper mill. The deterioration in the water quality in these monitoring stations is mostly due to untreated domestic wastewater, industrial effluents and agricultural runoffs.

5.8 <u>DATA STRUCTURE DETERMINATION AND SOURCE IDENTIFICATION:</u>

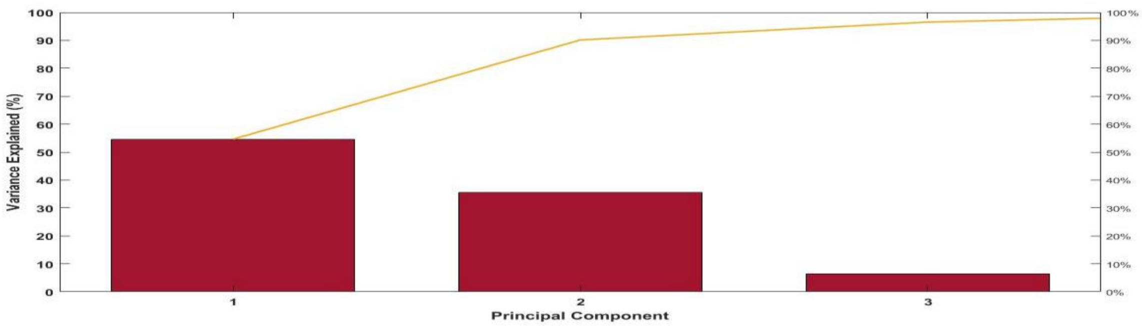
Principal component analysis/factor analysis was performed on the normalized data sets separately for the three different regions, viz., LP, MP and HP, as delineated by CA techniques, to compare the composition structure between analyzed water samples and the factors loadings of each variable. PCA of the three data sets yield four PCs for LP and five PCs for MP sites while three PCs were obtained for HP sites with each cases having eigen values (Component variance values) >1. An eigen value gives a measure of the significance for the factor, which with highest eigen value is the most significant. Eigen values of 1.0 or greater are considered significant.

5.8.1 SCREE PLOTS OF ALL MONITORING STATIONS:



Principal Component Analysis														
	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	F11	F12	F13	F14
Component variance	9.006	5.128	2.005	1.183	0.664	0.434	0.315	0.153	0.066	0.019	0.018	0.007	0.001	0.000
Variance explained (%)	47.401	26.990	10.554	6.226	3.494	2.284	1.657	0.807	0.346	0.102	0.096	0.037	0.005	0.002
Cumulative %	47.401	74.392	84.946	91.172	94.666	96.949	98.606	99.413	99.759	99.861	99.957	99.994	99.998	100.000

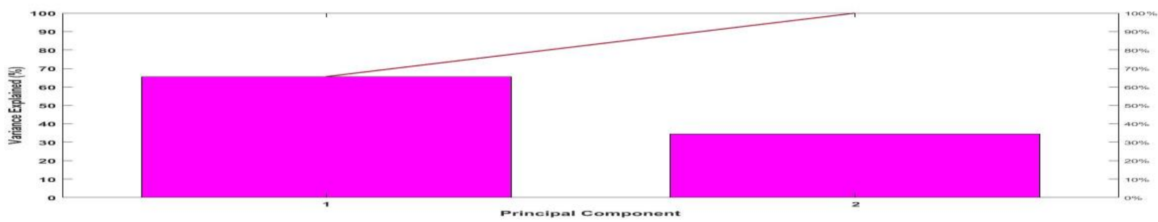
5.8.1.1 FOR CLASS A:



CLASSA				
PC1	PC2	PC3	PC4	PC5
0.0312	0.1428	0.1547	0.0699	0.082
-0.099	0.1143	-0.126	-0.0853	0.1494
0.0692	-0.126	0.0619	-0.0833	0.1467
0.1292	-0.011	-0.13	0.1624	0.077
0.1241	0.0682	-0.027	-0.0922	-0.045
0.1232	0.0681	-0.021	-0.0927	-0.0402

COMPONENT VARIANCES	PERCENT VARIANCE EXPLAINED
3.2785	54.641
2.1296	35.494
0.3839	6.3988
0.1632	2.7206
0.0447	0.7443
0	0.0008

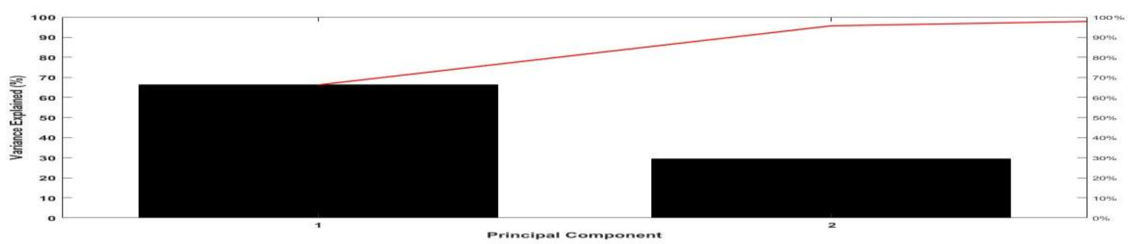
5.8.1.2 FOR CLASS B:



CLASSB
PC1
0.1833
0.1731

COMPONENT VARIANCES	PERCENT VARIANCE EXPLAINED
1.3121	65.6048

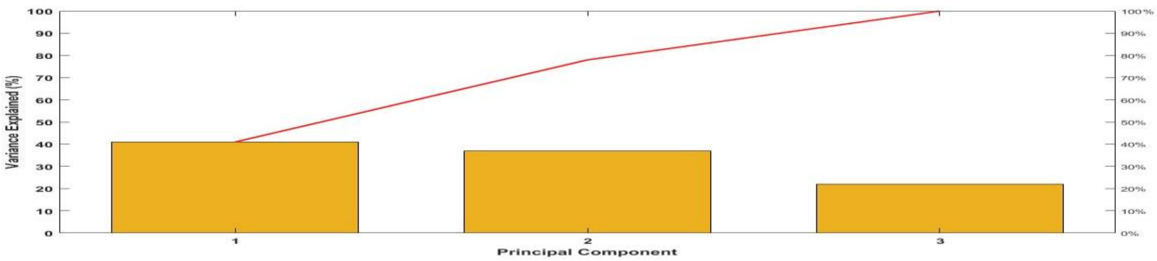
5.8.1.3 FOR CLASS C:



CLASSC	
PC1	PC2
0.1781	-0.099
0.1776	-0.0355
0.0878	0.2314

COMPONENT VARIANCES	PERCENT VARIANCE EXPLAINED
1.9874	0.8826
66.2479	29.4187

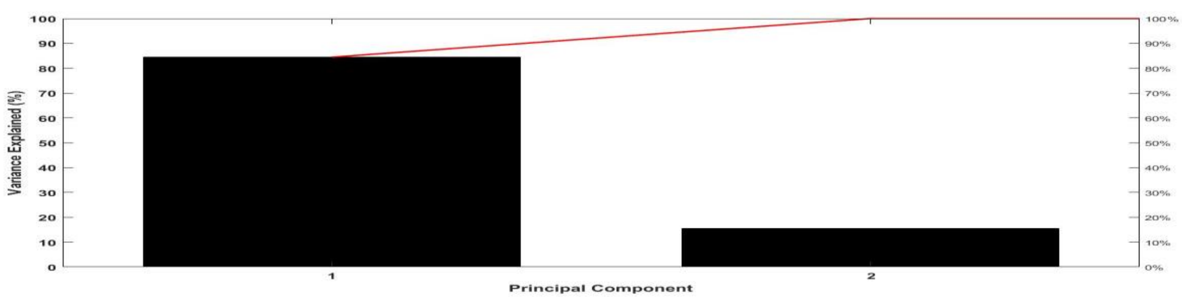
5.8.1.4 FOR CLASS D:



CLASSD	
PC1	PC2
0.1746	0.0928
0.1767	-0.089
-0.0075	0.2284

COMPONENT VARIANCES	PERCENT VARIANCE EXPLAINED
1.2306	1.1098
41.0199	36.9933

5.8.1.5 FOR CLASS E:



CLASSE			
PC1	PC2	PC3	PC4
0.1203	-0.0317	-0.0749	0.0866
0.1202	-0.0334	0.1809	-0.1092
0.1208	-0.0317	0.0412	0.1572
0.1203	0.03	-0.1478	-0.1339
0.0668	0.2537	0.0023	0.0001

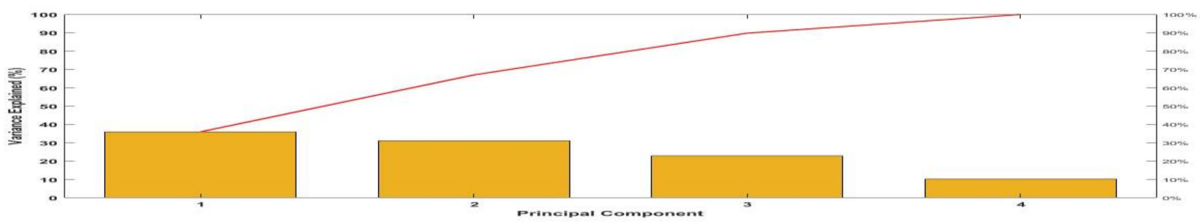
COMPONENT VARIANCES	PERCENT VARIANCE EXPLAINED

4.2232	84.4641
0.7764	15.5287
0.0002	0.0048
0.001	0.0018

5.8.2 LESS POLLUTED SITES:

For the data set pertaining to LP sites, four PCs were obtained having eigen value >1 as shown in the screen plot for LP sites. Among four PCs, PC1, explaining 35.9844% of the total variance, has moderate positive loadings on DO, BOD,TC,COD,F and SO_4^{2-} and Strong positive loading on pH, Fe, Free NH_3 and NH_4-N which is attributed to localized anthropogenic input and also due to deamination of nitrogen containing organic compounds rather than river runoffs. PC2, explaining 31.0345% of the total variance, moderate positive loadings on SAR, Free-NH_3, pH, TSS, TDS and strong positive loadings on Alkalinity, TKN and NH_4-N and strong negative loading on DO and CL. PC3, explaining 22.7988% of the total variance, has strong positive loadings on Fe, strong negative loading on pH, DO, Alkalinity and COD, moderate positive loading on Fe, TKN, TDS, TSS and NO_3^-. PC2 and PC3 represent organic pollution from domestic waste and non-point source pollution. PC4, explaining the lowest variance (10.1823%) has moderate loadings on Alkalinity, Fluoride and TKN and strong positive loading on Fe, TC which is due to normal biological degradation products of nitrogenous organic matter.

5.8.2.1 Scree plot for LP Sites:



5.8.2.1.1 Principal Component Analysis of LP sites

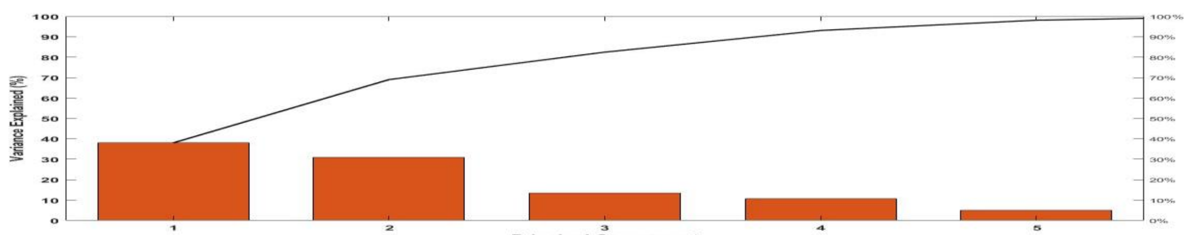
PARAMETERS	PC1	PC2	PC3	PC4
PH	0.0332	0.0206	-0.0077	-0.0179
DO	0.0148	-0.0024	-0.0081	-0.001
NO_3	-0.0174	0.0103	0.0064	-0.0068
TSS	-0.0031	0.003	0.0259	-0.0059
TDS	-0.0001	0.0002	0.0002	0
TH	-0.0004	0.0005	-0.0008	-0.0007
BOD	0.0069	0.0346	-0.0157	-0.0237
FE	0.048	0.0124	0.0766	0.0535
TC	0.0024	0.0097	-0.0019	0.0148
COD	0.0014	0.0318	-0.0183	-0.0033
ALKALINITY	-0.0479	0.0486	-0.0429	0.0283
NH_4-N	0.0687	0.0226	0.0044	-0.0209
FREE NH_3	0.0477	0.04	0.0214	-0.0278
TKN	-0.0245	0.0335	0.0201	0.0296

EC	-0.0003	0.0007	-0.0002	-0.0002
SAR	0	0.0001	0.0003	-0.0005
CL_2	0	-0.0001	-0.0001	-0.0001
SO_4^{2-}	0.0009	0.0001	0.0003	-0.0002
F	0.0114	0.0068	-0.0092	0.007
COMPONENT VARIANCES	6.837	5.8966	4.3318	1.9346
PERCENT VARIANCE EXPLAINED	35.9844	31.0345	22.7988	10.1823

5.8.3 MEDIUM POLLUTED SITES

For the data set pertaining to the MP sites, five PCs were obtained having eigen value >1 as depicted in screen plot for MP sites. Among total seven significant PCs, PC1, explaining about 38.0492% of the total variance, has strong positive loading on Fe, TSS, DO and moderate positive loadings on SAR, CL and Free-NH_3. These factors represent the contribution of excess localized anthropogenic input into water bodies, runoff from agricultural fields using phosphatic fertilizers and some industrial effluents. PC2, explaining about 30.9884% of the total variance, has strong positive loading on Fe, TSS, NH_4-N,BOD,COD and TKN and moderate loadings on TC, Free-NH_3,TDS,SAR and Chloride which represent the direct input of organic matter and domestic wastewater containing chemicals that are susceptible to oxidation from the nearby cities. PC3, explaining about 13.4605% of the total variance, has strong positive loading on TKN, Free-NH_3 and TSS and, moderate loading on NO_3, pH, BOD, COD, NH_4-N and SAR. In these areas, farmers use the fertilizer, which represents point and non-point source pollution from orchard and agriculture areas. PC4 explaining about 10.6159% of the total variance has strong positive loadings on Fe, DO, pH, TKN and moderate positive loadings on COD,TC,NH_4-N, Free-NH_3 and TSS and PC5 explaining about lowest variance of 5.0279% having strong positive loadings on TSS, pH, Free-NH_3 and Fluoride and moderate positive loadings on Fe, TDS,TH and BOD. The factor also represents the release of organic waste in to the river system.

5.8.3.1 Scree plot for MP Sites:



5.8.3.2 Principal Component Analysis of MP sites

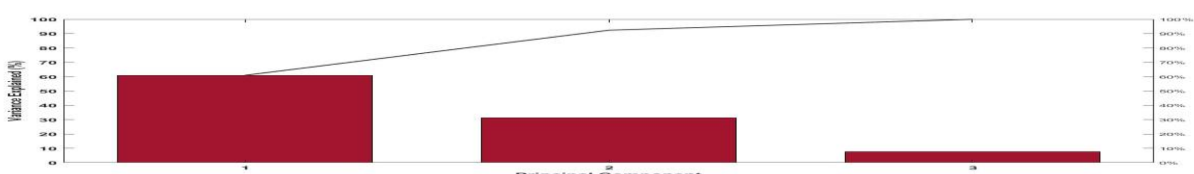
PARAMETERS	PC1	PC2	PC3	PC4	PC5
PH	-0.0176	-0.0161	0.0146	0.025	0.0254
DO	0.0213	-0.0186	-0.0059	0.0288	-0.0235
NO_3	-0.0162	0	0.0219	-0.0149	-0.0248
TSS	0.0399	0.0409	0.0313	0.0048	0.0597
TDS	-0.0001	0.0003	-0.0003	-0.0001	0.0005

TH	-0.0015	-0.0003	-0.0005	0.0007	0.0005
BOD	-0.0199	0.0344	0.0131	-0.0145	0.0003
FE	0.043	0.0418	-0.0077	0.0724	0.0084
TC	-0.0116	0.0169	-0.0074	0.008	-0.005
COD	-0.0397	0.0201	0.0045	0.0105	-0.0112
ALKALINITY	-0.0329	-0.0281	-0.0105	-0.0182	-0.0141
NH_4-N	-0.0286	0.0365	0.0027	0.0063	-0.0059
FREE NH_3	0.0049	0.0156	0.0474	0.0063	0.0139
TKN	-0.0141	0.0201	0.1435	0.0123	-0.0467
EC	-0.0007	0	-0.0002	0.0003	0
SAR	0.0006	0.0012	0.0001	-0.0006	-0.0007
CL_2	0	0.0001	0	0	0
SO_4^{2-}	-0.0008	-0.0007	-0.0001	0.0007	0
F	-0.0016	-0.0035	0.0077	-0.0068	0.0094
COMPONENT VARIANCES	7.2293	5.8878	2.5575	2.017	0.353
PERCENT VARIANCE EXPLAINED	38.0492	30.9884	13.4605	10.6159	5.0279

5.8.4 HEAVY POLLUTED SITES:

Lastly, for the data set pertaining to water quality in HP site, three PCs were obtained having eigen value >1 as shown in the scree plot for HP sites. Among the one PCs, PC1 explaining 60.9313% of total variance, has strong loadings on Chloride, TDS, SAR, EC, Sulphate, TH, pH, TKN,TSS. This factor can be interpreted as untreated wastewater and sewage disposal from both Sambalpur and Cuttack cities and also industrial effluents. The strong negative loading on NO_3 in PC1, is due to anaerobic conditions in river from the loading of high dissolved organic matter. PC2, explaining 31.4268% of the total variance, has strong positive loadings on F, Free-NH_3 and moderate positive loading on DO and pH. PC3 explaining about lowest variance of 7.6419% having strong positive loadings on TC, pH , TKN, BOD, DO and moderate positive loadings on Chloride, EC, TDS, SAR, Sulphate, Alkalinity, TH and strong negative loading on TSS, NH_4-N, Free-NH_3, Fe, Nitrate and Fluoride. These factors also represent pollution from domestic wastewater and non-point sources. Through the PCA, the sources of the pollutants were identified in the three zones. As mentioned above, it can be helpful to the government and managers, who can lay down different regulations and policies in three zones respectively.

5.8.4.1 Scree plot for HP Sites:



5.8.4.2 Principal Component Analysis of HP sites:

PARAMETERS	PC1	PC2	PC3
PH	0.0921	0.0865	0.1635
DO	0.0242	0.1239	0.0243

NO_3	-0.0335	-0.1195	-0.1691
TSS	0.0877	-0.058	-0.022
TDS	0.1432	-0.0407	0.0113
TH	0.1418	-0.0387	0.0103
BOD	-0.0649	-0.1332	0.0303
FE	0.0652	-0.0414	-0.0599
TC	-0.0631	-0.0576	0.2357
COD	-0.0542	-0.0813	0.003
ALKALINITY	0.0853	-0.0046	0.0104
NH_4-N	-0.0783	-0.1197	-0.0389
FREE NH_3	-0.0525	0.1417	-0.0516
TKN	0.0908	-0.089	0.0405
EC	0.1427	-0.0416	0.0116
SAR	0.1425	-0.0433	0.0107
CL_2	0.1437	-0.0411	0.0117
SO_4^{2-}	0.142	-0.0413	0.0106
F	0.0537	0.1483	-0.1817
COMPONENT VARIANCES	11.577	5.9711	1.452
PERCENT VARIANCE EXPLAINED	60.9313	31.4268	7.6419

APPLICATIONS:

The application of ***multivariate statistical analysis*** is an excellent technique for assessment of large and complex databases, generated by continuous monitoring of water quality to ***evaluate similarity and dissimilarity in the physicochemical characteristic of surface water bodies.*** These methods can also be used to discern water quality variables responsible for yearly variation among them and to categorize them on the basis of pollution levels besides identifying the source of pollution. Thus these techniques are believed to be valuable for water resource managers to design sampling, analytical protocols and the effective measures to control / management of pollution load in the surface water.

5.9.1 WATER QUALITY OF MAHANADI BASIN:

Accumulated all essentials data regarding water quality parameters and made relevant analysis. Here is the list of table below showing the water quality status of Mahanadi River Basin and water quality trend analysis (Up or Down) of the required monitoring stations which I have performed on the basis of time series graph for the year 2000-2014.

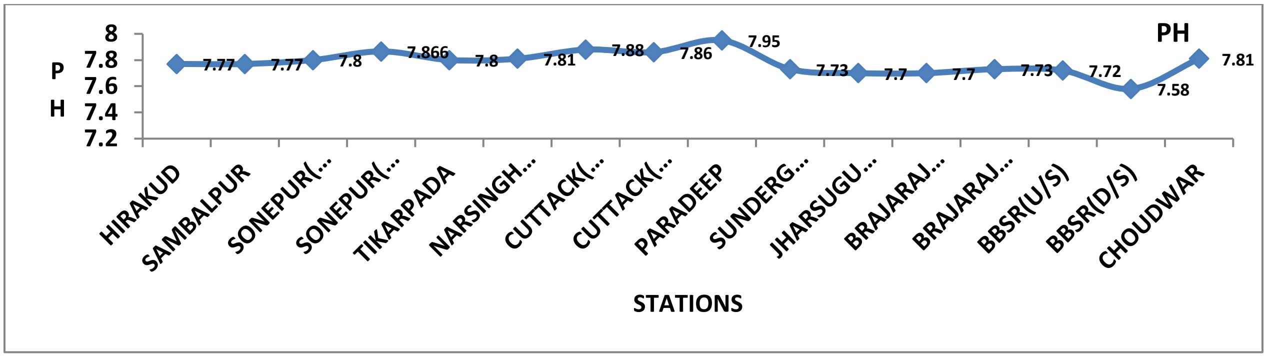
5.9.2 Water Quality Status of Mahanadi River Basin:

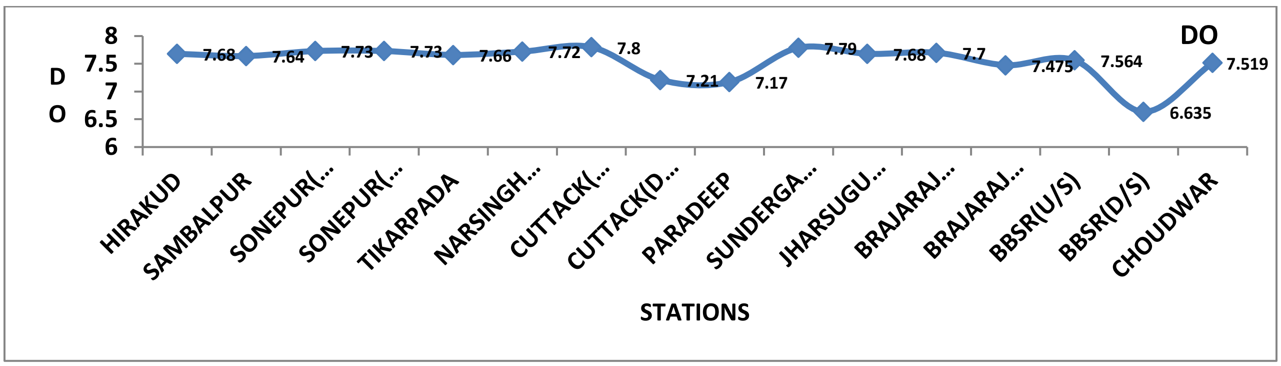
5.9.2.1 USE BASED WATER QUALITY STATUS:

5.9.2.2 WATER QUALITY IN RESPECT TO PRIMARY CRITERIA:

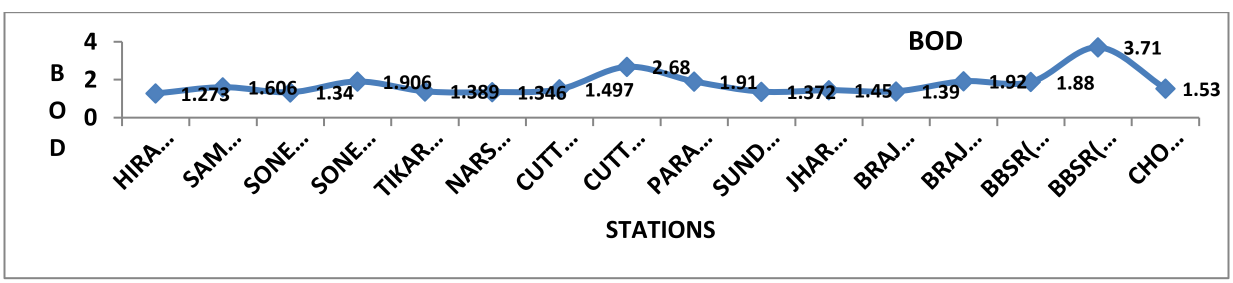
The Yearly average values of pH, DO, BOD and TC at different monitoring stations, pertaining to the period 2000-2014 are described in Tables.

5.9.2.2.1 PH AND DO: As may be seen from the data, pH remains mostly alkaline and the water is rich in oxygen. So the parameters conform to the quality criteria for Class-A.

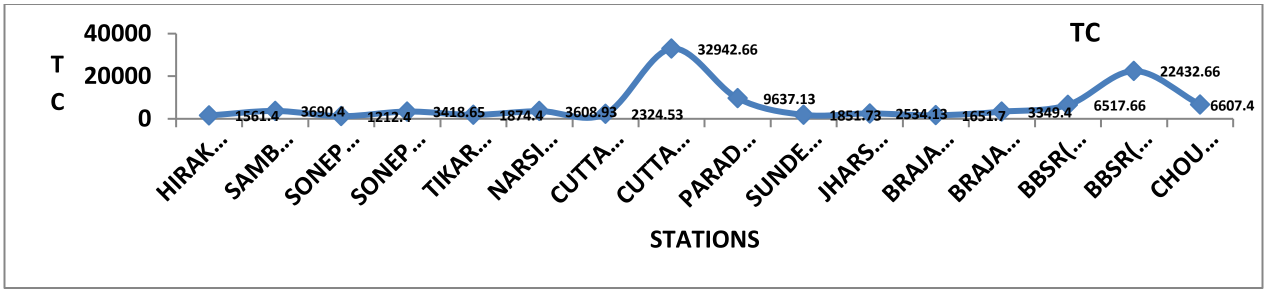




5.9.2.2.2 BOD: Except a few occasional deviations of small magnitudes from the stipulated value of 3 mg/l, the BOD at all the sampling stations generally conform to Class-B water quality except at Sambalpur D/s(Mahanadi), Cuttack D/s and FD/s (Kathojodi), Bhubaneswar D/s and FD/s (Daya). Even at these five stations, the BOD is not alarmingly high and the value rarely exceeds 5 mg/l. Percent violations of BOD during the entire period under report, at all stations are presented in the Figures.

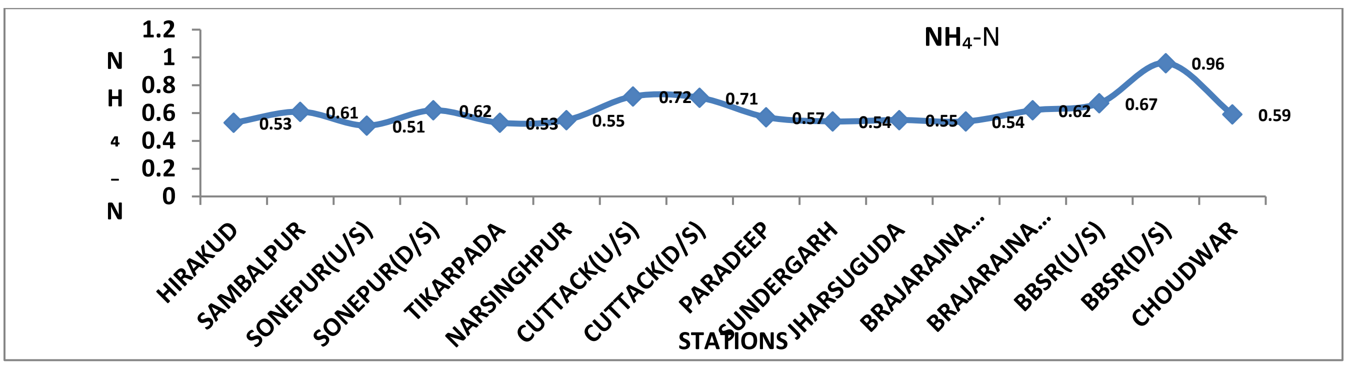


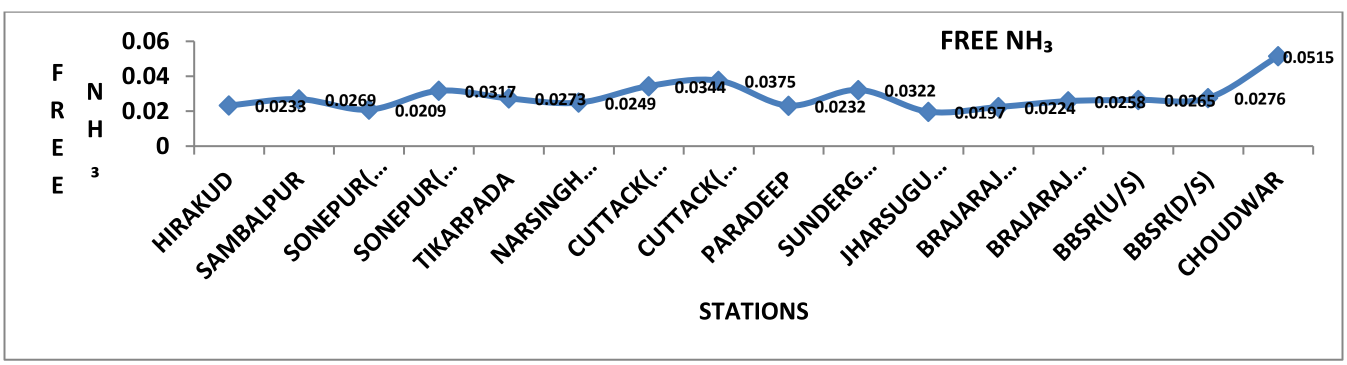
5.9.2.2.3 TC: The TC values at all stations, except Sambalpur D/s, Shankarmath and Huma on Mahanadi River, Cuttack (D/s) and FD/s (both on Mahanadi and kathojodi rivers) and Bhubaneswar D/s and FD/s in Daya generally conforms to Class-C inland surface water quality. The magnitude and frequency of violations 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.



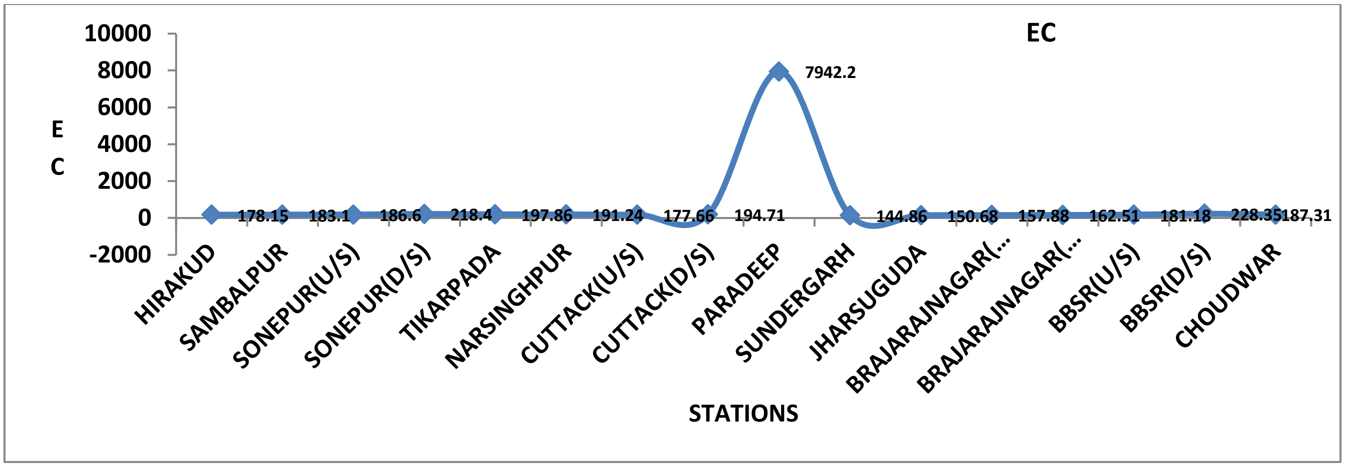
The annual average and the range of BOD and TC values at all the monitoring stations are given in above figures.

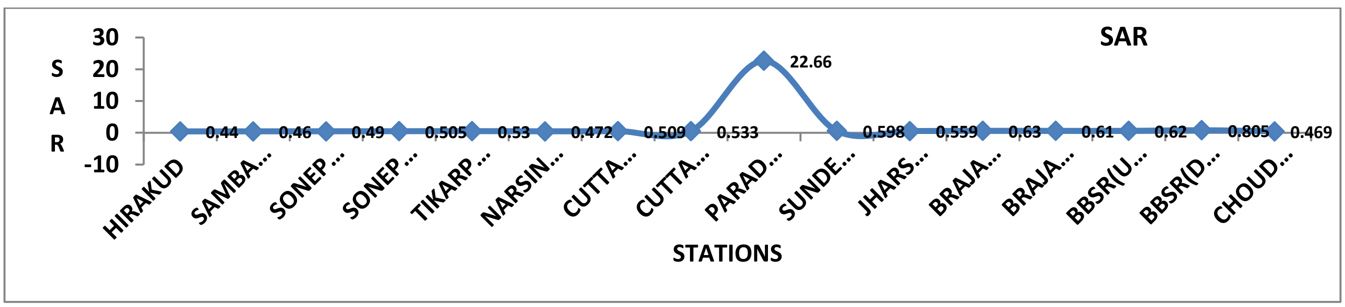
5.9.2.2.4 **<u>AMMONIA:</u>** The observed values of ammoniacal nitrogen and free ammonia are presented in Table. Free ammonia values at all stations conform to the stipulated values for Class-D inland surface water quality. No regular pattern can be discerned regarding to the level of ammonia in the river. Since ammonia is naturally present in domestic sewage and is also produced largely by deamination of nitrogen containing organic compounds, such observations are not entirely unexpected.





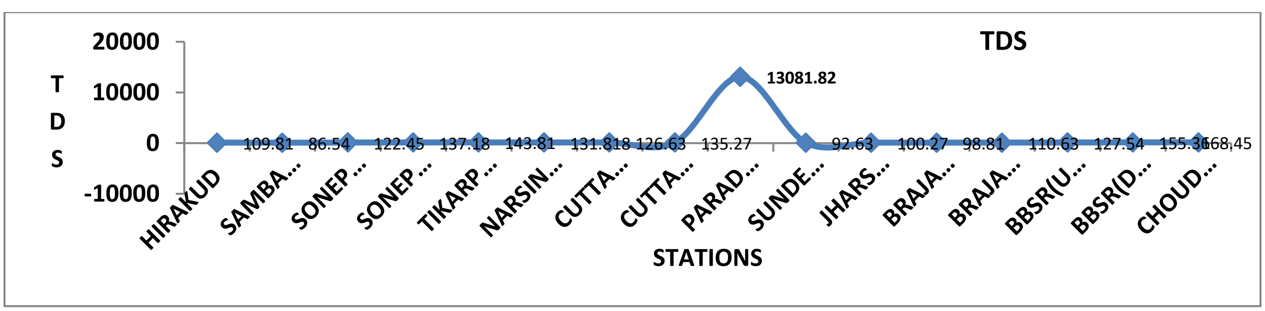
5.9.2.2.5 **<u>EC, SAR AND BORON:</u>** As described in Table EC, SAR and B are considered to be three primary water quality criteria for water to be used for irrigation purpose (Class E).EC, SAR and B values in IB, Mahanadi , Kathojodi , Kuakhai and Birupa rivers are presented in Table. From the data, it can be seen that the EC, SAR and B 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.

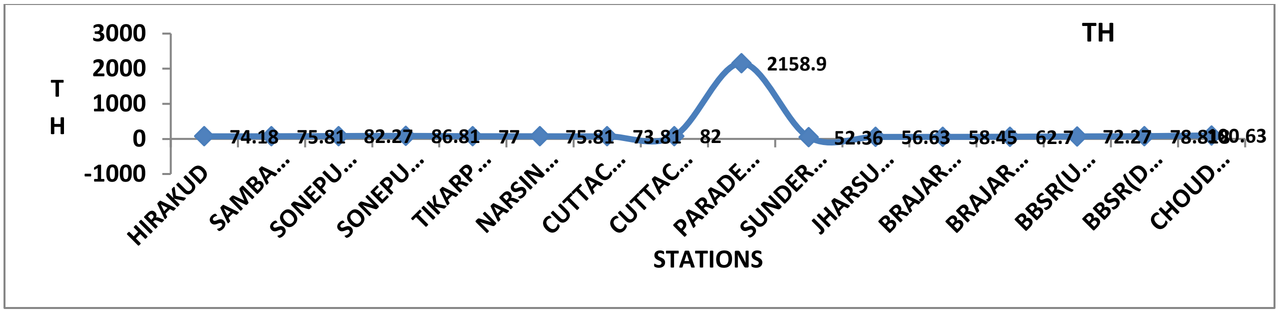


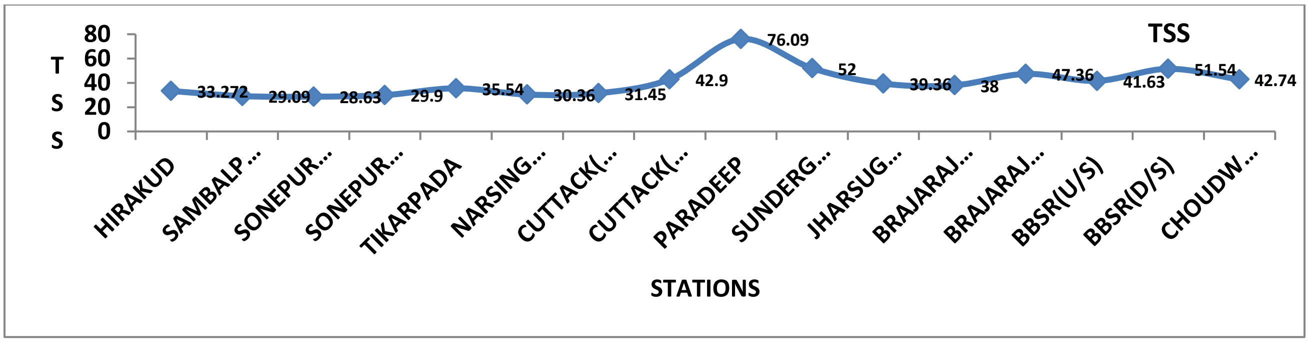


5.10 <u>WATER QUALITY IN RESPECT OF OTHER PARAMETERS:</u>

5.10.1 <u>TDS AND TOTAL HARDNESS:</u> TDS and Total hardness are given in Table. Comparison with the required TDS concentration and hardness of different use classes (Table), it is seen that the entire river stretch conform to Class-A, except at Paradeep U/s and D/s. In terms of degree of hardness, the river water (except Paradeep) may generally be described as moderately hard (Hardness 61 to 120).

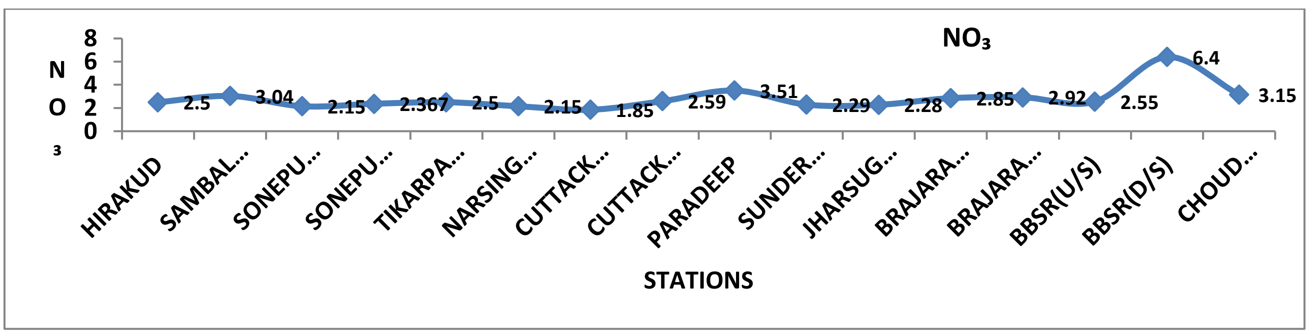




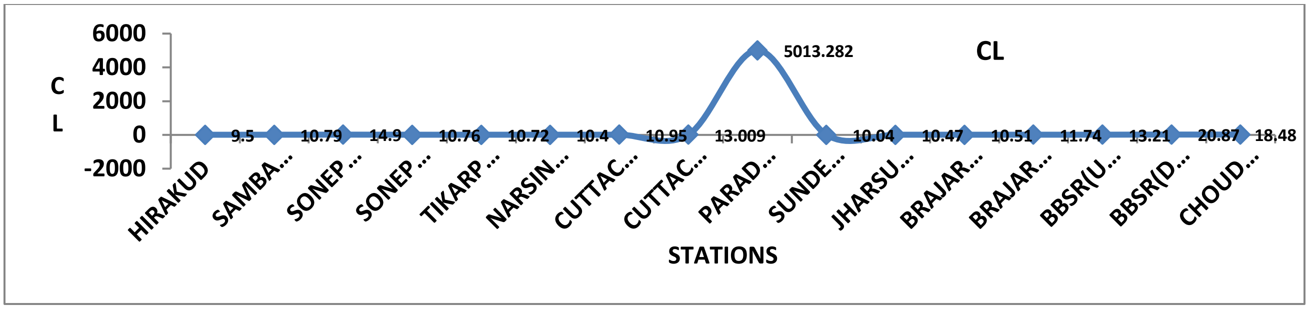


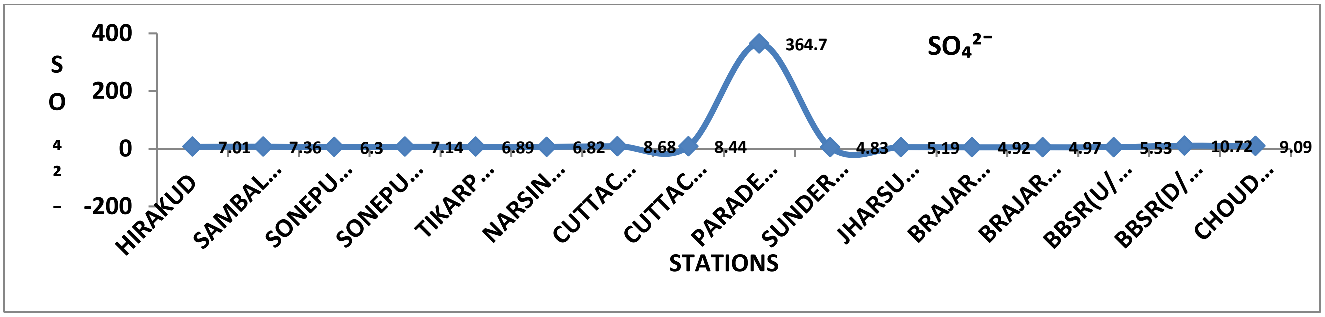
5.10.2 NITRATES:

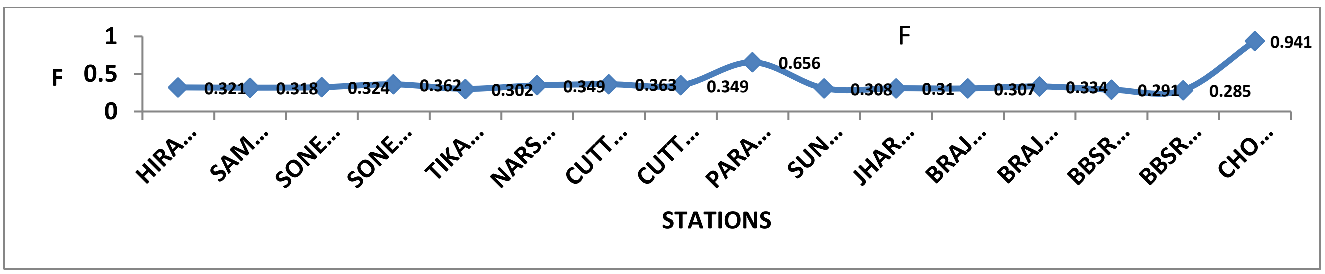
5.10.2 **NITRATES:** The river water is very low in nitrate concentration as revealed from the data for 2000-2014 (Table). The nitrate values in the entire stretch never exceeded the stipulated value for Class-A (20 mg/l).



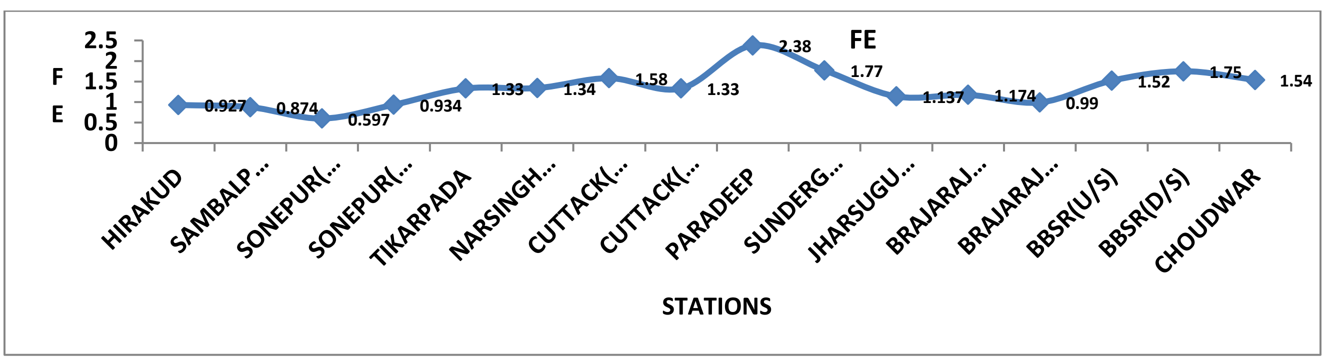
5.10.3 **CHLORIDE, SULPHATE and FLUORIDE:** Tolerance limits for chloride, sulphate and fluoride for different classes of inland surface water are given in Table. A comparison with the values of these parameters at different sampling stations as described in Table indicate that the water quality in respect of chlorides, sulphates and fluorides, conform to the highest class (i.e. Class-A). However, at Paradeep U/s and D/s, the chloride content as well as sulphate content are always much above the stipulated limit for Class-E inland surface water bodies. This may be described to the sea water ingression.







5.10.4 METALS AND CYANIDES: Water pollution from metal and cyanides constituents is expected to occur due to industrial effluents (unless some metals have geological origin). Data given in Table indicate that the concentration of these parameters is well within the tolerance limits.



5.11 USE BASED CLASSIFICATION:

From the water quality data and frequency discussions, it may be reasonable to conclude that the water quality at all stations except Power Channel U/s, Sambalpur D/s, Sambalpur FD/s at Sankarmath, Sambalpur FFD/s at Huma, Cuttack D/s, Cuttack FD/s, Paradeep U/s and D/s, Cuttack D/s and FD/s (Kathojodi), Bhubaneswar D/s and FD/s(Daya), can be classified as Class C/D/E. Water quality of power

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Channel U/s may be classified as Class-B. It may be safe to classify the water quality of Sambalpur D/s, Sambalpur FD/s at Sankarmath, Sambalpur FFD/s at Huma, Cuttack D/s, Cuttack FD/s, Cuttack D/s and FD/s (Kathojodi), Bhubaneswar D/s and FD/s (Daya), as Class D/E. In all cases, parameters responsible for downgrading the water quality are TC. BOD is also a major water quality downgrading parameter at Sambalpur D/s, Cuttack D/s (Kathojodi) and Bhubaneswar D/s and FD/s. Water quality at Paradeep U/s and D/s do not qualify even for Class-E due to several parameters (TC, EC, SAR, Chloride).

5.12 BIOLOGICAL ASSESSMENT OF WATER QUALITY:

The range of SI and DI values observed at different monitoring stations during 2000-2014 are presented in Table. Taking into considerations the observed biological indices and the BOD values (Table) , it may be concluded that the entire river stretch is in a state of slight to moderate pollution, as per the criteria given in Table.

5.13 WATER QUALITY IN TERMS OF WHOLESOMENESS:

5.13.1 WHOLESOMENESS IN TERMS OF REGULAR PARAMETERS:

The requirements in respect of regular monitoring parameters for different levels of degree of wholesomeness of water bodies are given in Table.

Of the 8 parameters listed in Table results of bioassay are not available. Hence presently the water qualities are assessed with regard to the remaining seven parameters.

pH, DO, BOD and EC values are given in Table.(Nitrite+Nitrate) Nitrogen and TSS values are given in Table. Considering pH, DO, BOD, EC, (Nitrite+Nitrate)-N and TSS values, the present level of wholesomeness of the river water may be considered as “desirable” except at Paradeep.

However, the situation changes entirely on introduction of FC values in the above assessment. Data given in Table (Percent violation of FC values from 2000 MPN/100ml) would show that except at Sundergarh, Brajarajnagar U/s, Power channel U/s and D/s, Sambalpur U/s, Sonepur U/s, D/s, Tel, Tikarpada, Narasinghpur, Cuttack U/s (Mahanadi and Kathojodi), the river water quality at all other stations is not even “acceptable” during most part of the period under report.

5.13.2 WHOLESOMENESS IN TERMS OF SPECIAL PARAMETERS:

Acceptable limits for the special parameters that are relevant to the present study are given in Table.

Total ammoniacal Nitrogen (ammonium + ammonia) as given in Table at all stations are within acceptable limits. Total phosphate-P (Table) at all stations except at cuttack FD/s (Kathojodi) and Bhubaneswar D/s (Daya) are within acceptable limit.

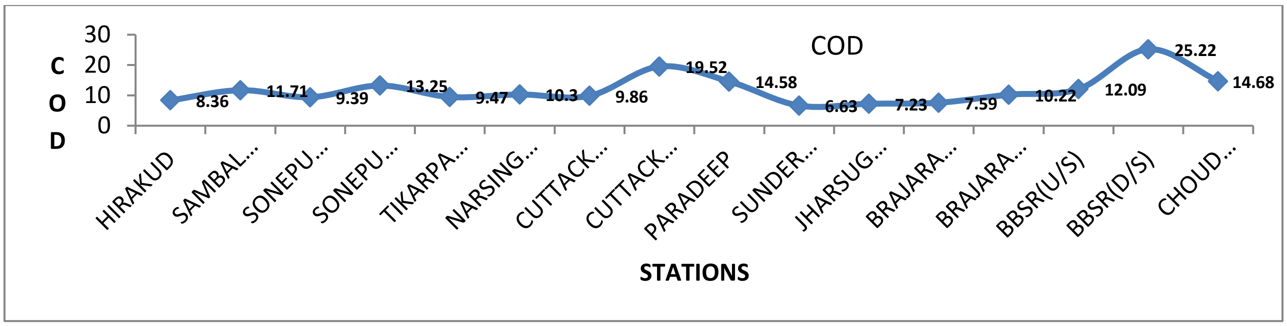
The total kjedahl nitrogen (TKN) reflecting organic pollution was observed (Table) to be mostly more than 3 mg/l at all stations, thus downgrading the water quality below acceptable limits with regard to organic pollution.

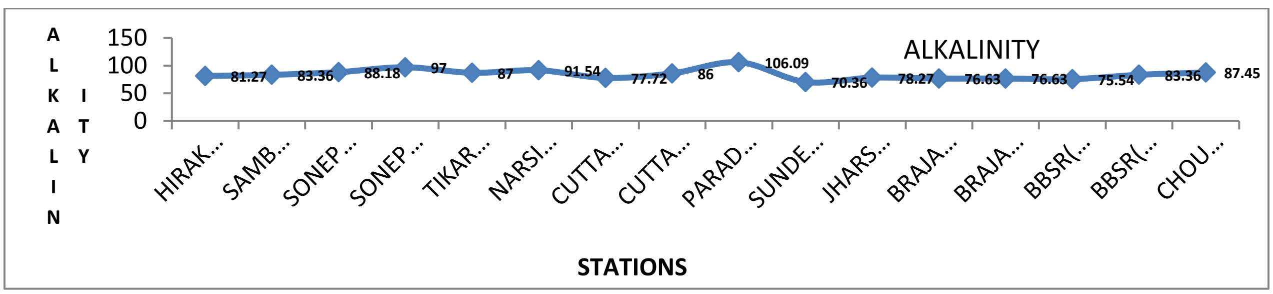
It is seen from Table that metal concentrations are within the acceptable limits.

Thus it may be summarized that, the water quality at all stations are below acceptable level, due mostly to FC and TKN. An additional factor at paradeep is EC.

5.13.3 WATER QUALITY IN TERMS OF COD AND ALKALINITY:

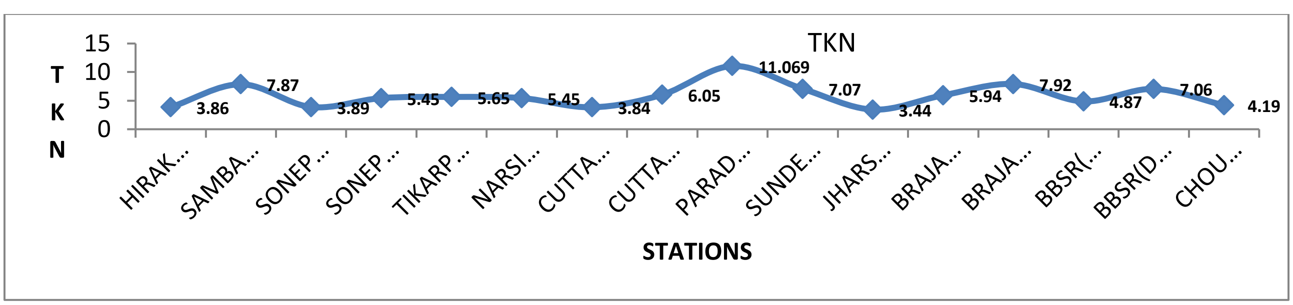
COD and alkalinity values are given in Tables. Except at the downstream of Sambalpur, Cuttack, Mahanadi and Kathojodi), cuttack FD/s (Kathojodi), Bhubaneswar (Daya) and Paradeep D/s(Mahanadi) , COD levels at all other stations generally remain less than 20 mg/l. Alkalinity levels at all stations are well within the acceptable limits for most beneficial use.





5.13.3.1 TKN:

TKN values are more important for stagnant water, since higher TKN values indicate a potential for eutrophication or higher level of ammonia in water, which may be toxic. The total kjedahl nitrogen (TKN) reflecting organic pollution was observed (Table) to be mostly more than 3 mg/l at all stations, thus downgrading the water quality below acceptable limits with regard to organic pollution.



5.14 WATER QUALITY TREND

5.14.1 MAHANADI RIVER:

About 86% of the catchment (72,691 sq. km. out of total of 84,372) and tributaries of Mahanadi (Seonath ,Jonk ,Hosdeo and Mond) above the dam are in Madhya Pradesh/chattisgarh. Since several large towns and industries (Rajnandagaon, Bhillai, Durg, Shimoga, Raipur, Bilaspur ,Korbo etc.) are lacated on the banks of these tributaries, they carry considerable pollution load to the reservoir water at Hirakud almost conforms to class –B, except for TC values.

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. 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.

The Bhubaneswar Office of the Chief Engineer (Mahanadi and eastern Rivers) of the Central Water Commission (CWC), Govt. of India, also monitors the water quality of Mahanadi at Tikarpada every month.

BOD values at Tikarpada as reported by CWC and State Pollution Control Board, odisha during the period 2000-2014 are given in Table. As may be seen, the values obtained by both the organizations are quite comparable and more or less of same trend.

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. Spatial variation in BOD and TC along the river stretch is shown in Figure.

5.14.2 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. Spatial variation of BOD and TC along IB River is presented in Figure.

5.14.3 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, variation of BOD and TC in Bheden River is presented in Figure.

5.14.4 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.

5.14.5 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.

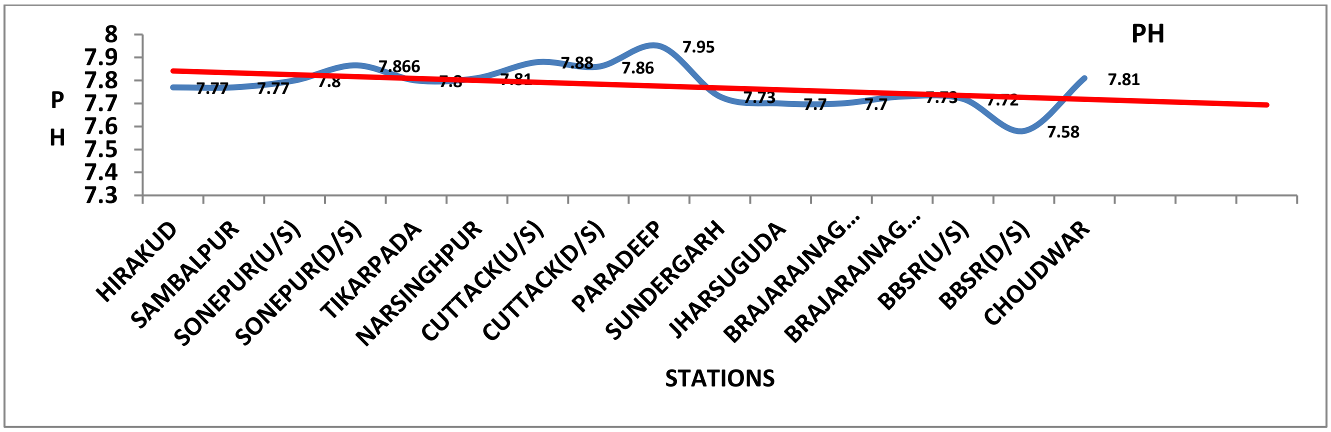
5.14.6 KUAKHAI AND DAYA RIVERS:

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.

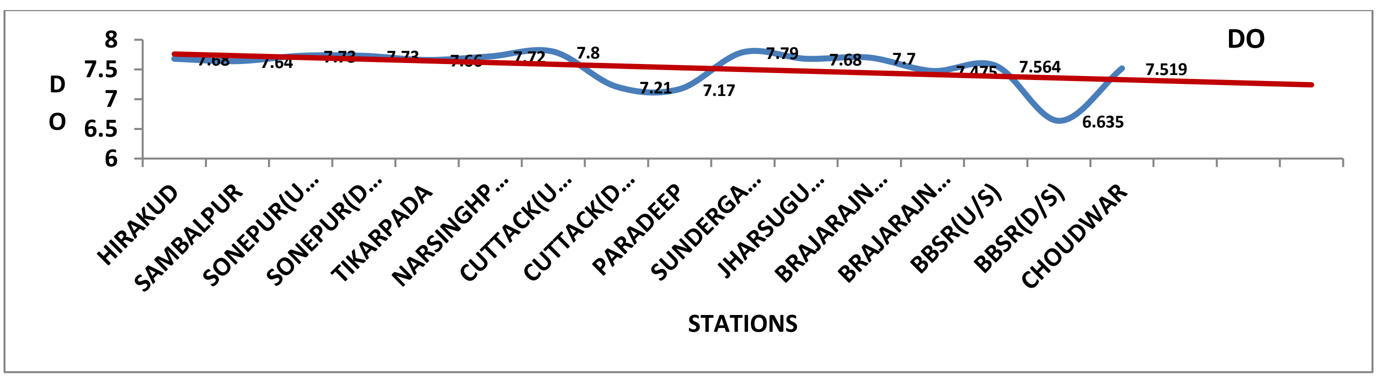
Bhubaneswar D/s on Daya (distributary of Kuakhai) is just beyond the city limits. The river receives the city waste water, atleast through one organized outfall, the Gangua Nallah, in between, as a consequence of which the water quality is downgraded beyond Class-c and unacceptable for most beneficial 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. Figure shows the variation of BOD and TC in Kathajodi , Kuakhai , Daya and Birupa rivers.

5.14.7 TIME SERIES GRAPH FOR TREND ANALYSIS OF WATER QUALITY PARAMETERS OF MAHANADI RIVER BASIN:

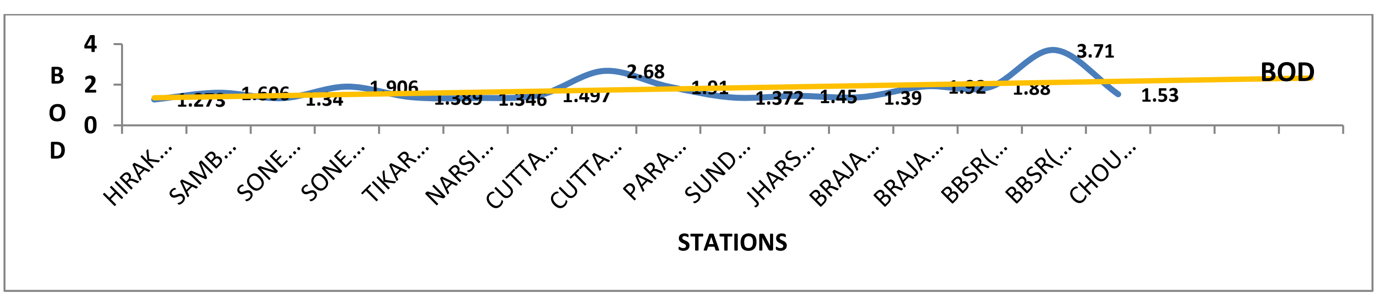
5.14.7.1 PH:



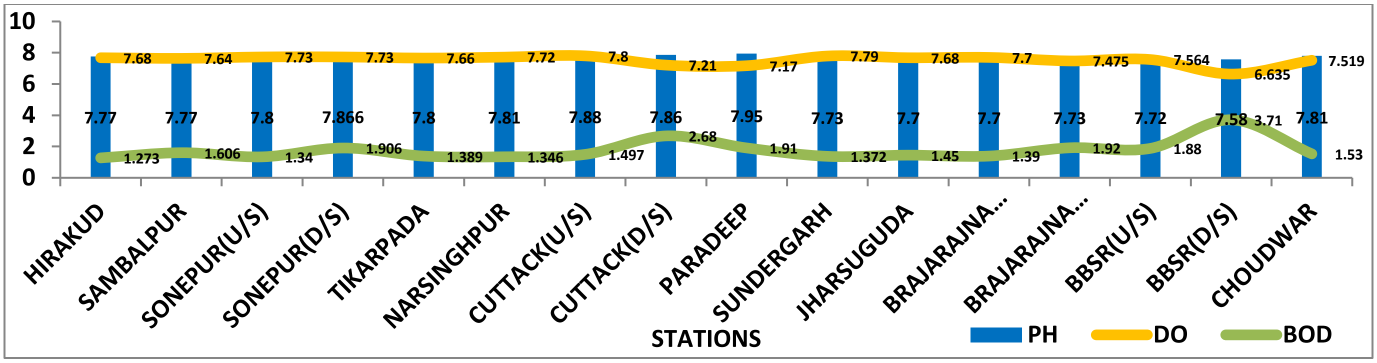
5.14.7.2 DO:



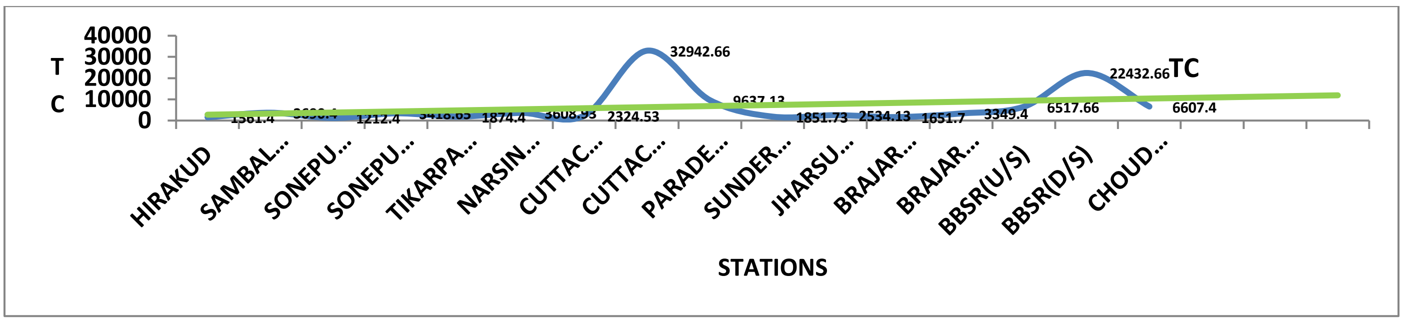
5.14.7.3 BOD:



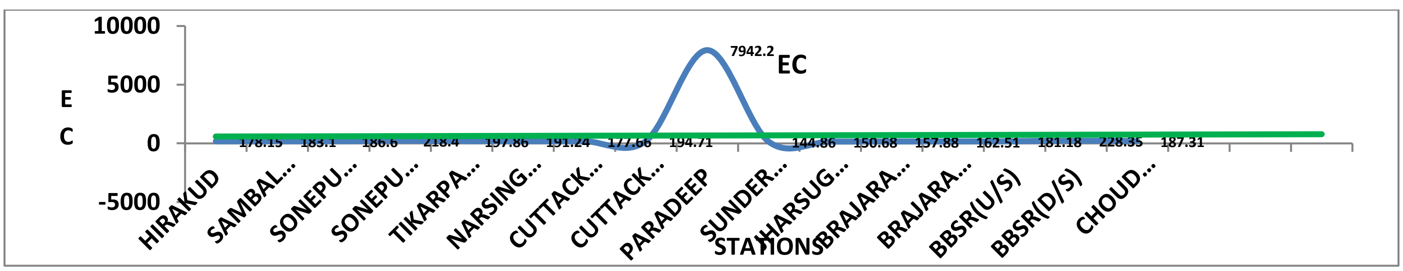
5.14.7.4 PH, DO AND BOD:



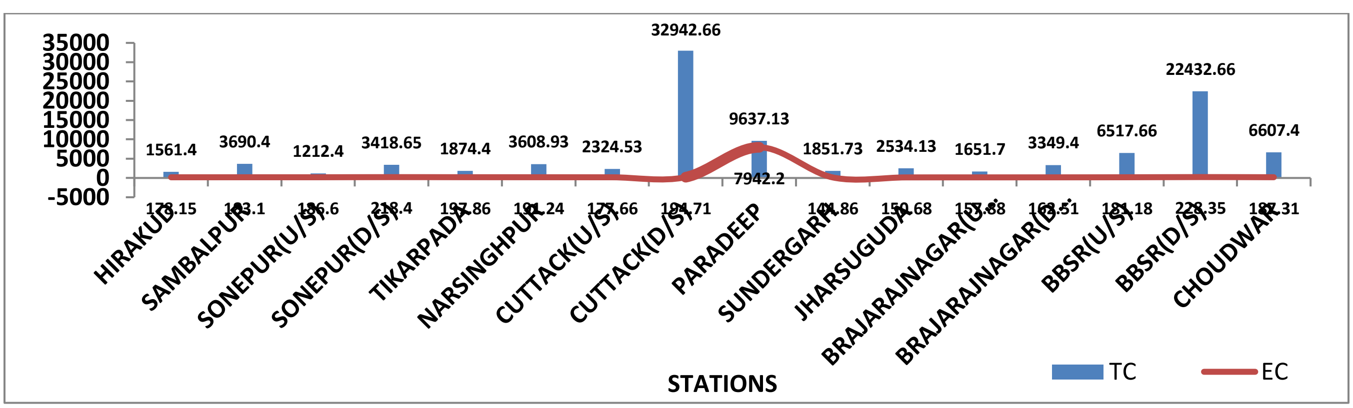
5.14.7.5 TC:



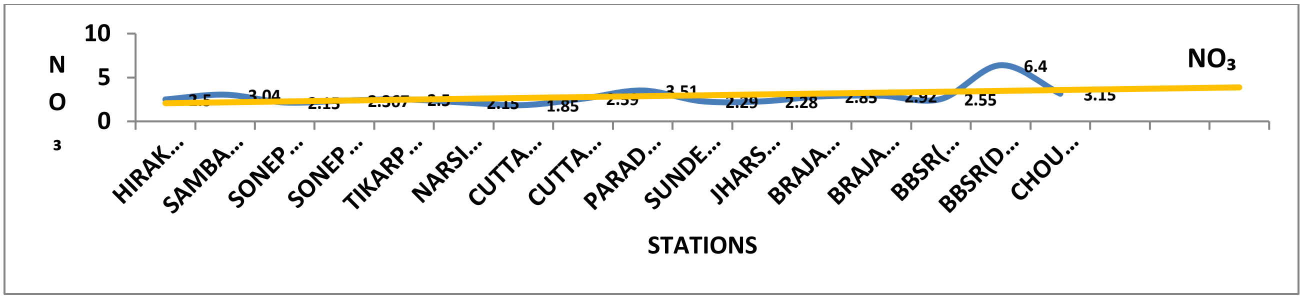
5.14.7.6 EC:



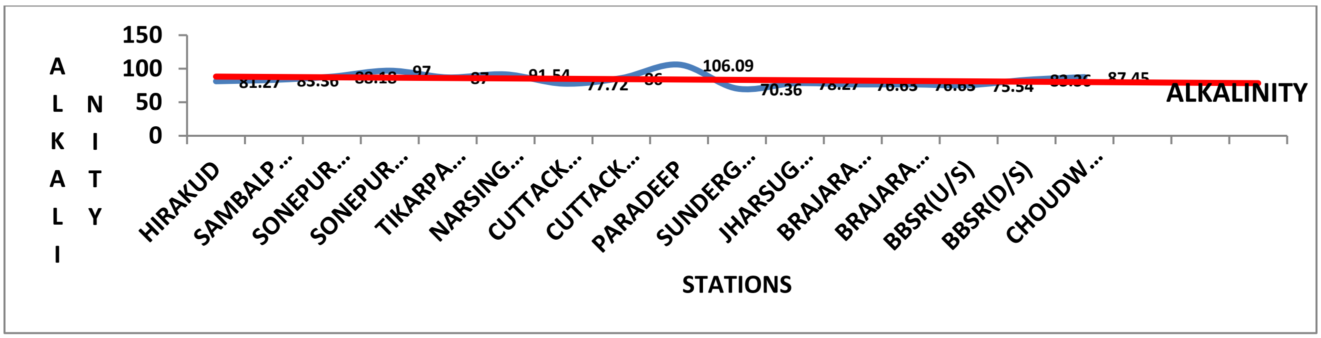
5.14.7.7 TC AND EC:



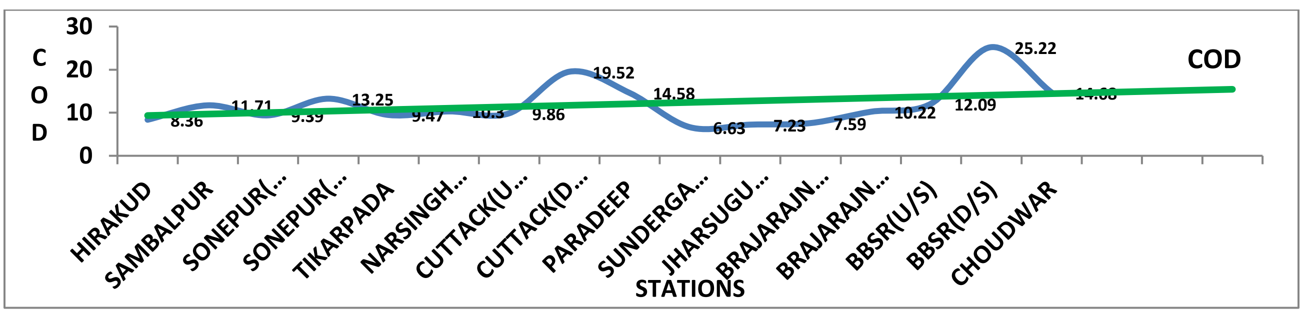
5.14.7.8 NITRATE:



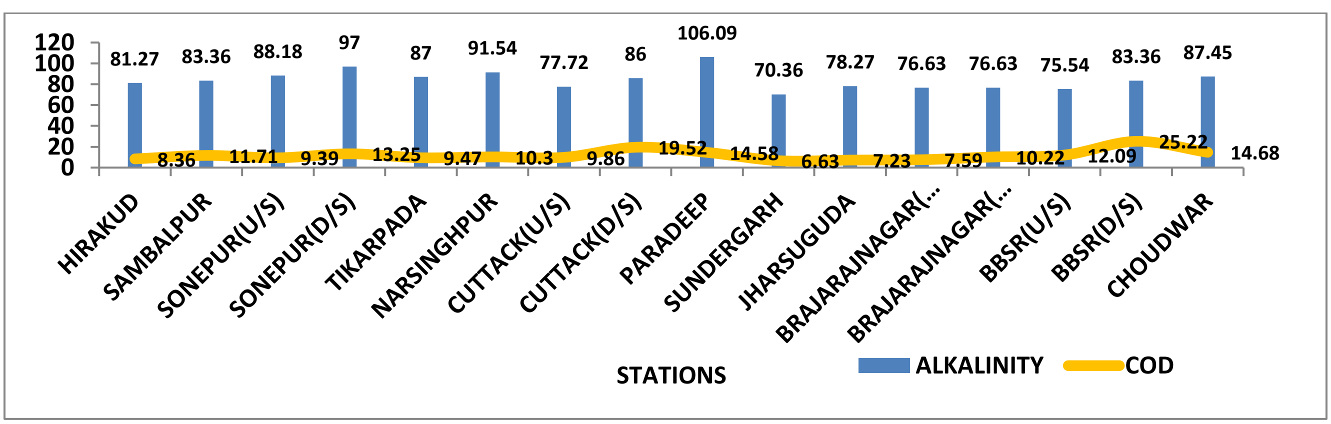
5.14.7.9 ALKALINITY:



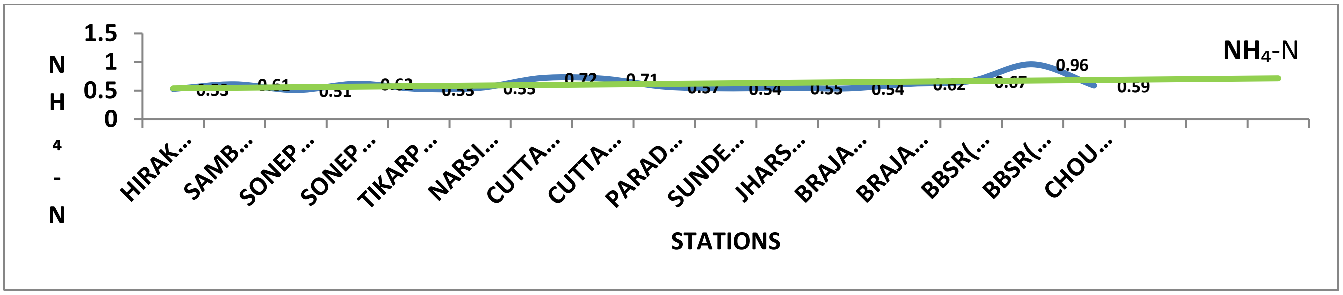
5.14.7.10 COD:



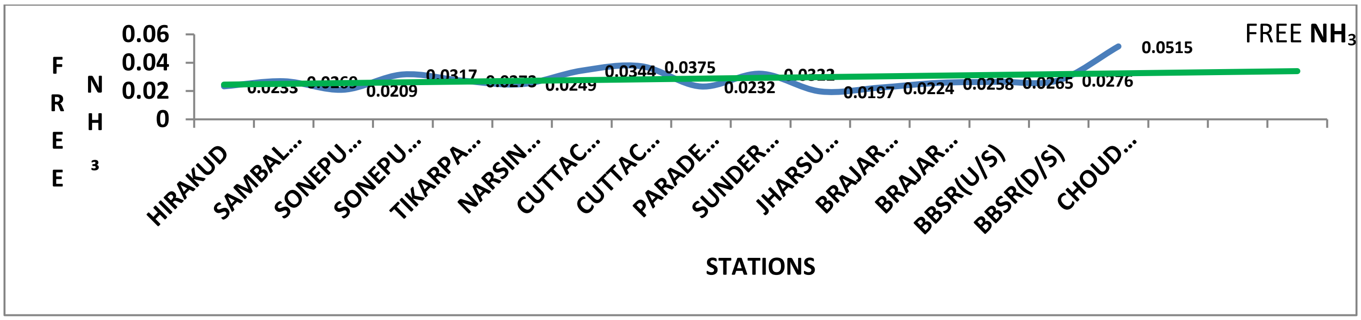
5.14.7.11 ALKALINITY AND COD:



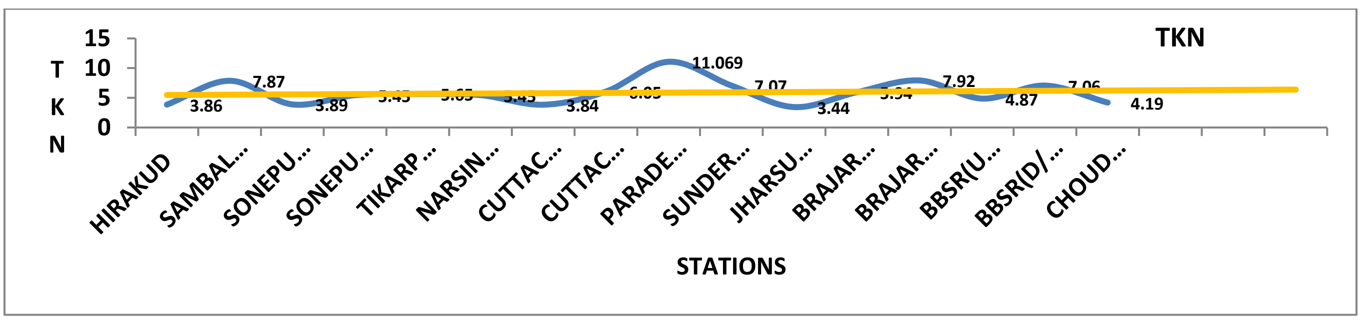
5.14.7.12 NH$_4$-N:



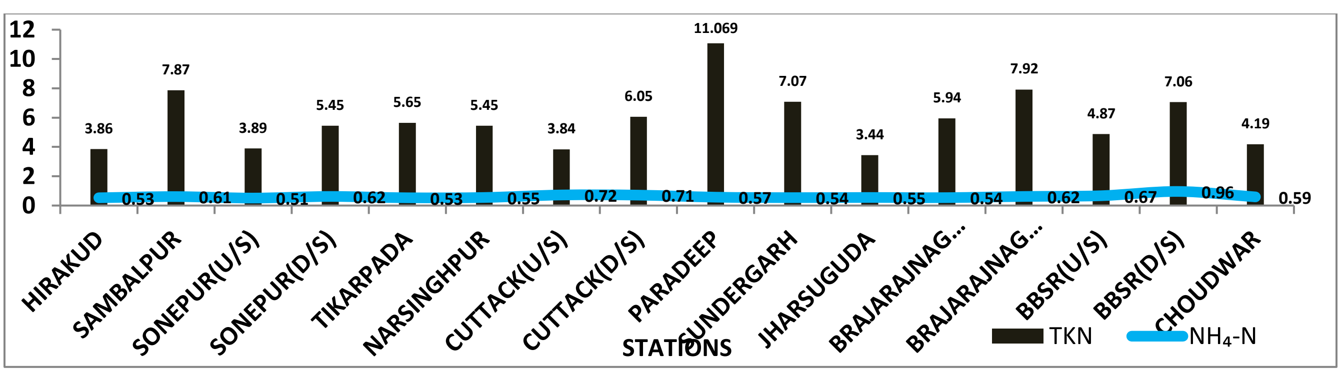
5.14.7.13 FREE AMMONIA:



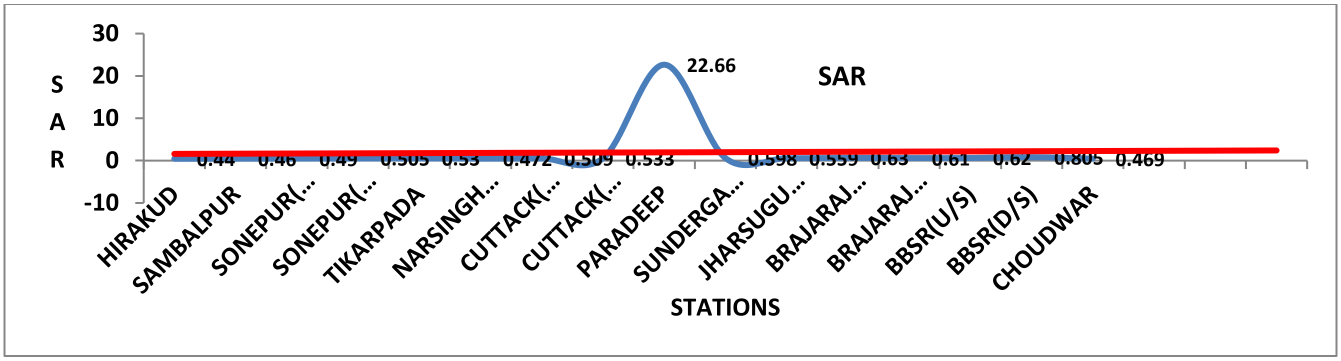
5.14.7.14 TKN:



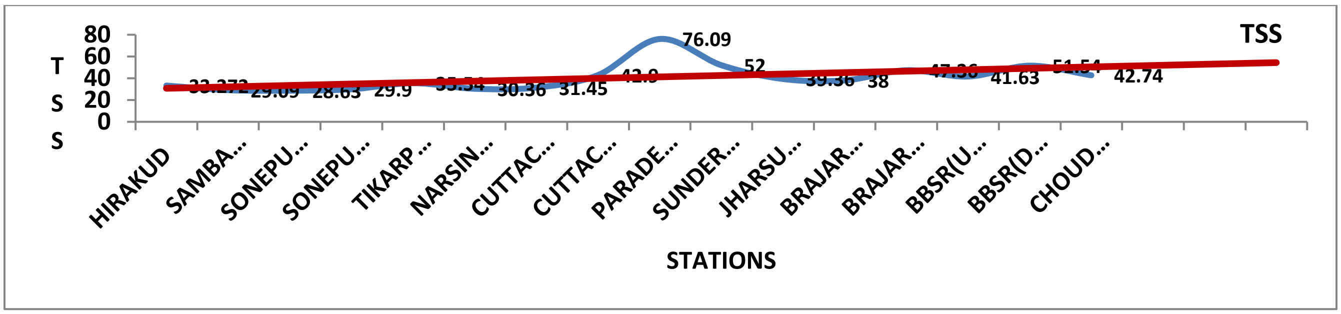
5.14.7.15 NH$_4$-N AND TKN:



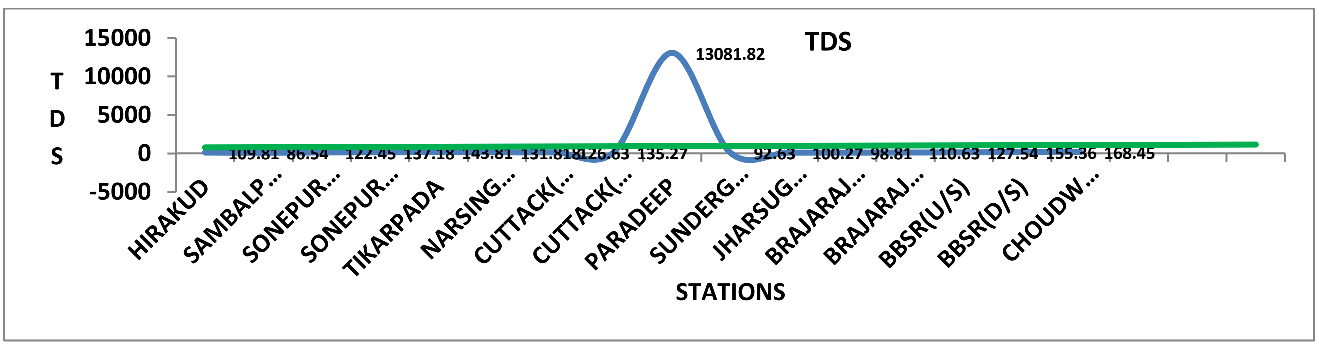
5.14.7.16 SAR:



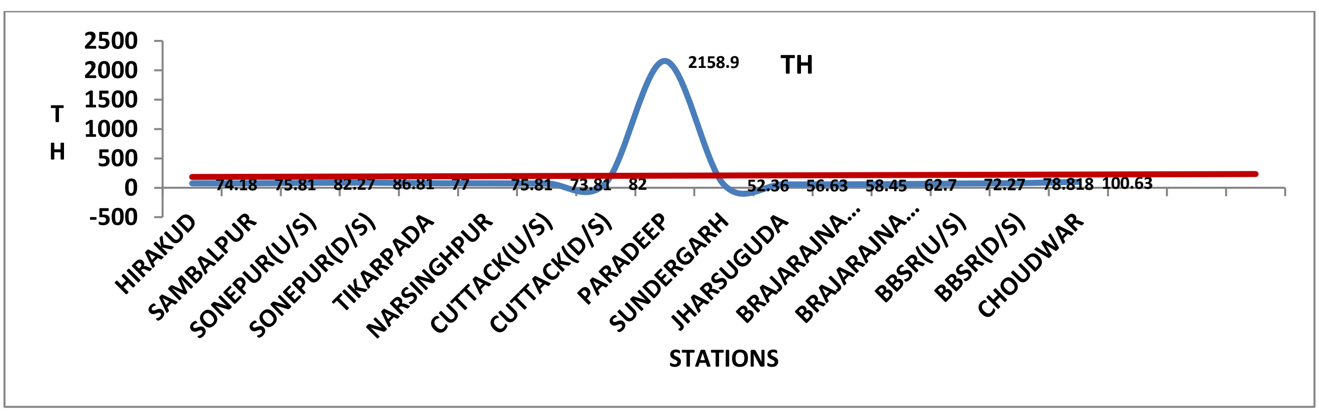
5.14.7.17 TSS:



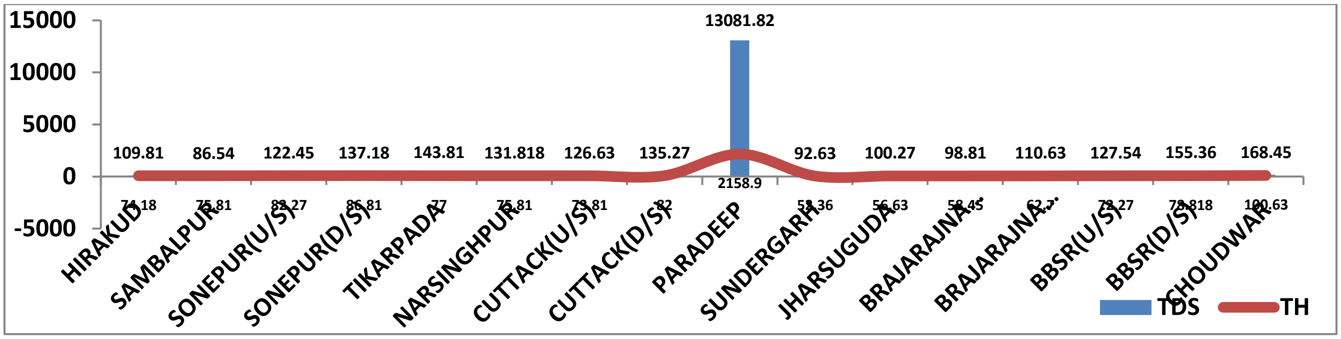
5.14.7.18 TDS:



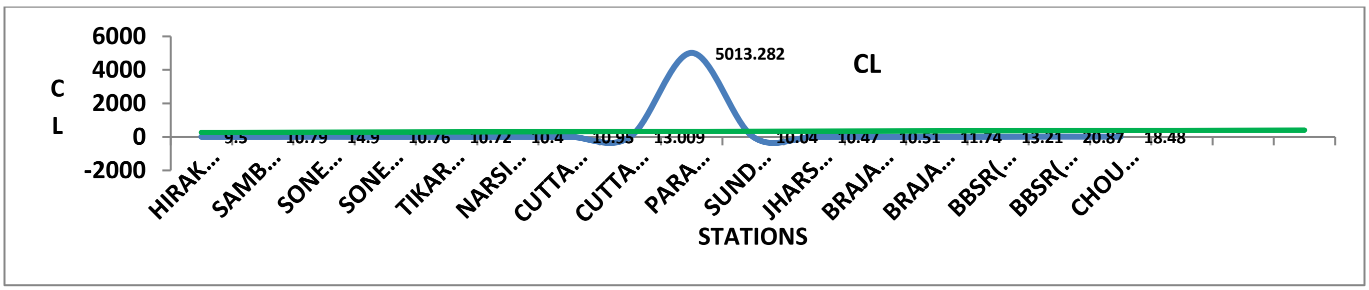
5.14.7.19 TH:



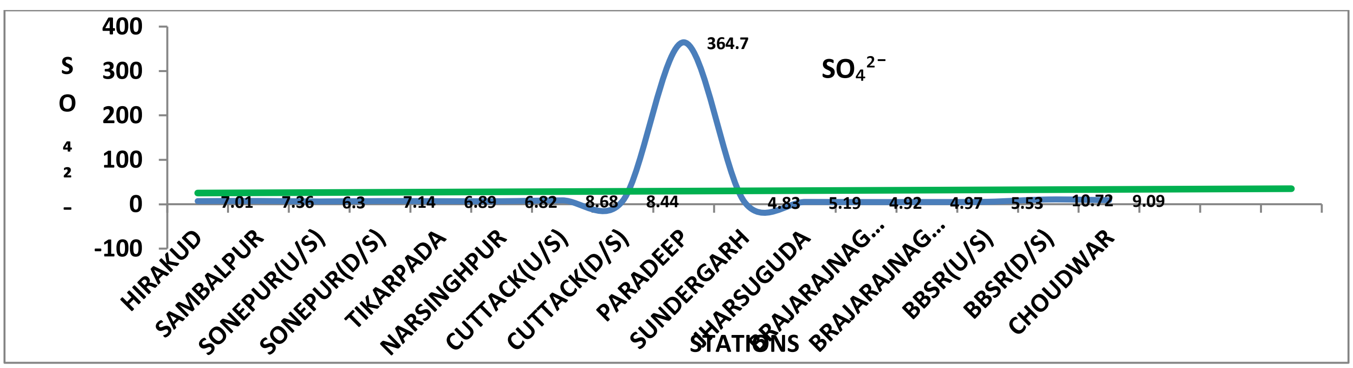
5.14.7.20 TDS AND TH:



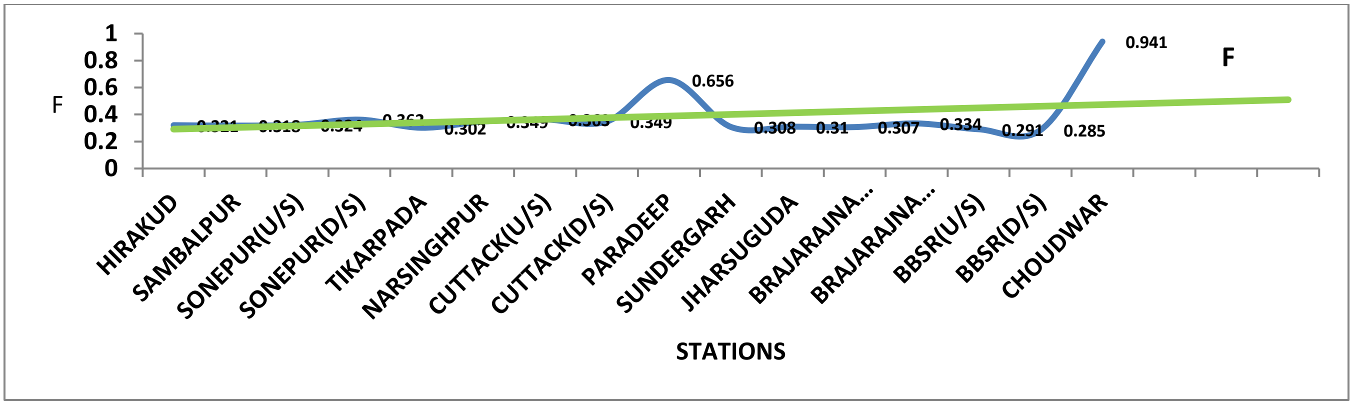
5.14.7.21 CHLORIDE:



5.14.7.22 SULPHATE:



5.14.7.23 FLUORIDE:


F
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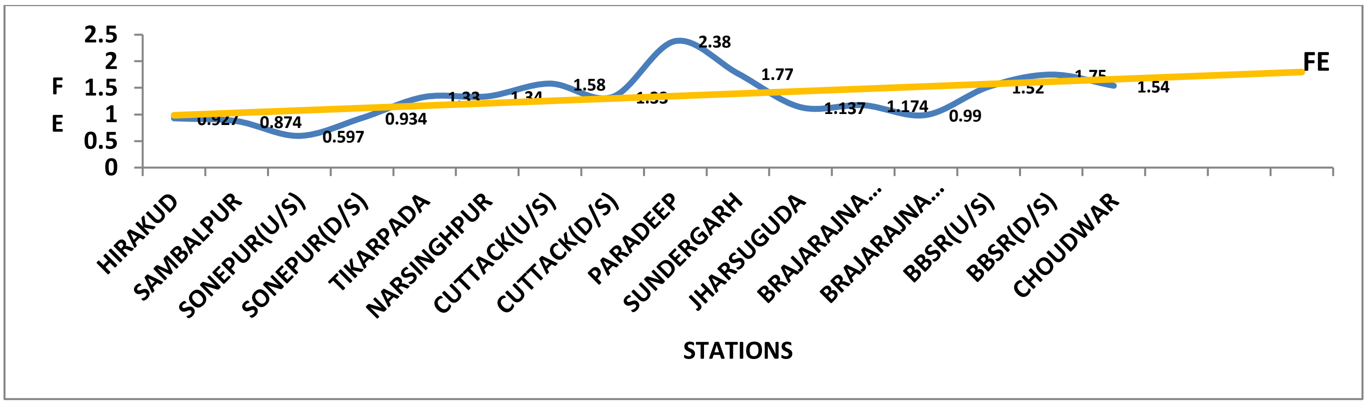
0.941
0.302
0.349
0.308
0.31
0.307
0.334
0.291
0.285
STATIONS
HIRAKUD
SAMBALPUR
SONEPUR(U/S)
SONEPUR(D/S)
TIKARPADA
NARSINGHPUR
CUTTACK(U/S)
CUTTACK(D/S)
PARADEEP
SUNDERGARH
JHARSUGUDA
BRAJARAJNA...
BRAJARAJNA...
BBSR(U/S)
BBSR(D/S)
CHOUDWAR

5.14.7.24 FE: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0.99
1.52
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STATIONS
HIRAKUD
SAMBALPUR
SONEPUR(U/S)
SONEPUR(D/S)
TIKARPADA
NARSINGHPUR
CUTTACK(U/S)
CUTTACK(D/S)
PARADEEP
SUNDERGARH
JHARSUGUDA
BRAJARAJNA...
BRAJARAJNA...
BBSR(U/S)
BBSR(D/S)
CHOUDWAR

5.15 MANN-KENDALL TREND ANALYSIS OF MONITORING STATIONS

In the present study, trend analysis of yearly average water quality parameters has been carried out. For this initially the available yearly average data was classified in the above period. Further 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 districts of Orissa has been determined. The trends in yearly average water quality parameters data were investigated through the Kendall's test for different stations of River Mahanadi.

5.15.1 TREND TEST FOR CUTTACK D/S

YEARLY	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
PH	7.875	7.9	7.9	7.7	7.6	7.775	7.88	7.93	7.8	8.1	7.65	8	8	7.9	7.9

VALUE OF P= 61
TEST STASTICS "t" = 0.84128
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 10% SIGNIFICANCE LEVEL

YEARLY	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
DO	6.45	6.38	7.58	7.65	7.55	7.6	7.1	7	7.05	7.45	6.8	7.3	7.7	7.2	7.4

VALUE OF P= 57
TEST STASTICS "t" = 0.44538
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 10% SIGNIFICANCE LEVEL

YEARLY	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
BOD	4.2	3.5	3.6	2.7	2.3	2.8	2.7	2.2	2.2	2.2	2.2	2.5	2.5	2.5	2.2

VALUE OF P= 19
TEST STASTICS "t" = -3.31564
THERE IS FALLING TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS FALLING TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS FALLING TREND IN DATA AT 10% SIGNIFICANCE LEVEL

YEARLY	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
TC	19563	13017	10860	7800	17608	46091	57467	27467	26617	14970	17133	35675	55417	82000	62455

VALUE OF P= 77
TEST STASTICS "t" = 2.42487
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS RAISING TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS RAISING TREND IN DATA AT 10% SIGNIFICANCE LEVEL

YEARLY	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
TSS	6	18	29	28	23	70	18	80	56	81	63

VALUE OF P= 42
TEST STASTICS "t" = 2.25765
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS RAISING TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS RAISING TREND IN DATA AT 10% SIGNIFICANCE LEVEL

YEARLY	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
ALKALINITY	73	90	108	98	88	92	86	78	79	78	76

VALUE OF P= 15
TEST STASTICS "t" = -1.94625
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS FALLING TREND IN DATA AT 10% SIGNIFICANCE LEVEL

YEARLY	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
COD	16.6	22.7	25.8	22	14.8	12.7	20	19.8	20.5	21.7	18.2

VALUE OF P= 24
TEST STASTICS "t" = -0.54495
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 10% SIGNIFICANCE LEVEL

YEARLY	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
NH_4-N	0.78	0.83	0.91	0.98	0.84	1.48	0.425	0.49	0.28	0.117

VALUE OF P= 14
TEST STASTICS "t" = -1.52053
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 10% SIGNIFICANCE LEVEL

YEARLY	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
FREE NH_3	0.03	0.05	0.037	0.044	0.043	0.089	0.028	0.03	0.017	0.006

VALUE OF P= 14
TEST STASTICS "t" = -1.52053
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 10% SIGNIFICANCE LEVEL

YEARLY	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
TKN	6.1	6.7	2	2.24	17.2	3.08	11.48	8.4	5.36	2.87	1.12

VALUE OF P= 23
TEST STASTICS "t" = -0.70065
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 10% SIGNIFICANCE LEVEL

YEARLY	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
EC	248.5	205.3	171	155	227.75	180.5	191.75	171.5	181	190	209.5	191	188	206	204

VALUE OF P= 27
TEST STASTICS "t" = -0.07785
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 10% SIGNIFICANCE LEVEL

YEARLY	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
SAR	0.46	0.59	0.51	0.94	0.51	0.51	0.67	0.51	0.745	0.42	0.49	0.42	0.38	0.39	0.46

VALUE OF P= 27
TEST STASTICS "t" = -0.07785
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 10% SIGNIFICANCE LEVEL

YEARLY	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
B	0.19	BDL	0.08	BDL	BDL	0.056	0.017	0.12	0.07	0.036	0.052	0.07	0.08

VALUE OF P= 44
TEST STASTICS "t" = 0.61009
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 10% SIGNIFICANCE LEVEL

YEARLY	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
TDS	174	158	209	125	132	123	98	119	116	118	116

VALUE OF P= 8
TEST STASTICS "t" = -3.03615
THERE IS FALLING TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS FALLING TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS FALLING TREND IN DATA AT 10% SIGNIFICANCE LEVEL

YEARLY	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
TH	80	124	78	82	84	84	78	71	75	75	71

VALUE OF P= 11
TEST STASTICS "t" = -2.56905
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS FALLING TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS FALLING TREND IN DATA AT 10% SIGNIFICANCE LEVEL

YEARLY	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
CL	11	30	10	6	6	14	16	12.6	12.9	12.9	11.7

VALUE OF P= 28
TEST STASTICS "t" = 0.07785
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 10% SIGNIFICANCE LEVEL

YEARLY	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
SULPHATE	8	8	15	6.4	10.9	9.4	6	6.7	7.39	7.07	8.03

VALUE OF P= 23
TEST STASTICS "t" = -0.70065
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 10% SIGNIFICANCE LEVEL

YEARLY	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
F	0.64	0.36	0.33	0.273	0.266	0.128	0.425	0.32	0.353	0.411	0.33

VALUE OF P= 24
TEST STASTICS "t" = -0.54495
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 10% SIGNIFICANCE LEVEL

YEARLY	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
NITRATE	5.3	3.1	4.7	4.5	3.9	1.7	2	0.797	2.658	1.904	1.816	0.582	1.67	1.111	3.174

VALUE OF P= 25
TEST STASTICS "t" = -2.72179
THERE IS FALLING TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS FALLING TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS FALLING TREND IN DATA AT 10% SIGNIFICANCE LEVEL

YEARLY	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
FE	0.92	0.48	1.312	0.529	0.05	0.083	0.787	4.11	2.575	1.575	2.267

VALUE OF P= 37
TEST STASTICS "t" = 1.47915
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 10% SIGNIFICANCE LEVEL

5.15.2 "TREND TEST FOR PARADEEP"

YEARLY	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
PH	7.805	7.805	8.103	7.45	7.475	7.625	7.6	7.75	7.675	7.9	7.95	8	7.9	8	7.9

VALUE OF P= 69
TEST STASTICS "t" = 1.63308
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 10% SIGNIFICANCE LEVEL

YEARLY	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
DO	6.75	6.75	6.525	6.125	7.05	7.3	7.575	7.825	7.2	7.6	7.175	7.6	7.6	7.5	7

VALUE OF P= 70
TEST STASTICS "t" = 1.73205
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS RAISING TREND IN DATA AT 10% SIGNIFICANCE LEVEL

YEARLY	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
BOD	2.2	2.2	4.9	3.1	2.4	2	1.4	1.4	1	0.9	1.8	1.2	1.5	1.5	1.2

VALUE OF P= 24
TEST STASTICS "t" = -2.82077
THERE IS FALLING TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS FALLING TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS FALLING TREND IN DATA AT 10% SIGNIFICANCE LEVEL

YEARLY	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
TC	1630	1630	25875	13400	21900	9050	17386	1900	1583	1987	1900	3209	5900	22020	15187

VALUE OF P= 57
TEST STASTICS "t" = 0.44538
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 10% SIGNIFICANCE LEVEL

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YEARLY	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
TSS	88	88	40	74	68	30	26	74	89	164	96

VALUE OF P= 32
TEST STASTICS "t" = 0.70065
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 10% SIGNIFICANCE LEVEL

YEARLY	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
TOTAL ALKALINITY	158	150	160	106	92	100	86	71	82	77	85

VALUE OF P= 8
TEST STASTICS "t" = -3.03615
THERE IS FALLING TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS FALLING TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS FALLING TREND IN DATA AT 10% SIGNIFICANCE LEVEL

YEARLY	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
COD	15.1	15.1	25.8	19	12.9	6.3	12.8	10.1	13.5	15.6	14.2

VALUE OF P= 22
TEST STASTICS "t" = -0.85635
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 10% SIGNIFICANCE LEVEL

YEARLY	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
NH_4-N	0.62	0.85	0.64	0.9	0.75	0.96	0.407	0.3	0.234	0.143

VALUE OF P= 12
TEST STASTICS "t" = -1.87830
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS FALLING TREND IN DATA AT 10% SIGNIFICANCE LEVEL

YEARLY	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
FREE NH_3	0.02	0.01	0.03	0.031	0.031	0.044	0.033	0.02	0.013	0.007

VALUE OF P= 21
TEST STASTICS "t" = -0.26833
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 10% SIGNIFICANCE LEVEL

YEARLY	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
TKN	3.8	9.2	39.8	2.8	45	2.24	7.28	5	2.67	2.85	1.12

VALUE OF P= 17
TEST STASTICS "t" = -1.63485
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 10% SIGNIFICANCE LEVEL

YEARLY	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
EC	1631	1631	7530	18283	12266	21796	16741	6820.5	3587	9695	5829.8	1477	6078	1618	4152

VALUE OF P= 40
TEST STASTICS "t" = -1.23718
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 10% SIGNIFICANCE LEVEL

YEARLY	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
SAR	60.9	45.3	40.68	31.06	7.78	1.051	36.58	9.48	2.73	13.77	6.52	16.2

VALUE OF P= 18
TEST STASTICS "t" = -2.05718
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS FALLING TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS FALLING TREND IN DATA AT 10% SIGNIFICANCE LEVEL

YEARLY	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
B	2.11	0.21	0.54	1.25	0.318	0.048	1.485	0.79	0.158	0.401	0.147	0.4

VALUE OF P= 25
TEST STASTICS "t" = -1.09716
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 10% SIGNIFICANCE LEVEL

YEARLY	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
TDS	11594	25668	48370	21908	4472	18340	4340	900	4177	1026	3105

VALUE OF P= 10
TEST STASTICS "t" = -2.72475
THERE IS FALLING TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS FALLING TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS FALLING TREND IN DATA AT 10% SIGNIFICANCE LEVEL

YEARLY	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
TH	1796	4300	6450	3800	76	3800	1300	311	1290	173	452

VALUE OF P= 14
TEST STASTICS "t" = -2.10195
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS FALLING TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS FALLING TREND IN DATA AT 10% SIGNIFICANCE LEVEL

YEARLY	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
CL	6097	17845	3497	10997	2499	8398	1300	355	2112	479.1	1567

VALUE OF P= 12
TEST STASTICS "t" = -2.41335
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS FALLING TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS FALLING TREND IN DATA AT 10% SIGNIFICANCE LEVEL

YEARLY	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
SULPHATE	251	4	234	362.7	221.2	1518	731	134	267.3	68.01	220.8

VALUE OF P= 25
TEST STASTICS "t" = -0.38925
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 10% SIGNIFICANCE LEVEL

YEARLY	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
F	0.92	1.39	0.96	1.11	0.445	0.149	0.667	0.4	0.484	0.315	0.386

VALUE OF P= 13
TEST STASTICS "t" = -2.25765
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS FALLING TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS FALLING TREND IN DATA AT 10% SIGNIFICANCE LEVEL

YEARLY	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
NITRATE	0	8.9	8	4.3	4.6	4.5	4.2	0.399	1.541	3.366	1.639	0.769	3.41	2.977	4.15

VALUE OF P= 38
TEST STASTICS "t" = -1.43513
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 10% SIGNIFICANCE LEVEL

YEARLY	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
FE	0.15	0.08	2.275	4.457	0.029	0.113	3.403	6.58	2.971	3.485	2.713

VALUE OF P= 36
TEST STASTICS "t" = 1.32345
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 10% SIGNIFICANCE LEVEL

5.15.3 "TREND TEST FOR TIKARPADA"

YEARLY	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
PH	7.675	7.9	7.825	7.775	7.575	7.35	7.725	7.875	7.875	7.65	8.1	8	7.8	8	8

VALUE OF P= 68
TEST STASTICS "t" = 1.53410
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 10% SIGNIFICANCE LEVEL

YEARLY	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
DO	7.175	7.3	7.85	7.65	7.475	7.225	7.8	7.725	7.95	8	7.525	7.4	8.3	7.6	8

VALUE OF P= 72
TEST STASTICS "t" = 1.93000
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS RAISING TREND IN DATA AT 10% SIGNIFICANCE LEVEL

YEARLY	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
BOD	3.5	2.1	2.5	1.24	1	0.9	1	1.2	1.1	1	1	1.5	1.4	0.8	0.6

VALUE OF P= 26
TEST STASTICS "t" = -2.62282
THERE IS FALLING TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS FALLING TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS FALLING TREND IN DATA AT 10% SIGNIFICANCE LEVEL

YEARLY	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
TC	270	1051	632	550	530	2740	2225	2200	2325	2300	2400	3345	2393	1880	3275

VALUE OF P= 80
TEST STASTICS "t" = 2.72179
THERE IS RAISING TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS RAISING TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS RAISING TREND IN DATA AT 10% SIGNIFICANCE LEVEL

YEARLY	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
TSS	10	30	3	28	72	4	3	82	58	73	28

VALUE OF P= 33
TEST STASTICS "t" = 0.85635
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 10% SIGNIFICANCE LEVEL

YEARLY	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
TOTAL ALKALINITY	89	90	104	90	98	88	92	73	75	85	73

VALUE OF P= 14
TEST STASTICS "t" = -2.10195
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS FALLING TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS FALLING TREND IN DATA AT 10% SIGNIFICANCE LEVEL

YEARLY	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
COD	5.2	11.3	15.8	9	11.6	4.8	8.1	10.9	11.8	8.3	7.4

VALUE OF P= 25
TEST STASTICS "t" = -0.38925
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 10% SIGNIFICANCE LEVEL

YEARLY	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
NH_4-N	0.462	0.59	0.83	0.66	0.67	1.05	0.481	0.17	0.332	0.132

VALUE OF P= 15
TEST STASTICS "t" = -1.34164
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 10% SIGNIFICANCE LEVEL

YEARLY	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
FREE NH_3	0.012	0.02	0.033	0.025	0.019	0.103	0.024	0.01	0.02	0.009

VALUE OF P= 18
TEST STASTICS "t" = -0.80498
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 10% SIGNIFICANCE LEVEL

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YEARLY	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
TKN	3.6	1.7	1.7	3.64	17.5	3.08	21.52	2.4	3.14	2.65	1.32

VALUE OF P= 24
TEST STASTICS "t" = -0.54495
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 10% SIGNIFICANCE LEVEL

YEARLY	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
EC	225	193.8	230.5	149.8	245.5	140.5	154.75	187.75	256	184	227.5	186	181	215	191

VALUE OF P= 51
TEST STASTICS "t" = -0.14846
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 10% SIGNIFICANCE LEVEL

YEARLY	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
SAR	0.49	0.96	0.87	0.51	0.59	0.29	0.29	0.53	1.131	0.46	0.45	0.39	0.36	0.37	0.4

VALUE OF P= 33
TEST STASTICS "t" = -1.93000
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS FALLING TREND IN DATA AT 10% SIGNIFICANCE LEVEL

YEARLY	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
B	0.17	0.06	0.01	BDL	0.003	0.041	0.075	BDL	0.04	0.066	0.088	0.09

VALUE OF P= 39
TEST STASTICS "t" = 0.82287
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 10% SIGNIFICANCE LEVEL

YEARLY	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
TDS	136	106	205	172	296	113	100	112	110	125	107

VALUE OF P= 20
TEST STASTICS "t" = -1.16775
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 10% SIGNIFICANCE LEVEL

YEARLY	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
TH	84	76	76	76	96	76	76	69	69	78	71

VALUE OF P= 13
TEST STASTICS "t" = -2.25765
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS FALLING TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS FALLING TREND IN DATA AT 10% SIGNIFICANCE LEVEL

YEARLY	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
CL	20	3	9	7	4	15	14	12.1	11.1	12.3	10.5

VALUE OF P= 29
TEST STASTICS "t" = 0.23355
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 10% SIGNIFICANCE LEVEL

YEARLY	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
SULPHATE	5	3	12	5	8.6	9.1	5.1	5.8	7.53	6.5	8.18

VALUE OF P= 34
TEST STASTICS "t" = 1.01205
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 10% SIGNIFICANCE LEVEL

YEARLY	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
F	0.3	0.12	0.37	0.348	0.345	0.105	0.418	0.33	0.35	0.297	0.346

VALUE OF P= 29
TEST STASTICS "t" = 0.23355
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 10% SIGNIFICANCE LEVEL

YEARLY	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
NITRATE	6	4.4	4.5	1.6	4.5	0.8	2.1	1.949	3.41	1.24	2.037	0.185	1.8	1.081	1.948

VALUE OF P= 28
TEST STASTICS "t" = -2.42487
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS FALLING TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS FALLING TREND IN DATA AT 10% SIGNIFICANCE LEVEL

YEARLY	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
FE	BDL	0.19	1.137	1.734	0.092	0.04	0.307	4.15	3.058	2.405	1.438

VALUE OF P= 29
TEST STASTICS "t" = 1.16276
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 10% SIGNIFICANCE LEVEL

5.15.4 "TREND TEST FOR SUNDERGARH"

PH:

VALUE OF P= 70
TEST STASTICS "t" = 1.73205
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS RAISING TREND IN DATA AT 10% SIGNIFICANCE LEVEL

DO:

VALUE OF P= 47
TEST STASTICS "t" = -0.54436
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 10% SIGNIFICANCE LEVEL

BOD:

VALUE OF P= 21
TEST STASTICS "t" = -3.11769
THERE IS FALLING TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS FALLING TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS FALLING TREND IN DATA AT 10% SIGNIFICANCE LEVEL

TC:

VALUE OF P= 67
TEST STASTICS "t" = 1.43513
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 10% SIGNIFICANCE LEVEL

AMMONIACAL NITROGEN:

VALUE OF P= 12
TEST STASTICS "t" = -1.87830
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS FALLING TREND IN DATA AT 10% SIGNIFICANCE LEVEL

FREE AMMONIA:

VALUE OF P= 21
TEST STASTICS "t" = -0.26833
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 10% SIGNIFICANCE LEVEL

SAR:

VALUE OF P= 28
TEST STASTICS "t" = -2.42487
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS FALLING TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS FALLING TREND IN DATA AT 10% SIGNIFICANCE LEVEL

TSS:

VALUE OF P= 35
TEST STASTICS "t" = 1.16775
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 10% SIGNIFICANCE LEVEL

TOTAL ALKALINITY:

VALUE OF P= 17
TEST STASTICS "t" = -1.63485
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 10% SIGNIFICANCE LEVEL

COD:

VALUE OF P= 33
TEST STASTICS "t" = 0.85635
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 10% SIGNIFICANCE LEVEL

TKN:

VALUE OF P= 15
TEST STASTICS "t" = -1.94625
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS FALLING TREND IN DATA AT 10% SIGNIFICANCE LEVEL

FE:

VALUE OF P= 40
TEST STASTICS "t" = 1.94625
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS RAISING TREND IN DATA AT 10% SIGNIFICANCE LEVEL

EC:

VALUE OF P= 52
TEST STASTICS "t" = -0.04949
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 10% SIGNIFICANCE LEVEL

BORON:

VALUE OF P= 56
TEST STASTICS "t" = 2.07430
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS RAISING TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS RAISING TREND IN DATA AT 10% SIGNIFICANCE LEVEL

TDS:

VALUE OF P= 25
TEST STASTICS "t" = -0.38925
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 10% SIGNIFICANCE LEVEL

TH:

VALUE OF P= 28
TEST STASTICS "t" = 0.07785
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 10% SIGNIFICANCE LEVEL

CL:

VALUE OF P= 30
TEST STASTICS "t" = 0.38925
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 10% SIGNIFICANCE LEVEL

SULPHATE:

VALUE OF P= 29
TEST STASTICS "t" = 0.23355
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 10% SIGNIFICANCE LEVEL

F:

VALUE OF P= 29
TEST STASTICS "t" = 0.23355
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 10% SIGNIFICANCE LEVEL

NITRATE:

VALUE OF P= 31
TEST STASTICS "t" = -2.12795
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS FALLING TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS FALLING TREND IN DATA AT 10% SIGNIFICANCE LEVEL

5.15.5 "TREND TEST FOR SONEPUR D/S"

PH:

VALUE OF P= 62
TEST STASTICS "t" = 0.94026
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 10% SIGNIFICANCE LEVEL

DO:

VALUE OF P= 51
TEST STASTICS "t" = -0.14846
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 10% SIGNIFICANCE LEVEL

BOD:

VALUE OF P= 29
TEST STASTICS "t" = -2.32590
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS FALLING TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS FALLING TREND IN DATA AT 10% SIGNIFICANCE LEVEL

TC:

VALUE OF P= 60
TEST STASTICS "t" = 0.74231
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 10% SIGNIFICANCE LEVEL

TSS:

VALUE OF P= 33
TEST STASTICS "t" = 0.85635
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 10% SIGNIFICANCE LEVEL

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TOTAL ALKALINITY:

VALUE OF P= 16
TEST STASTICS "t" = -1.79055
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS FALLING TREND IN DATA AT 10% SIGNIFICANCE LEVEL

COD:

VALUE OF P= 28
TEST STASTICS "t" = 0.07785
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 10% SIGNIFICANCE LEVEL

NH_4-N:

VALUE OF P= 12
TEST STASTICS "t" = -1.87830
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS FALLING TREND IN DATA AT 10% SIGNIFICANCE LEVEL

FREE AMMONIA:

VALUE OF P= 17
TEST STASTICS "t" = -0.98387
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 10% SIGNIFICANCE LEVEL

TKN:

VALUE OF P= 26
TEST STASTICS "t" = -0.23355
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 10% SIGNIFICANCE LEVEL

EC:

VALUE OF P= 52
TEST STASTICS "t" = -0.04949
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 10% SIGNIFICANCE LEVEL

SAR:

VALUE OF P= 42
TEST STASTICS "t" = -1.03923
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 10% SIGNIFICANCE LEVEL

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B:

VALUE OF P= 53
TEST STASTICS "t" = 1.70825
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS RAISING TREND IN DATA AT 10% SIGNIFICANCE LEVEL

TDS:

VALUE OF P= 18
TEST STASTICS "t" = -1.47915
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 10% SIGNIFICANCE LEVEL

TH:

VALUE OF P= 28
TEST STASTICS "t" = 0.07785
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 10% SIGNIFICANCE LEVEL

CL:

VALUE OF P= 37
TEST STASTICS "t" = 1.47915
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 10% SIGNIFICANCE LEVEL

SULPHATE:

VALUE OF P= 41
TEST STASTICS "t" = 2.10195
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS RAISING TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS RAISING TREND IN DATA AT 10% SIGNIFICANCE LEVEL

FLOURINE:

VALUE OF P= 29
TEST STASTICS "t" = 0.23355
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 10% SIGNIFICANCE LEVEL

NITRATE:

VALUE OF P= 51
TEST STASTICS "t" = -0.14846
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 10% SIGNIFICANCE LEVEL

FE:

VALUE OF P= 31
TEST STASTICS "t" = 0.54495
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 10% SIGNIFICANCE LEVEL

5.15.6 "TREND TEST FOR SAMBALPUR"

PH:

VALUE OF P= 68
TEST STASTICS "t" = 1.53410
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 10% SIGNIFICANCE LEVEL

DO:

VALUE OF P= 38
TEST STASTICS "t" = -1.43513
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 10% SIGNIFICANCE LEVEL

BOD:

VALUE OF P= 31
TEST STASTICS "t" = -2.12795
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS FALLING TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS FALLING TREND IN DATA AT 10% SIGNIFICANCE LEVEL

TC:

VALUE OF P= 61
TEST STASTICS "t" = 0.84128
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 10% SIGNIFICANCE LEVEL

TSS:

VALUE OF P= 38
TEST STASTICS "t" = 1.63485
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 10% SIGNIFICANCE LEVEL

TOTAL ALKALINITY:

VALUE OF P= 15
TEST STASTICS "t" = -1.94625
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS FALLING TREND IN DATA AT 10% SIGNIFICANCE LEVEL

COD:

VALUE OF P= 37
TEST STASTICS "t" = 1.47915
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 10% SIGNIFICANCE LEVEL

NH_4-N:

VALUE OF P= 15
TEST STASTICS "t" = -1.34164
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 10% SIGNIFICANCE LEVEL

FREE AMMONIA:

VALUE OF P= 14
TEST STASTICS "t" = -1.52053
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 10% SIGNIFICANCE LEVEL

TKN:

VALUE OF P= 22
TEST STASTICS "t" = -0.85635
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 10% SIGNIFICANCE LEVEL

EC:

VALUE OF P= 58
TEST STASTICS "t" = 0.54436
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 10% SIGNIFICANCE LEVEL

SAR:

VALUE OF P= 37
TEST STASTICS "t" = -1.53410
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 10% SIGNIFICANCE LEVEL

B:

VALUE OF P= 48
TEST STASTICS "t" = 1.09816
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 10% SIGNIFICANCE LEVEL

TDS:

VALUE OF P= 22
TEST STASTICS "t" = -0.85635
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 10% SIGNIFICANCE LEVEL

TH:

VALUE OF P= 21
TEST STASTICS "t" = -1.01205
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 10% SIGNIFICANCE LEVEL

CL:

VALUE OF P= 30
TEST STASTICS "t" = 0.38925
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 10% SIGNIFICANCE LEVEL

SULPHATE:

VALUE OF P= 36
TEST STASTICS "t" = 1.32345
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 10% SIGNIFICANCE LEVEL

F:

VALUE OF P= 34
TEST STASTICS "t" = 1.01205
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 10% SIGNIFICANCE LEVEL

NITRATE:

VALUE OF P= 27
TEST STASTICS "t" = -2.52385
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS FALLING TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS FALLING TREND IN DATA AT 10% SIGNIFICANCE LEVEL

FE:

VALUE OF P= 31
TEST STASTICS "t" = 0.54495
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 10% SIGNIFICANCE LEVEL

5.15.7 "TREND TEST FOR NARSINGHPUR"

PH:

VALUE OF P= 77
TEST STASTICS "t" = 2.42487
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS RAISING TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS RAISING TREND IN DATA AT 10% SIGNIFICANCE LEVEL

DO:

VALUE OF P= 48
TEST STASTICS "t" = -0.44538
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 10% SIGNIFICANCE LEVEL

BOD:

VALUE OF P= 22
TEST STASTICS "t" = -3.01872
THERE IS FALLING TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS FALLING TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS FALLING TREND IN DATA AT 10% SIGNIFICANCE LEVEL

TC:

VALUE OF P= 71
TEST STASTICS "t" = 1.83103
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS RAISING TREND IN DATA AT 10% SIGNIFICANCE LEVEL

TSS:

VALUE OF P= 40
TEST STASTICS "t" = 1.94625
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS RAISING TREND IN DATA AT 10% SIGNIFICANCE LEVEL

TOTAL ALKALINITY:

VALUE OF P= 10
TEST STASTICS "t" = -2.72475
THERE IS FALLING TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS FALLING TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS FALLING TREND IN DATA AT 10% SIGNIFICANCE LEVEL

COD:

VALUE OF P= 28
TEST STASTICS "t" = 0.07785
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 10% SIGNIFICANCE LEVEL

NH_4-N:

VALUE OF P= 10
TEST STASTICS "t" = -2.23607
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS FALLING TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS FALLING TREND IN DATA AT 10% SIGNIFICANCE LEVEL

FREE AMMONIA:

VALUE OF P= 16
TEST STASTICS "t" = -1.16276
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 10% SIGNIFICANCE LEVEL

TKN:

VALUE OF P= 21
TEST STASTICS "t" = -1.01205
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 10% SIGNIFICANCE LEVEL

EC:

VALUE OF P= 66
TEST STASTICS "t" = 1.33615
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 10% SIGNIFICANCE LEVEL

SAR:

VALUE OF P= 30
TEST STASTICS "t" = -2.22692
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS FALLING TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS FALLING TREND IN DATA AT 10% SIGNIFICANCE LEVEL

B:

VALUE OF P= 38
TEST STASTICS "t" = 0.68573
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 10% SIGNIFICANCE LEVEL

TDS:

VALUE OF P= 16
TEST STASTICS "t" = -1.79055
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS FALLING TREND IN DATA AT 10% SIGNIFICANCE LEVEL

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TH:

VALUE OF P= 25
TEST STASTICS "t" = -0.38925
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 10% SIGNIFICANCE LEVEL

CL:

VALUE OF P= 33
TEST STASTICS "t" = 0.85635
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 10% SIGNIFICANCE LEVEL

SULPHATE:

VALUE OF P= 33
TEST STASTICS "t" = 0.85635
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 10% SIGNIFICANCE LEVEL

F:

VALUE OF P= 20
TEST STASTICS "t" = -1.16775
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 10% SIGNIFICANCE LEVEL

NITRATE:

VALUE OF P= 49
TEST STASTICS "t" = -0.34641
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 10% SIGNIFICANCE LEVEL

FE:

VALUE OF P= 37
TEST STASTICS "t" = 1.47915
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 10% SIGNIFICANCE LEVEL

5.15.8 "TREND TEST FOR JHARSUGUDA"

PH:

VALUE OF P= 71
TEST STASTICS "t" = 1.83103
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS RAISING TREND IN DATA AT 10% SIGNIFICANCE LEVEL

DO:

VALUE OF P= 50
TEST STASTICS "t" = -0.24744
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 10% SIGNIFICANCE LEVEL

BOD:

VALUE OF P= 22
TEST STASTICS "t" = -3.01872
THERE IS FALLING TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS FALLING TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS FALLING TREND IN DATA AT 10% SIGNIFICANCE LEVEL

TC:

VALUE OF P= 62
TEST STASTICS "t" = 0.94026
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 10% SIGNIFICANCE LEVEL

TSS:

VALUE OF P= 35
TEST STASTICS "t" = 1.16775
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 10% SIGNIFICANCE LEVEL

TOTAL ALKALINITY:

VALUE OF P= 9
TEST STASTICS "t" = -2.88045
THERE IS FALLING TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS FALLING TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS FALLING TREND IN DATA AT 10% SIGNIFICANCE LEVEL

COD:

VALUE OF P= 35
TEST STASTICS "t" = 1.16775
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 10% SIGNIFICANCE LEVEL

NH_4-N:

VALUE OF P= 9
TEST STASTICS "t" = -2.41495
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS FALLING TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS FALLING TREND IN DATA AT 10% SIGNIFICANCE LEVEL

FREE AMMONIA:

VALUE OF P= 20
TEST STASTICS "t" = -0.44721
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 10% SIGNIFICANCE LEVEL

TKN:

VALUE OF P= 17
TEST STASTICS "t" = -1.63485
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 10% SIGNIFICANCE LEVEL

EC:

VALUE OF P= 49
TEST STASTICS "t" = -0.34641
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 10% SIGNIFICANCE LEVEL

TDS:

VALUE OF P= 14
TEST STASTICS "t" = -2.10195
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS FALLING TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS FALLING TREND IN DATA AT 10% SIGNIFICANCE LEVEL

B:

VALUE OF P= 48
TEST STASTICS "t" = 1.09816
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 10% SIGNIFICANCE LEVEL

SAR:

VALUE OF P= 38
TEST STASTICS "t" = -1.43513
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 10% SIGNIFICANCE LEVEL

TH:

VALUE OF P= 16
TEST STASTICS "t" = -1.79055
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS FALLING TREND IN DATA AT 10% SIGNIFICANCE LEVEL

CL:

VALUE OF P= 33
TEST STASTICS "t" = 0.85635
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 10% SIGNIFICANCE LEVEL

F:

VALUE OF P= 27
TEST STASTICS "t" = -0.07785
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 10% SIGNIFICANCE LEVEL

NITRATE:

VALUE OF P= 22
TEST STASTICS "t" = -3.01872
THERE IS FALLING TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS FALLING TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS FALLING TREND IN DATA AT 10% SIGNIFICANCE LEVEL

FE:

VALUE OF P= 37
TEST STASTICS "t" = 1.47915
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 10% SIGNIFICANCE LEVEL

5.15.9 "TREND TEST FOR HIRAKUD"

PH:

VALUE OF P= 67
TEST STASTICS "t" = 1.43513
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 10% SIGNIFICANCE LEVEL

DO:

VALUE OF P= 40
TEST STASTICS "t" = -1.23718
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 10% SIGNIFICANCE LEVEL

BOD:

VALUE OF P= 35
TEST STASTICS "t" = -1.73205
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS FALLING TREND IN DATA AT 10% SIGNIFICANCE LEVEL

TC:

VALUE OF P= 88
TEST STASTICS "t" = 3.51359
THERE IS RAISING TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS RAISING TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS RAISING TREND IN DATA AT 10% SIGNIFICANCE LEVEL

TSS:

VALUE OF P= 31
TEST STASTICS "t" = 0.54495
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 10% SIGNIFICANCE LEVEL

TOTAL ALKALINITY:

VALUE OF P= 18
TEST STASTICS "t" = -1.47915
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 10% SIGNIFICANCE LEVEL

COD:

VALUE OF P= 43
TEST STASTICS "t" = 2.41335
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS RAISING TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS RAISING TREND IN DATA AT 10% SIGNIFICANCE LEVEL

NH_4-N:

VALUE OF P= 9
TEST STASTICS "t" = -2.41495
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS FALLING TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS FALLING TREND IN DATA AT 10% SIGNIFICANCE LEVEL

FREE AMMONIA:

VALUE OF P= 16
TEST STASTICS "t" = -1.16276
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 10% SIGNIFICANCE LEVEL

TKN:

VALUE OF P= 20
TEST STASTICS "t" = -1.16775
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 10% SIGNIFICANCE LEVEL

EC:

VALUE OF P= 65
TEST STASTICS "t" = 1.23718
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 10% SIGNIFICANCE LEVEL

TDS:

VALUE OF P= 28
TEST STASTICS "t" = 0.07785
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 10% SIGNIFICANCE LEVEL

B:

VALUE OF P= 58
TEST STASTICS "t" = 2.31834
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS RAISING TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS RAISING TREND IN DATA AT 10% SIGNIFICANCE LEVEL

SAR:

VALUE OF P= 34
TEST STASTICS "t" = -1.83103
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS FALLING TREND IN DATA AT 10% SIGNIFICANCE LEVEL

TH:

VALUE OF P= 19
TEST STASTICS "t" = -1.32345
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 10% SIGNIFICANCE LEVEL

CL:

VALUE OF P= 40
TEST STASTICS "t" = 1.94625
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS RAISING TREND IN DATA AT 10% SIGNIFICANCE LEVEL

SULPHATE:

VALUE OF P= 28
TEST STASTICS "t" = 0.07785
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 10% SIGNIFICANCE LEVEL

F:

VALUE OF P= 30
TEST STASTICS "t" = 0.38925
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 10% SIGNIFICANCE LEVEL

NITRATE:

VALUE OF P= 48
TEST STASTICS "t" = -0.44538
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 10% SIGNIFICANCE LEVEL

FE:

VALUE OF P= 34
TEST STASTICS "t" = 1.01205
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 10% SIGNIFICANCE LEVEL

5.15.10 "TREND TEST FOR CHOUDWAR"

PH:

VALUE OF P= 65
TEST STASTICS "t" = 1.23718
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 10% SIGNIFICANCE LEVEL

DO:

VALUE OF P= 58
TEST STASTICS "t" = 0.54436
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 10% SIGNIFICANCE LEVEL

BOD:

VALUE OF P= 26
TEST STASTICS "t" = -2.62282
THERE IS FALLING TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS FALLING TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS FALLING TREND IN DATA AT 10% SIGNIFICANCE LEVEL

TC:

VALUE OF P= 56
TEST STASTICS "t" = 0.34641
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 10% SIGNIFICANCE LEVEL

TSS:

VALUE OF P= 37
TEST STASTICS "t" = 1.47915
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 10% SIGNIFICANCE LEVEL

TOTAL ALKALINITY:

VALUE OF P= 19
TEST STASTICS "t" = -1.32345
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 10% SIGNIFICANCE LEVEL

COD:

VALUE OF P= 23
TEST STASTICS "t" = -0.70065
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 10% SIGNIFICANCE LEVEL

NH_4-N:

VALUE OF P= 18
TEST STASTICS "t" = -0.80498
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 10% SIGNIFICANCE LEVEL

TKN:

VALUE OF P= 19
TEST STASTICS "t" = -1.32345
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 10% SIGNIFICANCE LEVEL

EC:

VALUE OF P= 64
TEST STASTICS "t" = 1.13820
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 10% SIGNIFICANCE LEVEL

SAR:

VALUE OF P= 28
TEST STASTICS "t" = -0.68573
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 10% SIGNIFICANCE LEVEL

TDS:

VALUE OF P= 24
TEST STASTICS "t" = -0.54495
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 10% SIGNIFICANCE LEVEL

TH:

VALUE OF P= 28
TEST STASTICS "t" = 0.07785
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 10% SIGNIFICANCE LEVEL

CL:

VALUE OF P= 40
TEST STASTICS "t" = 1.94625
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS RAISING TREND IN DATA AT 10% SIGNIFICANCE LEVEL

SULPHATE:

VALUE OF P= 35
TEST STASTICS "t" = 1.16775
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 10% SIGNIFICANCE LEVEL

F:

VALUE OF P= 22
TEST STASTICS "t" = -0.85635
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 10% SIGNIFICANCE LEVEL

NITRATE:

VALUE OF P= 43
TEST STASTICS "t" = -0.94026
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 10% SIGNIFICANCE LEVEL

FE:

VALUE OF P= 40
TEST STASTICS "t" = 1.94625
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS RAISING TREND IN DATA AT 10% SIGNIFICANCE LEVEL

5.15.11 "TREND TEST FOR BRAJARAJNAGAR D/S"

PH:

VALUE OF P= 63
TEST STASTICS "t" = 1.03923
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 10% SIGNIFICANCE LEVEL

DO:

VALUE OF P= 51
TEST STASTICS "t" = -0.14846
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 10% SIGNIFICANCE LEVEL

BOD:

VALUE OF P= 18
TEST STASTICS "t" = -3.41461
THERE IS FALLING TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS FALLING TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS FALLING TREND IN DATA AT 10% SIGNIFICANCE LEVEL

TC:

VALUE OF P= 47
TEST STASTICS "t" = -0.54436
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 10% SIGNIFICANCE LEVEL

TSS:

VALUE OF P= 36
TEST STASTICS "t" = 1.32345
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 10% SIGNIFICANCE LEVEL

TOTAL ALKALINITY:

VALUE OF P= 15
TEST STASTICS "t" = -1.94625
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS FALLING TREND IN DATA AT 10% SIGNIFICANCE LEVEL

COD:

VALUE OF P= 27
TEST STASTICS "t" = -0.07785
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 10% SIGNIFICANCE LEVEL

NH_4-N:

VALUE OF P= 13
TEST STASTICS "t" = -1.69941
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS FALLING TREND IN DATA AT 10% SIGNIFICANCE LEVEL

FREE AMMONIA:

VALUE OF P= 18
TEST STASTICS "t" = -0.80498
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 10% SIGNIFICANCE LEVEL

TKN:

VALUE OF P= 18
TEST STASTICS "t" = -1.47915
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 10% SIGNIFICANCE LEVEL

EC:

VALUE OF P= 56
TEST STASTICS "t" = 0.34641
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 10% SIGNIFICANCE LEVEL

SAR:

VALUE OF P= 31
TEST STASTICS "t" = -2.12795
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS FALLING TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS FALLING TREND IN DATA AT 10% SIGNIFICANCE LEVEL

B:

VALUE OF P= 46
TEST STASTICS "t" = 0.85412
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 10% SIGNIFICANCE LEVEL

TDS:

VALUE OF P= 15
TEST STASTICS "t" = -1.94625
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS FALLING TREND IN DATA AT 10% SIGNIFICANCE LEVEL

ISSN: 2278-0181

TH:

VALUE OF P= 11
TEST STASTICS "t" = -2.56905
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS FALLING TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS FALLING TREND IN DATA AT 10% SIGNIFICANCE LEVEL

CL:

VALUE OF P= 26
TEST STASTICS "t" = -0.23355
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 10% SIGNIFICANCE LEVEL

F:

VALUE OF P= 25
TEST STASTICS "t" = -0.38925
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 10% SIGNIFICANCE LEVEL

NITRATE:

VALUE OF P= 29
TEST STASTICS "t" = -2.32590
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS FALLING TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS FALLING TREND IN DATA AT 10% SIGNIFICANCE LEVEL

FE:

VALUE OF P= 40
TEST STASTICS "t" = 1.94625
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS RAISING TREND IN DATA AT 10% SIGNIFICANCE LEVEL

5.15.12 "TREND TEST FOR BBSR D/S"

PH:

VALUE OF P= 55
TEST STASTICS "t" = 0.24744
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 10% SIGNIFICANCE LEVEL

DO:

VALUE OF P= 42
TEST STASTICS "t" = -1.03923
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 10% SIGNIFICANCE LEVEL

BOD:

VALUE OF P= 68
TEST STASTICS "t" = 1.53410
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 10% SIGNIFICANCE LEVEL

TC:

VALUE OF P= 92
TEST STASTICS "t" = 3.90949
THERE IS RAISING TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS RAISING TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS RAISING TREND IN DATA AT 10% SIGNIFICANCE LEVEL

TSS:

VALUE OF P= 39
TEST STASTICS "t" = 1.79055
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS RAISING TREND IN DATA AT 10% SIGNIFICANCE LEVEL

TOTAL ALKALINITY:

VALUE OF P= 14
TEST STASTICS "t" = -2.10195
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS FALLING TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS FALLING TREND IN DATA AT 10% SIGNIFICANCE LEVEL

COD:

VALUE OF P= 41
TEST STASTICS "t" = 2.10195
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS RAISING TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS RAISING TREND IN DATA AT 10% SIGNIFICANCE LEVEL

NH_4-N:

VALUE OF P= 22
TEST STASTICS "t" = -0.08944
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 10% SIGNIFICANCE LEVEL

FREE AMMONIA:

VALUE OF P= 18
TEST STASTICS "t" = -0.80498
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 10% SIGNIFICANCE LEVEL

TKN:

VALUE OF P= 38
TEST STASTICS "t" = 1.63485
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 10% SIGNIFICANCE LEVEL

EC:

VALUE OF P= 70
TEST STASTICS "t" = 1.73205
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS RAISING TREND IN DATA AT 10% SIGNIFICANCE LEVEL

SAR:

VALUE OF P= 52
TEST STASTICS "t" = -0.04949
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 10% SIGNIFICANCE LEVEL

B:

VALUE OF P= 53
TEST STASTICS "t" = 1.70825
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS RAISING TREND IN DATA AT 10% SIGNIFICANCE LEVEL

TDS:

VALUE OF P= 23
TEST STASTICS "t" = -0.70065
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 10% SIGNIFICANCE LEVEL

TH:

VALUE OF P= 25
TEST STASTICS "t" = -0.38925
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 10% SIGNIFICANCE LEVEL

CL:

VALUE OF P= 37
TEST STASTICS "t" = 1.47915
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 10% SIGNIFICANCE LEVEL

SULPHATE:

VALUE OF P= 36
TEST STASTICS "t" = 1.32345
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 10% SIGNIFICANCE LEVEL

F:

VALUE OF P= 26
TEST STASTICS "t" = -0.23355
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 10% SIGNIFICANCE LEVEL

NITRATE:

VALUE OF P= 72
TEST STASTICS "t" = 1.93000
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS RAISING TREND IN DATA AT 10% SIGNIFICANCE LEVEL

FE:

VALUE OF P= 39
TEST STASTICS "t" = 1.79055
THERE IS NO TREND IN DATA AT 1% SIGNIFICANCE LEVEL
THERE IS NO TREND IN DATA AT 5% SIGNIFICANCE LEVEL
THERE IS RAISING TREND IN DATA AT 10% SIGNIFICANCE LEVEL

5.16 RESULT OF MANN-KENDALL TREND ANALYSIS OF MONITORING STATIONS

		SIGNIFICANCE LEVEL		
STATIONS	PARAMETER	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
	NH_4-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

5.17 OVERALL SUMMARY OF OBSERVATIONS OF WATER QUALITY PARAMETERS OF MAHANADI RIVER BASIN:

MONITORING STATION	USE BASED		BIOLOGICAL		DEGREE OF WHOLESOMENESS	
	CLASS	PARAMETERS RESPONSIBLE FOR DOWNGRADING THE WATER QUALITY	STATUS OF POLLUTION	PARAMETERS RESPONSIBLE FOR DOWNGRADING THE WATER QUALITY	LEVEL	PARAMETERS RESPONSIBLE FOR DOWNGRADING THE WATER QUALITY
SUNDERGARH(IB)	C/D/E	TC	-	-	BELOW ACCEPTABLE	TKN
JHARSUGUDA(IB)	C/D/E	TC	-	-	BELOW ACCEPTABLE	FC,TKN
BRAJARAJNAGAR(U/S) (IB)	C/D/E	TC	SLIGHT TO MODERATE POLLUTION	SI,DI	BELOW ACCEPTABLE	TKN
BRAJARAJNAGAR(D/S) (IB)	C/D/E	TC	SLIGHT TO MODERATE POLLUTION	SI,DI	BELOW ACCEPTABLE	FC,TKN
JHARSUGUDA(BHEDEN)	C/D/E	TC	-	-	BELOW ACCEPTABLE	TKN
HIRAKUD	C/D/E	TC	-	-	BELOW ACCEPTABLE	TKN
POWER CHANNEL(U/S)	B	TC	-	-	BELOW ACCEPTABLE	TKN
POWER CHANNEL(D/S)	C/D/E	TC	-	-	BELOW ACCEPTABLE	TKN
SAMBALPUR(U/S)	C/D/E	TC	SLIGHT TO MODERATE POLLUTION	SI,DI	BELOW ACCEPTABLE	FC,TKN

SAMBALPUR(D/S)	D/E	BOD,TC	SLIGHT TO MODERATE POLLUTION	SI,DI,BOD	BELOW ACCEPTABLE	FC,TKN
SAMBALPUR(FD/S) AT SANKARMATH	C/D/E	TC	-	-	BELOW ACCEPTABLE	FC,TKN
SAMBALPUR FFD/S AT HUMA	C/D/E	TC	-	-	BELOW ACCEPTABLE	FC,TKN
SONEPUR(U/S)	C/D/E	TC	-	-	BELOW ACCEPTABLE	TKN
SONEPUR(D/S)	C/D/E	TC	-	-	BELOW ACCEPTABLE	TKN
TEL	C/D/E	TC	-	-	BELOW ACCEPTABLE	TKN
TIKARPADA	C/D/E	TC	-	-	BELOW ACCEPTABLE	TKN
NARASINGHPUR	C/D/E	TC	-	-	BELOW ACCEPTABLE	TKN
MUNDULI	C/D/E	TC	-	-	BELOW ACCEPTABLE	FC,TKN
CUTTACK(U/S)	C/D/E	TC	SLIGHT TO MODERATE POLLUTION	SI,DI	BELOW ACCEPTABLE	TKN
CUTTACK(D/S)	C/D/E	TC	SLIGHT TO MODERATE POLLUTION	SI,DI	BELOW ACCEPTABLE	FC,TKN
CUTTACK(FD/S)	C/D/E	TC	-	-	BELOW ACCEPTABLE	FC,TKN
PARADEEP(U/S)	*		-	-	BELOW ACCEPTABLE	EC,FC,TKN

PARADEEP(D/S)	*		-	-	BELOW ACCEPTABLE	EC,FC,TKN
CUTTACK(U/S)(KATHOJODI)	C/D/E	TC	-	-	BELOW ACCEPTABLE	FC,TKN
CUTTACK(D/S) (KATHOJODI)	D/E	BOD,TC	SLIGHT TO MODERATE POLLUTION	SI,DI,BOD	BELOW ACCEPTABLE	FC,TKN
CUTTACK FD/S AT MATTAGAJPUR	D/E	BOD,TC	-	-	BELOW ACCEPTABLE	FC,TKN
CUTTACK FD/S AT SANKHATRASA	C/D/E	TC	-	-	BELOW ACCEPTABLE	FC,TKN
CHOUDWAR(D/S)(BIRUPA)	C/D/E	TC	SLIGHT TO MODERATE POLLUTION	SI,DI	BELOW ACCEPTABLE	FC,TKN
BHUBANESWAR FU/S(KUAKHAI)	C/D/E	TC	-	-	BELOW ACCEPTABLE	FC,TKN
BHUBANESWAR(U/S)(KUAKHAI)	C/D/E	TC	SLIGHT TO MODERATE POLLUTION	SI,DI	BELOW ACCEPTABLE	FC,TKN
BHUBANESWAR(D/S)(DAYA)	D/E	BOD,TC	SLIGHT TO MODERATE POLLUTION	SI,DI,BOD	BELOW ACCEPTABLE	FC,TKN
BHUBANESWAR FD/S (DAYA)	D/E	BOD,TC	-	-	BELOW ACCEPTABLE	FC,TKN

* MEANS USE BASED WATER QUALITY STATUS DOES NOT MEET ANY DESIGNATED CLASS DUE TO PARAMETERS LIKE EC, TDS, TH, CL AND SULPHATE.

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CHAPTER 06

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.
- Threatened rising of organic and inorganic waste levels which a consequence of human activity is definitely going to hamper on water quality and its ecosystem directly or indirectly. These anthropogenic consequences obviously hamper the aesthetic properties of aquatic systems and impose potential health hazards not only aquatic organisms but also other terrestrial life forms including human beings. ***So to sustain the river quality healthy,*** we should concern about the waste and its disposal system. Particularly the diversion of local drains which carry effluents from various sources from the city area and their treatment has to be made.
- 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 16 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. Also this analysis allowed the identification of three different zones for LP and MP and HP in the river, with different water quality. The major pollutants in all the three zones are contributed by local anthropogenic activities rather than agricultural/ land drainage. The intensity of microbial activities and the influx of organic sewage are reflected through the high BOD, NH_3-N, NO_3, TKN values for cluster-III in HP, which are more than the permissible limit for drinking water. The inverse relationship between DO with

BOD and DO with TKN and TP in HP sites implies that the organic nitrogen part plays a major role in the depletion of DO in the river systems.

- ***The PCs obtained from principal component analysis*** indicate that parameters responsible for water quality variations are mainly related to untreated or partially treated municipal sewage, domestic and industrial wastewater. 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.
- 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, NH_4-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 NH_4-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, NH_4-N, TH, Nitrate and rising trend occurs due to PH at 10% significance level. This results as thewater 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, NH_4-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, 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.

CHAPTER 07

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