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Modelling Of Water Quality Ontrace and Toxic Metals in Brahmani River Basin

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Abstract: *The present investigation is aimed at assessing the concentration of heavy metal ions along the stretches of Brahmani river basin. Fifteen samples were collected along the stretches of Brahmani basin during the period 2000 to 2015. The purpose of this study was to estimate nine heavy metals (Cu, Zn, Cd, Pb, Hg, Fe, As, Ni and Cr) in the surface water of the BrahmaniRiver, one of the most important rivers in Odisha, India. In the selected research area, the Brahmani River is receiving the domestic, industrial, and municipal waste waters/effluents all along its course. All in all, the ascendancy of the analyzed heavy metals in the surface water of Brahmani followed the sequence: Cu>Ni>Pb>Cr>As>Fe>Zn>Hg>Cd. My findings highlighted the deterioration of water quality in the rivers due to industrialization, mining and human activities.*

Keywords: *Brahmani River, Heavy metals, Cu, Zn, Cd, Pb, Fe, As, Hg, Ni and Cr.*

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I. Introduction

Brahmaniriver which is the second largest river of Odisha is also one of the most important peninsular river systems in India. The confluence of the Rivers Koel and Sankh at Vedvyasa near Rourkela in the district of Sundergarh gives rise to the river Brahmani. It travels southward through the districts of Sundergarh, Deogarh, Angul, Dhenkanal, Jajpur and Kendrapara and finally flows in to Bay of Bengal. It makes the lifeline of the inhabitants of these districts. Major industries like Rourkela Steel Plant (RSP) at Rourkela, National Aluminium Company (NALCO) at Anugul and the upcoming industries like Bhusan Steel Plant and the Kalinga Nagar Industrial Complex in the district of Jajpur are all in the bank of Brahmani river, which is considered as one of the India's important industrialized areas known for ore mining, steel production, power generation, cement production and other related activities. So Brahmani River is joined by several drains carrying industrial effluents, city wastes and mining residues. As water is one the most basic necessities of the habitants, its safeness must be studied before use. The present study aims at detecting the presence of trace and toxic heavy metals.

Heavy metals are metallic elements which have a high atomic weight and have much high density at least 5 times that of water. They are stable elements i.e. they cannot be metabolized by the body and bio-accumulative i.e. passed up the food chain to humans. They are highly toxic and can cause damaging effects even at very low concentrations. Increasing urbanization and industrialization have increased the levels of trace metals, especially heavy metals, in water ways. There are over 50 elements that can be classified as heavy metals, but only 17 that are considered to be both very toxic and relatively accessible. Mercury, lead, arsenic, cadmium, selenium, copper, zinc, nickel, and chromium should be given particular attention in terms of water pollution. Heavy metal toxicity has severe effect on our mental health, nervous system, kidneys, lungs and other organ functions. Surface water bodies get polluted due to urban sewage discharge (Dayal, 1994; Jain and Salman, 1995; Pophaliet al., 1990) Present study is focused on quantitative analysis of heavy metals of Brahmani River.

II. Review Of Literature

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

Dugan [1972] suggested that all biological reactions occur in water and it is the integrated system of biological metabolic reactions in an aqueous solution that is essential for the maintenance of life. **Pani [1986]** in his study realized that due to increasing industrialization on one hand and exploding population on the other, the demands of water supply have been increasing tremendously. Moreover considerable part of this limited quality of water is polluted by sewage, industrial waste and a wide range of synthetic chemicals. Heavy metal are considered as major environmental pollutants and regarded to be Cytotoxic, Mutagenic, and Carcinogenic. The Heavy Metal pollution of natural environment has been consistently increasing through effluents, sedimentation of rocks and mining activities **(Manjit [1988])**. **Priti Singh et.al [2005]** assess and map the spatial distribution of surface water quality of the Mahanadi, Odisha by using GIS.APHA's standard laboratory procedure has been adopted to assess the quality of ground water. The spatial distribution map of pH, Chlorides, Magnesium and sulphate shows that, these parameters are within range as per standard. **Samantray et al.** were studied the water quality of Mahanadi and its distributaries rivers, streams, Atharabanki river and Taldanda Canal adjoining Paradeep in three different seasons namely summer, pre-monsoon and winter..Their findings highlighted the deterioration of water quality in the rivers due to industrialization and human activities **(Samantray et al., 2006).Kamal [2007]** carried out on physicochemical parameter of river water affects the biological characteristics and indicates the status of water quality. Different types of Physicochemical parameters of water are pH, DO, BOD, COD, Chloride, TDS, Nitrate, Sulphates, TH, EC and Fluoride. These parameters are solely responsible for water quality. **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. **SwarnaLatha [2008].** 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 as found from **Guru Prasad, 2005.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 hydrogeochemicalfacies were identified and the surface waters were classified with regards to the changes in their major chemical compositions. **Shimaa M. Ghoraba et.al [2008]** collected many ground water samples from different districts of Mahanadi,Odisha. 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 andPuttaiah, 2008).Khare et.al [2010]** carried out on water quality assessment of Mahanadi, Sambalpur. He was done water analysis for the parameters like pH, DO, BOD, COD, TDS, calcium, Magnesium and Hardness for lake water. **Venkatesharajuet al., [2010]** signifieswater recourses have critical importance to both natural and human development. It is essential for agriculture, industry and human existence. Water is one of the most abundant compounds of the ecosystem. **Mona A. Hagras et.al [2011]** assessed the quality of groundwater and to characterize the hydrochemical characteristics of the surface water in Odisha, surface water samples were collected from different cities of Odisha analyzed for 15 water quality parameters. **Lohani et.al [2011]** depicts drinking water quality management through various physicochemical parameters and health hazard problems with their remedial measures in Bhubaneswar city of Odisha. **Sahu[2015]** describes the effect of poor water quality on human health was noted for the first time in 1854 by John Snow, when he traced the outbreak of cholera epidemic in London to the Thames river water which was grossly polluted with raw sewage. **Rout [2016]** carried out an analysis was carried out by taking certain important parameters like pH, dissolved oxygen (DO), biological oxygen demand (BOD), chemical oxygen demand (COD), Chloride, total dissolved oxygen (TDS), Nitrate, sulphates, total hardness (TH), electrical conductivity (EC) and Fluoride. **Vega et al., [2016]**signifies the application of different multivariate statistical techniques, such as cluster analysis (CA), principal component analysis (PCA) helps in the interpretation of complex data matrices to better understand the water quality and ecological status of the studied systems.

III. Study Area And Data Collection

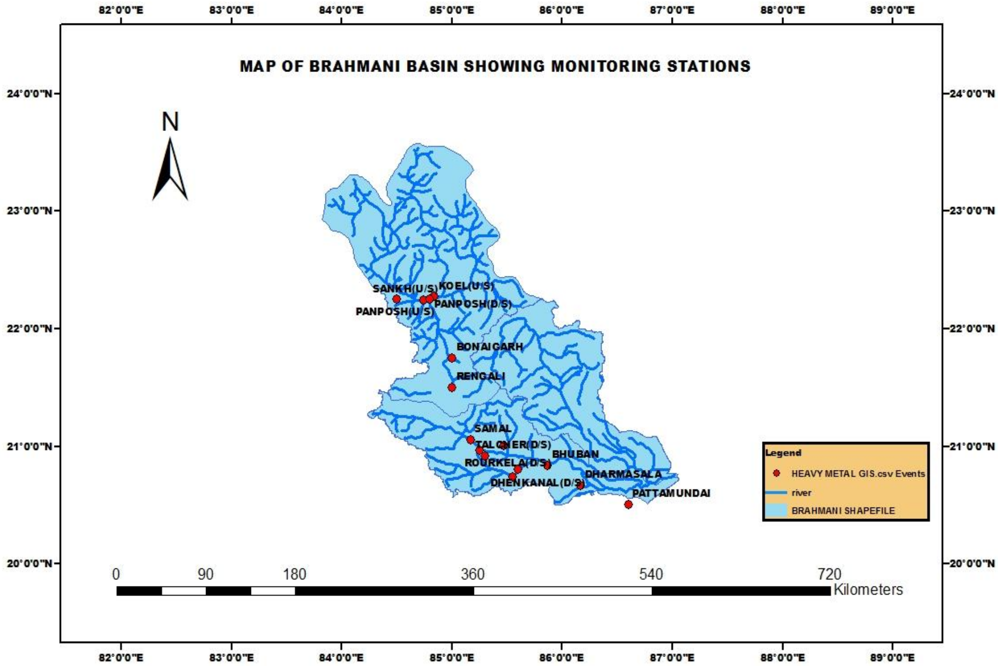
STUDY SITE:

Brahmani, the second major river in Odisha, is formed by the combined waters of South Koel and Sankh rivers at Vedvyasa near Rourkela in the Sundergarh district. The left bank tributary South Koel originates near Nagri village in the Ranchi district of Jharkhand state. After its confluence with river Karo in Singhbhum district, it is known as koel. From Manoharpur, it flows in the south-west direction for a distance of about 54 km uptoVedvyasa where the right bank tributary Sankh joins with it. River Sankh originates an elevation of 1000 m near village Lupungpat in Ranchi district of Jharkhand state.

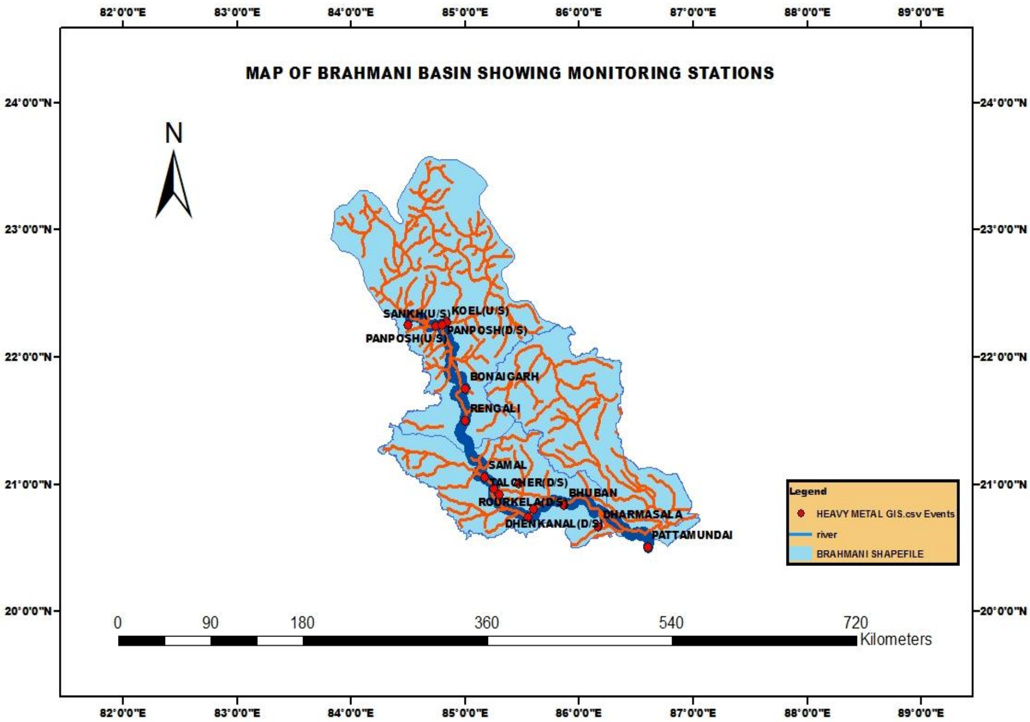
River Brahmani travels southward through valleys incised in the Gadjat Hills to form the famous Gangpur Basin. In this stretch the river is joined by several fast flowing tributaries. The deltaic region of Brahmani starts from Jenapur at river distance equals to 315 km, where the Kalamitra Island divides the river into two branches.

The basin area of river Brahmani in Odisha constitutes 57.63% of the total basin area. The basin covers 9 revenue districts of the State.

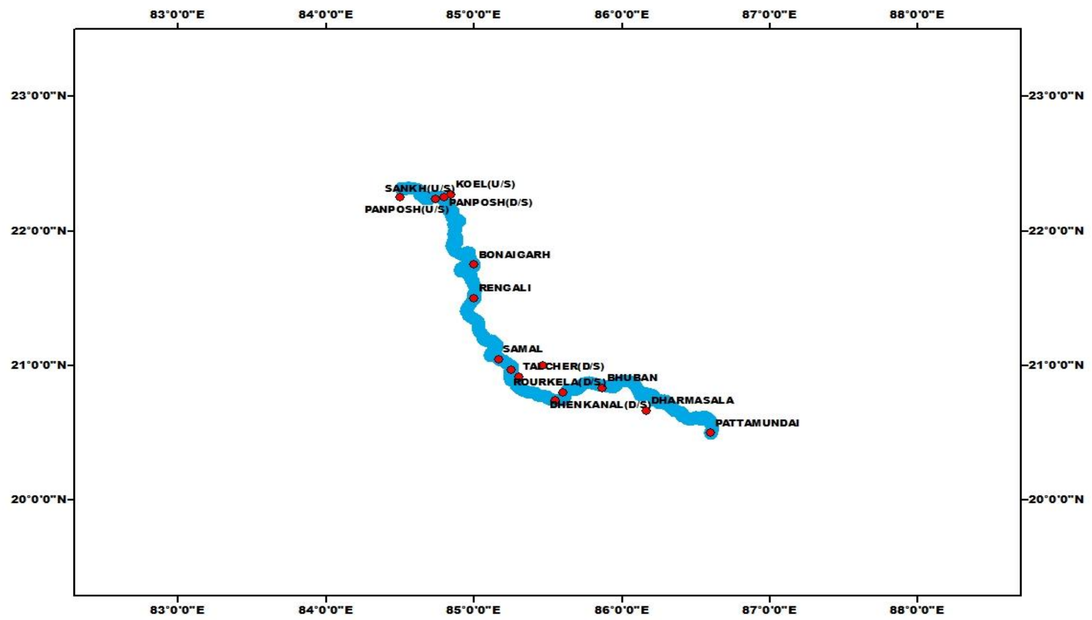
The below (figure 1,2 & 3) showing monitoring stations of Brahmani basin by the application of GIS Software.



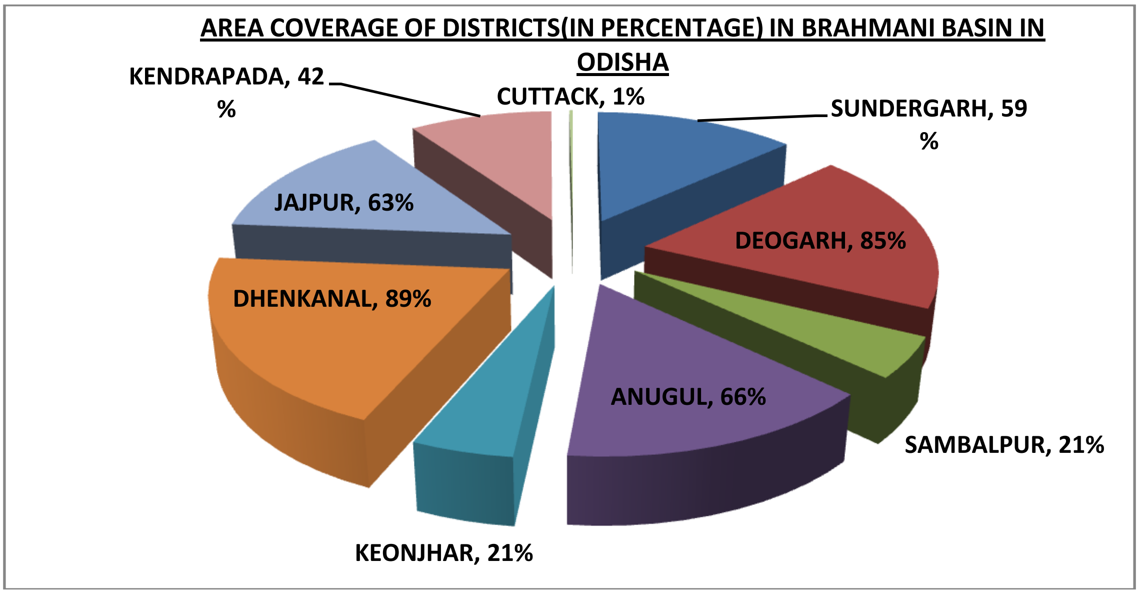
(**Figure1.**Brahmani basin showing fifteen monitoring stations)



(**Figure2.** Flow path of Brahmani basin showing monitoring stations)



(**Figure3.**Brahmani basin showing flow path accompanied with monitoring stations)



(**Figure4.** Area coverage of districts of Brahmani basin in Odisha)

Fifteen different stations as mentioned below are selected across the stretch of the Brahmani River. The selection of the sites was done depending upon the industrial and mining activities along the river bank (Table 1)

Table1.Showing the monitoring stations and the justification on the site selected

SL NO	MONITORING STATION	JUSTIFICATION ON THE SITE SELECTED
1	SANKHA(U/S)	D/S of Mandira dam
2	KOEL(U/S)	Before confluence with river sankha and after waste water discharge of koelnagar
3	PANPOSH(U/S)	Water quality before industrial activity after confluence of Sankh and Koel
4	PANPOSH(D/S)	Impact of industrial activities like RSP and domestic waste water discharge from Rourkela city.
5	ROURKELA(D/S)	To asses water quality improvement at further down stream of Rourkela city and identification of polluted stretch.

6	BONAIGARH	To asses the improvement of water quality.
7	RENGALI	A multipurpose dam
8	SAMAL	Samal Barrage, Water intake point for TSTPP,Kaniha
9	TALCHER(U/S)	Water intake point of industries and mines
10	TALCHER(D/S)	Impact of industrial and muncipal discharge. Downstream of the confluence of Nandirajhor with Brahmani
11	DHENKANAL(U/S)	Upstream of Dhenkhanal town
12	DHENKANAL(D/S)	Downstream of Dhenkhanal town
13	BHUBAN	A major human settlement with water intake point
14	DHARMASALA	Thickly populated area with intensive agriculture practice D/s of industrial activities at Kalinganagar
15	PATTAMUNDAI	Thickly populated area, Tidal effect

IV. Methodology

GIS APPLICATION

GEOGRAPHIC INFORMATION SYSTEM:

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

INVERSE DISTANCE WEIGHT (IDW):

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

STASTICAL ANALYSIS: In recent years, various statistical procedures based on multivariate data taken fromriver system have been used to formulate environmental classifications, which help for a better understanding of the chemical processes occurring in the river environment. Cluster analyses (CA) were carried out for data set obtained yearly from 2000-2015. 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 CAtechnique 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.

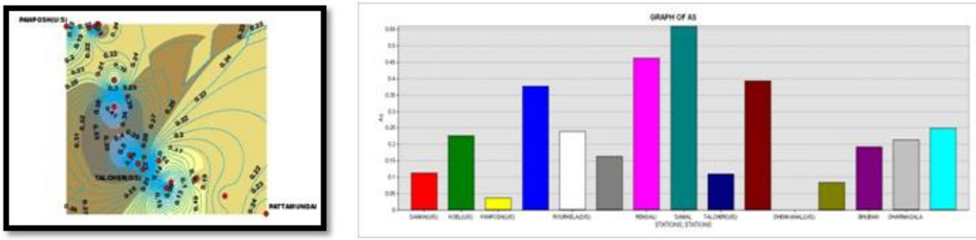
CLUSTER ANALYSIS:

Cluster analysis (CA) is used to develop meaningful aggregations or groups of entitiesbased 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.

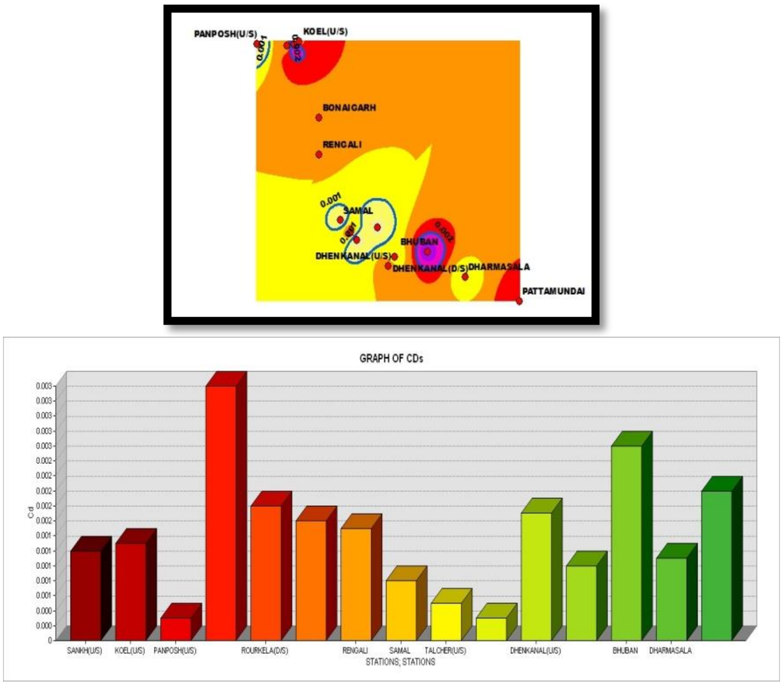
V. Results And Discussion

WATER QUALITY MODELLING USING GIS APPLICATION:

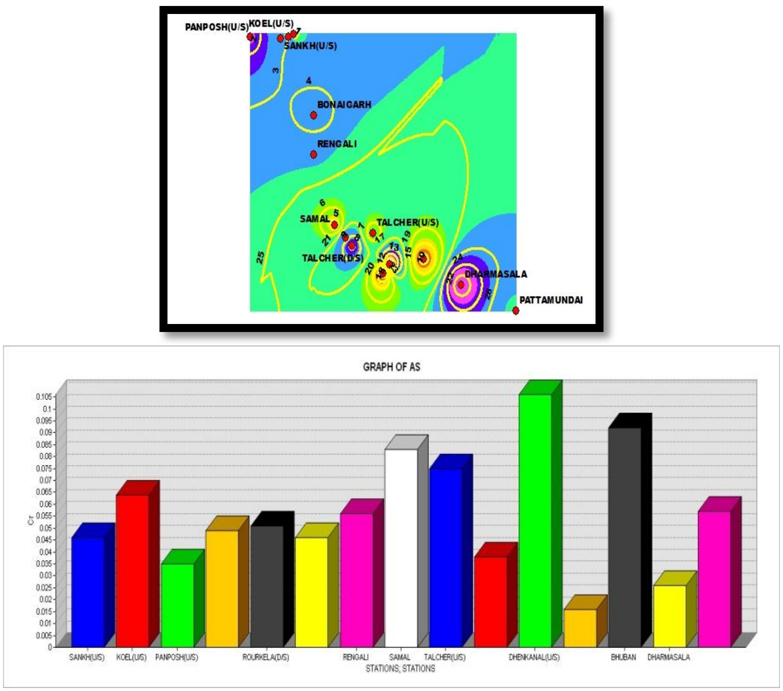
Spatial patterns of water quality trends for 15 sites in the Brahmani River basin of Odisha were examined for nine parameters. This study suggests that spatial analysis of watershed data at different scales should be a vital part of identifying the fundamental spatial distribution of water quality (**Figure 5-13**).



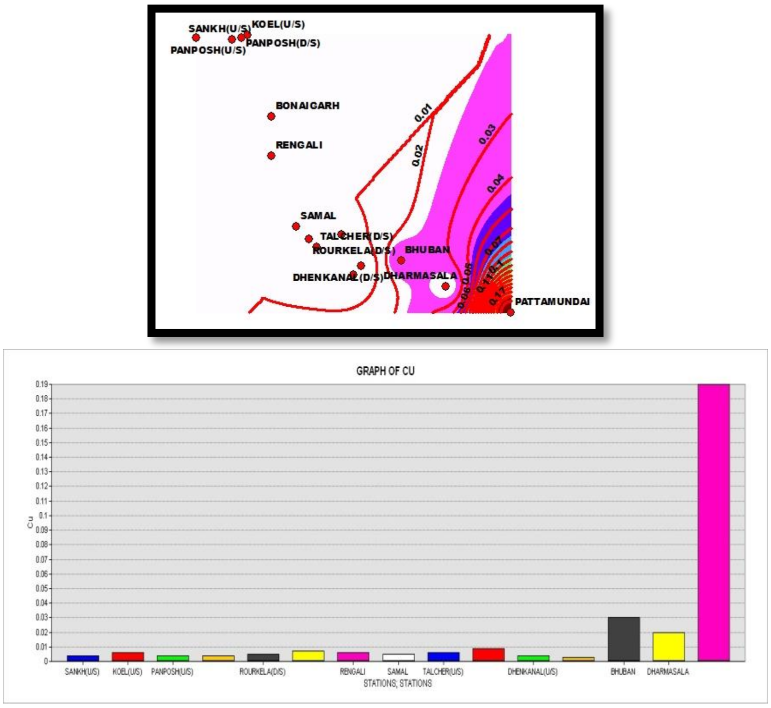
(**Figure5**. Interpolation of Arsenic using IDW)



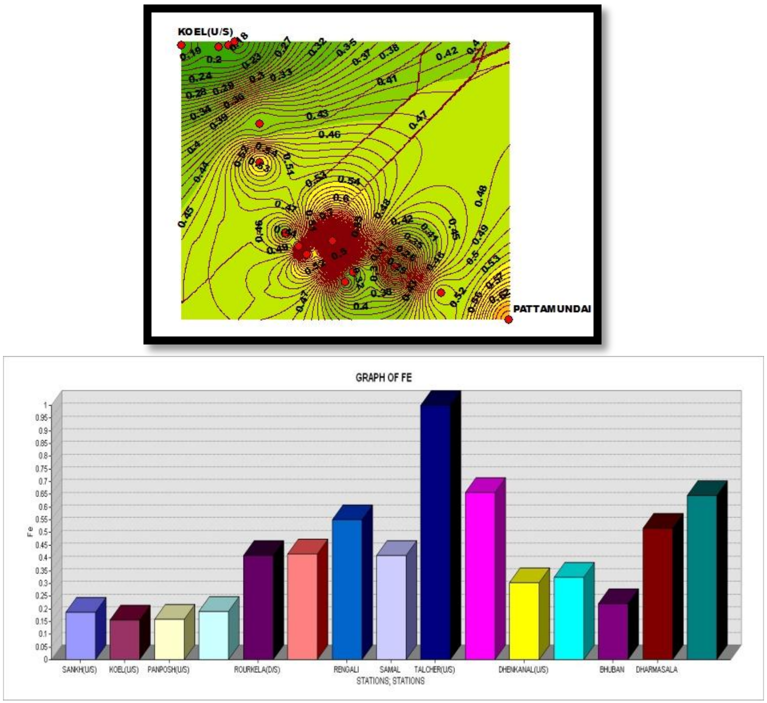
(**Figure6.** Interpolation of Cadmium using IDW)



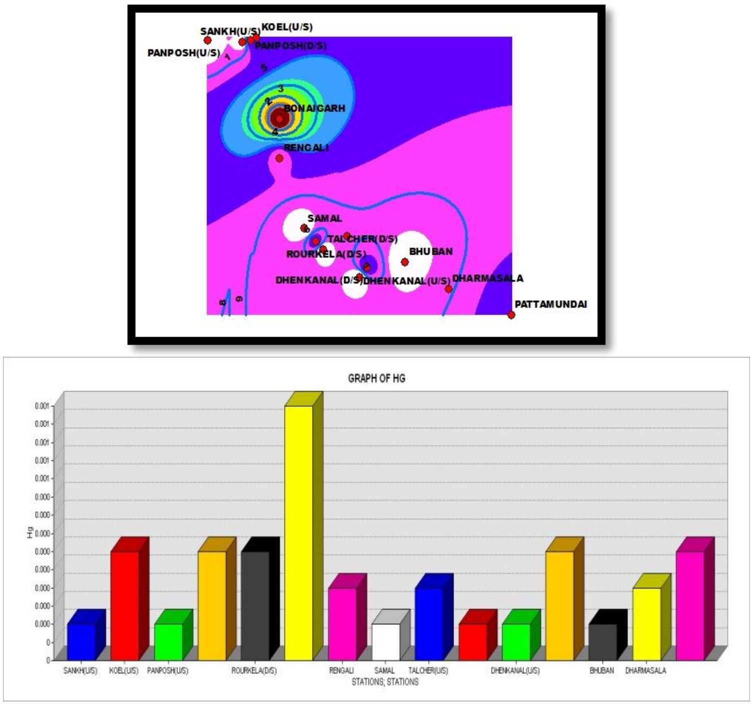
(**Figure7.** Interpolation of Chromium using IDW)



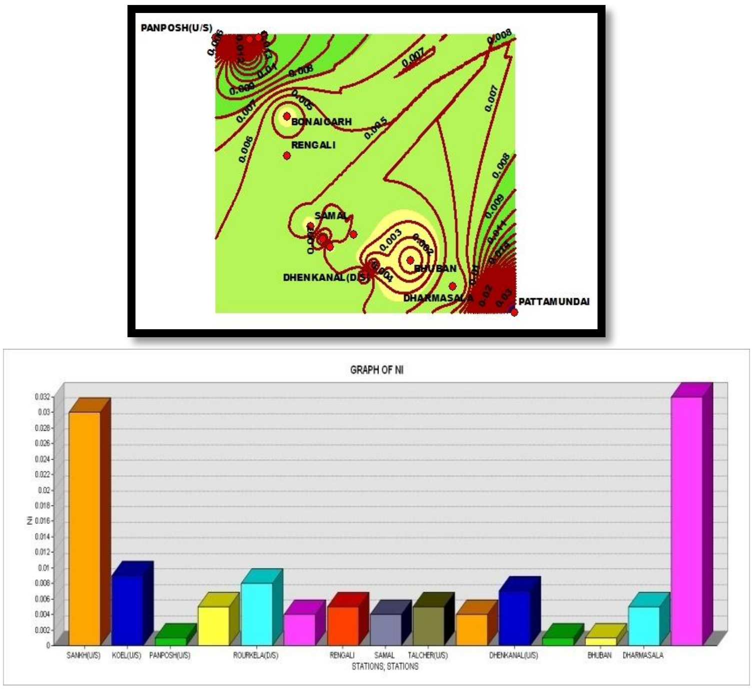
(**Figure8.** Interpolation of Copper using IDW)



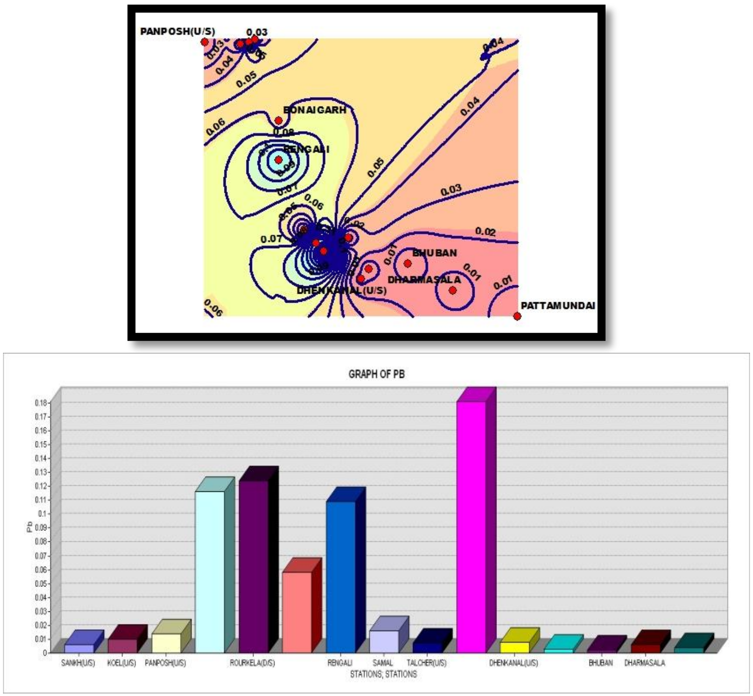
(**Figure9.** Interpolation of Fe using IDW)



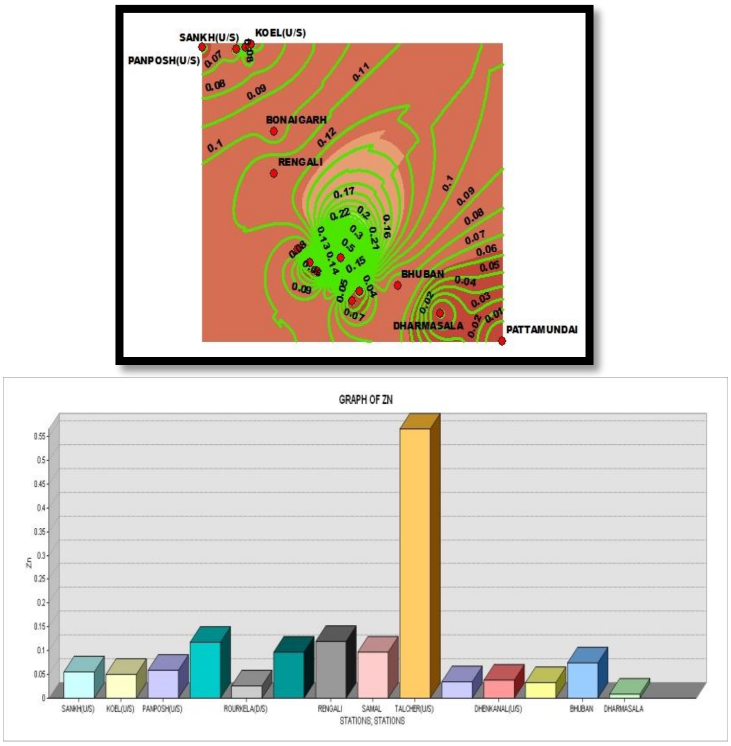
(**Figure10.** Interpolation of Hg using IDW)



(**Figure11**. Interpolation of Ni using IDW)



(**Figure12.** Interpolation of Pb using IDW)

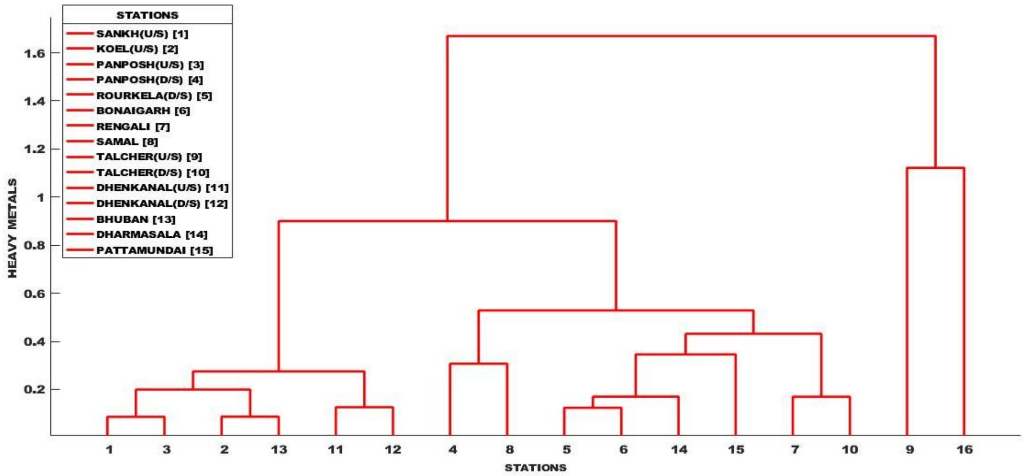


(**Figure13.** Interpolation of Zn using IDW)

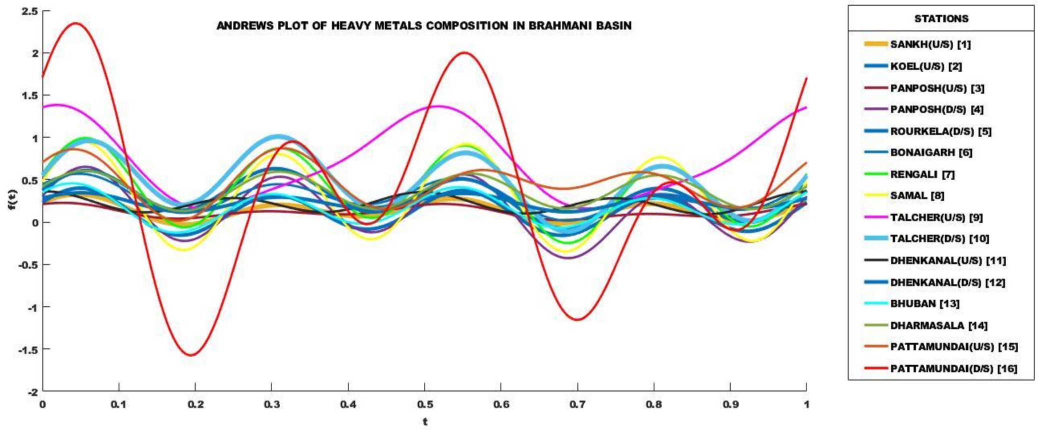
SPATIAL SIMILARITIES AND SITE GROUPING

In this study, sampling sites classification was performed by theuse of cluster analysis. The relationships among the stations were obtained through cluster analyses usingWard's method (linkage between groups), with Euclidian distance as a similarity measure and were synthesized into dendrogram plots (Figure 14). Since we used hierarchical agglomerative cluster analysis, the numberof clusters was also decided by water environment quality, which is mainly effected by land use and industrial structure. The physicochemical parameters like Arsenic, Cadmium, Iron, Mercury, Lead, Zinc, Nickel, Chromium and Copper 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 15 monitoringstations 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 shown in under each cluster are depicted in Ward's minimum variance dendrogram& Andrews plot (Figure 15).

AGGLOMERATIVE HIERARCHICAL CLUSTER ANALYSIS (AHC)



(**Figure14.**Dendrogram showing clustering of monitoring sites according to heavy metal characteristics of the Brahmani river basin)



(**Figure15**. Andrew plots showing heavy metal composition of monitoring sites of the Brahmani river basin)

CLUSTER- I (1-2-3-11-12-13): Monitoring sites, mainly located in between the Sankh (U/s) uptoBhubanincluding Koel, Panposh (U/s), Dhenkanal (U/s), Dhenkanal (D/s) namely (stations 1-2-3-11-12-13) 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.

CLUSTER- II (4-5-6-7-8-10-14-15): This cluster sites mainly located in between Panposh D/s uptoPattamundai including Rourkela, Bonaigarh, Rengali, Samal, Talcher (D/s), Dharmasalanamely (stations 4-5-6-7-8-10-14-15).These sites are classified as moderately polluted (MP).

From the data, it is seen that there is deterioration of water quality at Panposh D/s and Talcher D/s. This is an expected observation since a number of large and medium industries and mines are operating at Rourkela and AngulTalcher industrial complex.

The spatial variation of water quality is in a predictable way. By the time the river reaches Bonaigarh there is a significant improvement in water quality, which remain more or less the same up to Talcher U/s through Rengali and Samal, since there is no major urban settlements or waste water outfalls in this stretch. After confluence of Nandira River with Brahmani River, the water quality at Talcher D/s deteriorates both with respect to Hg and Cd. Though As value increases in comparison to U/s stations of Talcher still it remains within the prescribed limit where both Pb and Ni counts significantly exceeds the prescribed limit. The water quality gets improved uptoDhenkanal U/s. Impact of Dhenkanal town on the water quality of Brahmani River is not that much significant irrespective of increase in Cd and Fe counts.

After Bhuban, there is some restoration in the water quality which continues uptoPottamundai through Dharmasala. The magnitude of improvement in the water quality in this stretch is however not the same as that in the Bonaigarh-Rengali-Samal stretch, since there is increase in the population density and intensity in agricultural activities as the river enters into the deltaic region.

CLUSTER- III (9-16):This cluster mainly includes Talcher D/s and Pattamundai D/s. These sites are classified as highly polluted (HP). During the eighties and early nineties, the water quality of the river at Rourkela and Angul-Talcher caused much concern. Presently, however, there is no indication of any severe industrial pollution in these two stretches. This could be because of some effective control measures taken by the industries and mines, subsequently. A significant step in this direction is recycling/reusing of waste water by some of the major polluting units and reduction in the quantity of effluent generation by some large industries. Improvement in the water quality over the years is reflected in the water quality trend at Talcher D/s and the rivulet Nandira. This small tributary of Brahmani originates at Golabandha and after travelling a distance of about 39 km, joins Brahmani at kamalnaga. Most of the major industries and mines in the Angul-Talcher area are located in the catchment of Nandira. Till late nineties, it is used to receive effluent (directly or indirectly) heavily laden with suspended solids and other pollutants, from many major industries. With improved pollution control measures and recycling of waste water, the quantum of effluent discharged to Nandira has now been reduced considerably, leading to a significant improvement in its water quality and hence at Talcher D/s.

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.

VI. Conclusion:

In the present study, Fe was found in the range of 0.019 ppb to 5.248 ppb which is well within the permissible limits as prescribed by WHO and BIS standards. Concentration of Cu was within acceptable limits though relatively higher values at Bhuban, Talcher and Pottamundai. Concentration of Hg was below detection limit during most of the times. Concentrations of other metals like As, Cd, Ni, Zn, Pb and Cr were within permissible limits of WHO and BIS.

Since the effect of copper contamination is more good than bad for health, the water of BrahmaniRiver is suitable for drinking and irrigation purposes in heavy metal concentration point of view.

In this case study, **multivariate statistical techniques** were used to evaluate **spatial variations in surface water quality of the Brahmani river basin**. Hierarchical cluster analysis grouped 15 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 arecontributed 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 Cd, As, Pbvalues for cluster-III in HP, which are more than the permissible limit for drinking water.Pb, Ni in HP sites implies that the organic nitrogen part plays a major role in the depletion of DO in the river systems.

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