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Evaluation and Correlation Analysis of Surface Water In and Around Mangalore Coastal Belt, Karnataka, India

Kiran, D.A* and Ramaraju, H.K.
Department of Civil Engineering, Dayananda Sagar College of Engineering, Bengaluru, India
✉ dakiran07@gmail.com

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Abstract: Urbanisation, industrialisation, population growth and various agricultural activities in and around coastal areas have led to a significant amount of pollutants into the surrounding aquatic ecosystem such as estuary, river, sea, seashore and coastal wetlands. This causes ecological degradation. Pollution is one of the major challenges to the sustainability of coastal areas. In the study area, major industries are located on the Gurupur river bank which joins the Nethravati river to form a common estuary before entering the Arabian sea. The major activities that are responsible for coastal pollution in the study area are discharge and disposal of untreated domestic and industrial wastes to estuaries, rivers, nearshore waters and harbour activities. Gurupura and Nethravthi are two west flowing rivers of the Mangaluru coastal region. They receive a large amount of pollution load from the nearby industries causing the deterioration of the water quality. In this study, 10 surface water samples which include stream water, river water and sea water, were collected during the pre-monsoon and post-monsoon and analysed for various water quality parameters by adopting standard methods. The study reveals that the electrical conductivity, total dissolved solids and chlorides concentration of most of the surface water samples were met above the standard limits in both seasons. From the correlation analysis, it was found that a very strong correlation was observed between chlorides and hardness (0.9691), TDS and conductivity (0.9227) during post-monsoon season of 2018 and TDS and conductivity (1.00), COD and chlorides (0.8922), DO and chlorides (0.8810) during pre-monsoon of 2019.

Key words: Industrialisation, surface water. correlation analysis, Mangaluru, chlorides.

Introduction

Water is the most essential material and increasing demand with urbanization and industrialization. Human activities and other developmental activities continuously stress the coastal climate**.** For short term economic benefits, inappropriate and over use of natural resources has resulted in long term environmental degradation**.** In estuarine and coastal sea waters, increased nitrogen loads raise the levels of eutrophication (Galloway et al., 1995).

Since a decade, Baikampady industrial area, Mangalore has been subject to environmental degradation. The wastes from industries were discharged into the coastal water through pipelines. Such discharges may disturb the aquatic life and nearby ecology (Kiran and Ramaraju, 2019**).** It is one of the most polluted industrial clusters in Karnataka state with a CEPI score of more than 70 (KSPCB, 2017-18). It includes a large number of highly polluting industries; it may cause ill effects on the nearby surface waters through its discharges. Many streams forming the surface water are flowing in the area carrying waste waters from the industries, they are going to end up with the Gurupura River near Total Oil India Limited (TOIL) and the Arabian Sea. Due to this, the Gurupura river is getting polluted severely effecting the biodiversity of the region. A limited study was carried on this aspect in the

*Corresponding Author

region. So, the present study was focused on studying water quality parameters with the results of correlation analysis conducted on surface water quality parameters from the samples collected during the premonsoon and postmonsoon season of the study area.

One of the most commonly used and documented statistical techniques for summarising scientific research data is correlation analysis. To explain practical water conditions, mathematical models like correlation analysis were used to estimate water quality. It measures the closeness of the relationship between chosen independent and dependent variables. The correlation coefficient is used to calculate coalition strength between two continuous variables. This tells whether the relationship is positive or negative between the variables. Pearson's correlation (*r*) is the most widely used indicator of correlation. A systematic statistical analysis of water quality parameter correlation coefficients helps to determine the overall quality of water and also provides necessary ideas for the implementation of water quality management programmes. Pearson's correlation coefficient is expressed by *r* (rho), and the value ranges between -1.0 and 1.0 with the values being absolute and non-dimensional with no units. Here -1.0 represents perfect negative correlation, lesser than -0.8 represents strongly negative correlation, -0.5 represents moderately negative correlation, 0 represents zero or nil or no correlation and 1.0 represents perfect positive correlation, 0.8 represents strongly positive correlation and 0.5 represents moderately positive correlation (Ratnasari et al., 2016). A positive correlation coefficient means that an increase in one variable causes an increase in the other, indicating a causal relationship between the variables. A negative correlation denotes an inverse relationship in which one variable rises while the other falls. In the present study, for the analysis of the surface water quality in the Mangalore coastal belt, correlation analysis is performed using Pearson Correlation Matrix.

Materials and Methods

Mangaluru or Mangalore is located in the Dakshina Kannada district of Karnataka with coordinates 12.9141° N and 74.8560° E. The coastal belt of Mangaluru spreads about 22 kms with the Western Ghats on the East side and the Arabian Sea on the West side. It was located at an elevation of 22 m above mean sea level. Weathered and fractured gneiss, granite and schist are the major water bearing formations of the region. Netravathi and Gurpur are the two major rivers that serve as the sources of water supply for both drinking and industrial purposes. The average rainfall of the area is above 3500 mm (Manjunatha et al., 2015). Baikampady Industrial Region, where most industries are located and surrounding areas, is the research area for the present study.

Ten surface water (SW) samples were collected near the industries' outlet points and near sea shores (SW1 to SW10) during the post-monsoon and pre-monsoon seasons of 2018 and 2019. Monsoon season was not taken for the sampling due to the reason that the monsoon brings heavy rainfall to the southwest coast of Karnataka may cause dilution of pollutants. The sampling was performed during the morning hours and the samples were protected during transport from direct sunlight. Using well-cleaned polythene bottles, water samples were collected and were tightly closed and brought to the laboratory for further analysis. The collected water samples were analysed by adopting the standard methods (APHA, 2017). Sampling location maps are shown in Figure 1. And in the present study, the physico-chemical parameters of surface waters are used to judge the interrelation between the parameters using Pearson's correlation Matrix.

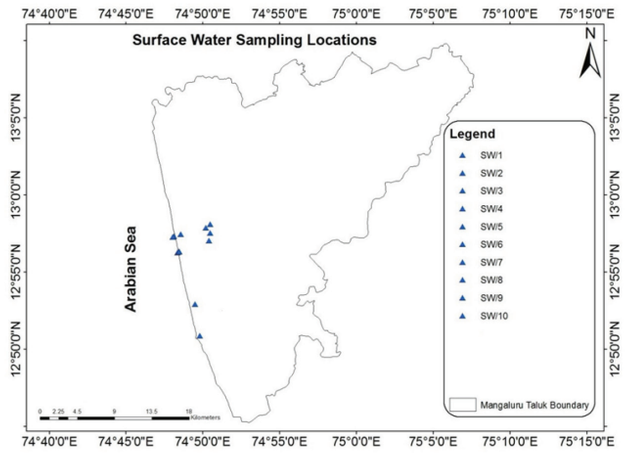

Figure 1: Map showing the surface water sampling locations in the study area.

Results and Discussions

Physicochemical Characteristics of the Surface Water Samples

pH: It expresses the acidity and alkalinity of the solution. In the present study, pH ranged from 7.2 to 8.45 during pre-monsoon season and 6.6 to 7.84 during post-monsoon season. For culturing of the fish, the pH

of the water should be in the range from 7 to 8 (Kiran and Ramaraju, 2019).

Turbidity: In surface water samples, turbidity ranged from 0.2 NTU to 2.1 NTU during the pre-monsoon period and 0.7 NTU to 4.9 NTU during the post-monsoon season. Clay particles, silt particles, organic matter, plankton and other microscopic organisms can cause water turbidity in the biological productivity of water bodies (Kishore et al., 2005).

Electrical Conductivity (EC): It mainly relies on the amount of dissolved solids present in the water. Its values ranged between 10600 µs/cm and 38700 µs/cm during pre-monsoon season and 15040 µs/cm to 44500 µs/cm during the post-monsoon season.

Total Dissolved Solids (TDS*)*: The various kinds of minerals present in the water denote the amount of dissolved solids. The total dissolved solids varied from 6890 mg/l to 25155 mg/l and 9776 mg/l to 28925 mg/l during the pre-monsoon and post-monsoon season, respectively.

Alkalinity: The chief source of alkalinity is the considerable amounts of dissolved carbon dioxide in the natural waters. The growth of phytoplankton was due to the higher alkalinity (Andrade et al., 2011). In the present study, the total alkalinity varied between 196 mg/l and 528 mg/l and 100.5 to 252 mg/l during pre-monsoon and post-monsoon season, respectively.

Total Hardness: The total hardness in the study ranges from 340 mg/l to 7434 mg/l and 84.2 mg/l to 7400 mg/l during pre-monsoon and post-monsoon season, respectively. Due to the high levels of hardness toxicity of zinc in fish may increase (Lloyd, 1960).

Chlorides: Chlorides are mineral salts and are thus not influenced by sewage's biological activity. This happens naturally in all sources of water. The chloride content in the water sample varied from 490 mg/l to 13554 mg/l and 820.3 mg/l to 14463 mg/l during pre-monsoon and post-monsoon season, respectively.

Dissolved Oxygen: It is the amount of oxygen dissolved in water. In the present study, DO values ranged from 1.2 mg/l to 5.3 mg/l and 2.3 mg/l to 5.4 mg/l during pre-monsoon and post-monsoon season respectively. DO is of predominant importance in restricting the maintenance of aquatic life (Andrade et al., 2011).

Biochemical Oxygen Demand (BOD): The amount of microorganisms and their organic matter load present in the sample is provided by the biochemical oxygen demand. In the present study, BOD ranges from 5 mg/l to 32 mg/l during pre-monsoon season and 8 mg/l to 45 mg/l during post-monsoon season.

Chemical Oxygen Demand (COD): COD is a dependable parameter in giving a conclusion regarding the extent of pollution in water (Effendi et al., 2015). In this study, COD values ranged from 150 mg/l to 708 mg/l and 608 mg/l to 1032 mg/l during pre-monsoon and post-monsoon season respectively.

Statistical Analysis

Water quality relies on various parameters if strong correlation lives among the different parameters and the combined effect of interrelationship among these parameters reflects on the water quality (Jothivenkatachalam et al., 2010; Samson and Elangoyan, 2017).

Tables 1 and 2 represent the normal distribution analysis and correlation matrix for pre-monsoon season. Parameters such as pH, total hardness, chlorides, DO, BOD and COD in the analysed sample show the Kurtosis with a negative value, which indicate that the positioning of these parameters has flat peak compared to the normal distribution pattern. The skewness with negative values pH (-0.22), EC (-1.99), TDS (-1.99) and DO (-0.19) shows that the data were spread towards the lower values or had a negative tail in the left direction. Positive values of skewness indicated their tail distributed towards the higher values which pointed out that data were distributed in the right direction of the tail. From Table 2, a highly positive correlation was observed between TDS and EC (1.000), COD and chlorides (0.8922), DO and chlorides (0.8810) where between DO and alkalinity (-0.5633), BOD and hardness (-0.4486), alkalinity and pH (-0.3737), hardness and alkalinity (-0.3684) highly negative correlation was observed. A very poor positive correlation was observed between COD and BOD (0.1821), BOD and turbidity (0.1940). While there was almost no correlation is observed between Chlorides and Turbidity (0.0173).

Tables 3 and 4 represent the normal distribution analysis and correlation matrix for post monsoon season. Negative values of Kurtosis were seen in the parameters such as pH, turbidity, EC, total alkalinity, total hardness, chlorides, DO, BOD and COD. The negative values of skewness of total alkalinity (-0.57), DO (-1.135) and COD (-0.17547) indicated that the data were distributed towards the lower values or having a negative tail in the left direction.

Table 1: Statistical analysis of SW quality parameters during pre monsoon season

	Mean	*Median*	*Mode*	*SD*	*Skewness*	*Kurtosis*	*Variance*
pH	7.859	7.85	8.1	0.37	-0.22	-0.30	0.14
Turbidity, NTU	1.03	1.05	1.3	0.54	0.38	0.89	0.29
EC, µs/cm	31420	34950	#N/A	8370.96	-1.99	4.31	70072888.89
TDS, mg/l	20423	22717.5	#N/A	5441.12	-1.99	4.31	29605795.56
Total Alkalinity, mg/l	259.2	236	236	99.35	2.65	7.47	9869.51
Total Hardness, mg/l	3048.3	3051	#N/A	2510.23	0.55	-0.99	6301242.23
Chlorides, mg/l	5540.389	4395.7	#N/A	5152.47	0.34	-1.81	26547969.27
DO, mg/l	3.5	3.6	5.1	1.58	-0.19	-2.02	2.48
BOD, mg/l	15.6	12	#N/A	9.08	0.81	-0.59	82.49
COD, mg/l	409.4	374	#N/A	197.93	0.31	-1.50	39175.82

Table 2: Correlation matrix for SW samples during pre monsoon season

	pH	*Turbidity*	*Conductivity*	*TDS*	*Alkalinity*	*Hardness*	*Chlorides*	*DO*	*BOD*	*COD*
pH	1									
Turbidity	-0.3388	1								
Conductivity	0.2641	0.4289	1							
TDS	0.2641	0.4289	1	1						
Alkalinity	-0.3737	0.2151	-0.2335	-0.2335	1					
Hardness	0.7709	-0.0480	0.5972	0.5972	-0.3684	1				
Chlorides	0.8270	0.0173	0.5034	0.5034	-0.3391	0.7701	1			
DO	0.7811	-0.2563	0.3832	0.3832	-0.5633	0.6405	0.8810	1		
BOD	-0.2116	0.1940	-0.0239	-0.0239	-0.1591	-0.4486	-0.1229	0.1473	1	
COD	0.7057	0.1979	0.5682	0.5682	-0.2790	0.5925	0.8922	0.7913	0.1821	1

Table 4 shows a highly positive correlation was observed between chlorides and hardness (0.9691), TDS and conductivity (0.9227), chlorides and pH (0.8156) where the highly negative correlation was observed between DO and alkalinity (-0.6960), alkalinity and conductivity (-0.6486), alkalinity and TDS (-0.6146). A very poor positive correlation was observed between Conductivity and pH (0.1577), COD and Alkalinity (0.1192). While there was almost no correlation is observed between hardness and turbidity (0.0043).

Conclusions

In order to identify anthropogenic activities and their impacts along the coastal area of Mangaluru, the present study was conducted, and the conclusions are as follows.

The study shows that the concentration of electrical conductivity, total dissolved solids and chlorides of most surface water samples are above the normal limits according to IS: 2296-1982 Standard: Inland Surface Water Class-E. Due to industrial emissions, low DO values have been observed in almost all stream samples. In almost all the surface water samples obtained, high values of BOD and COD were also found and also it is evident that pollution level in the post-monsoon season was higher than the pre monsoon in terms of BOD, COD and chlorides. But in terms of concentration of EC, TDS, hardness and DO, the pollution level was higher in pre-monsoon season. From the correlation analysis, a very strong correlation was observed between

Table 3: Statistical analysis of SW quality parameters during post monsoon season

	Mean	*Median*	*Mode*	*SD*	*Skewness*	*Kurtosis*	*Variance*
pH	7.323	7.3	7.7	0.537609	0.110747	-1.16359	0.289023
Turbidity, NTU	2.29	2.05	#N/A	1.377961	0.684543	-0.39405	1.898778
EC, µs/cm	29357	28350	27900	9800.261	0.280363	-0.49335	96045112
TDS in mg/l	18039.35	18427.5	#N/A	5572.508	0.387718	0.407919	31052844
Total Alkalinity, mg/l	191.98	200	#N/A	52.44987	-0.57026	-1.03295	2750.988
Total Hardness, mg/l	2883.831	2078.63	#N/A	2944.18	0.456272	-1.67383	8668198
Chlorides, mg/l	6866.245	5924.45	#N/A	5979.743	0.16494	-2.1975	35757330
DO, mg/l	4.024	3.87	#N/A	1.103723	-0.13534	-1.48881	1.218204
BOD, mg/l	23	24	30	11.85093	0.358488	-0.44678	140.4444
COD, mg/l	836.2	815	#N/A	150.0895	-0.17547	-1.3229	22526.84

Table 4: Correlation matrix for SW samples during post monsoon season

	pH	*Turbidity*	*Conductivity*	*TDS*	*Alkalinity*	*Hardness*	*Chlorides*	*DO*	*BOD*	*COD*
pH	1									
Turbidity	0.4065	1								
Conductivity	0.1577	-0.4728	1							
TDS	0.1466	-0.3731	0.9227	1						
Alkalinity	-0.1652	0.5650	-0.6486	-0.6146	1					
Hardness	0.7772	0.0043	0.4879	0.4225	-0.3427	1				
Chlorides	0.8156	0.0487	0.4725	0.4087	-0.4638	0.9691	1			
DO	0.5767	-0.1177	0.6192	0.6078	-0.6960	0.7294	0.7914	1		
BOD	-0.1341	0.4620	-0.3148	-0.1944	0.2246	-0.4456	-0.3609	-0.0987	1	
COD	0.4017	0.0477	0.3697	0.2584	0.1192	0.6812	0.6061	0.2012	-0.4435	1

chlorides and hardness (0.9691), TDS and conductivity (0.9227) during post-monsoon season of 2018 and TDS and conductivity **(**1.00**)**, COD and chlorides **(**0.8922**)**, DO and chlorides **(**0.8810**)** during pre-monsoon of 2019. This study showed that all the physicochemical parameters of surface waters are more or less correlated with each other.

The study also shows that anthropogenic activities along the coastal area have caused the values of the physicochemical properties of the water samples to differ. Thus, urgent action or attention to the spread of pollution near the coastal region is needed.

Suggestive Measures:

- Industrial waste water/municipal waste water should be treated according to international standards, prior to disposal near coastal water and the Government should strictly enforce the law.
- More number of seminars/workshops with practical information and awareness programmes about the importance of water, air, soil and environment to be conducted and effective implementation of the Ministry of Ecology, Forest, Environment Norms.
- The government should set up a task force to look at the different aspects of land use management and coastal water management.

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