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STATISTICAL ANALYSIS OF WATER QUALITY DATA FOR THE PURNA RIVER ESTUARY OF NAVSARI, GUJARAT

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Abstract
Purna is the perennial river of Navsari district. As river passes through the Navsari district the water quality gets influenced by the tidal action and discharges of effluents such as cremation ground wastes and domestic as well as anthropogenic pollution. During study period total 72 samples were collected from 3 different sites during May'08-April'09 and May'12 – April'13 to check the water quality of Purna River. 4 variables, namely Temperature, pH, Dissolved oxygen and Chloride were observed during 2008-2009 where as 17 variables such as Temperature, pH, Dissolved oxygen, Chloride, COD, BOD, Salinity, Sulphate, Nitrate, Nitrite, Phosphate, Ammonical nitrogen and Heavy metals (Copper, Nickel, Zinc, Cadmium and Lead) were observed during 2012-2013. Statistical analysis methods such as descriptive statistics, correlation, and regression and Cluster analysis were applied to check interrelationship between water quality variables. According to statistical analysis it observed that all variables are interrelated and water quality was significantly influenced by tidal action as well as anthropogenic pollution.

Key Words: Purna River, Anthropogenic Pollution, Descriptive Statistics, Correlation, Regression, Cluster Analysis.

Introduction

The South Gujarat coast line broken by several small tidal creeks and a few minor estuaries like the Mindhola, the Purna, the Ambika, the Auranga and the Damanganga which drains into the Arabian Sea. The Purna is a perennial river of Navsari district (Lat. 21° 55' N , Lon. 72° 45' E) among major estuaries of South Gujarat, which originates in Amravati district of Maharashtra and flows through Akola, Buldhana and Jalgaon district, bounded by a fault along the Satpuras range and debouches into the Arabian Sea. Thus there is presence of three distinct zones with distinct channel morphology. An upstream river dominated zone, a central mixed energy zone and a seaward marine dominated estuarine zone [5]**.** Thus, estuaries become areas of constant change caused by varying meteorological and hydrographic factors that regulate the physicochemical properties of estuarine water and sediments [16]. As Purna passes through the Navsari district, it gets locally contaminated due to the discharge of domestic sewage, Cremation ground wastes, small scale industrial effluent. It also receive the fresh water from the upstream and sea water from downstream due to tidal action which cause changes in physico-chemical characteristic of water. To evaluate the water quality of Purna river estuary from the three different sites namely Jalalpore, Kasbapar and Viraval, 4 variables, namely Temperature, pH, Dissolved oxygen and Chloride were observed during 2008-2009 where as 17 variables such as Temperature, pH, Dissolved oxygen, Chloride, COD, BOD, Salinity, Sulphate, Nitrate, Nitrite, Phosphate, Ammonical nitrogen and Heavy metals (Copper, Nickel, Zinc, Cadmium and Lead) were observed during 2012-2013.

Standard deviation is most widely used measure of dispersion of a series [15]. Correlation is the most elemental way to assess the strength of association between two variables. It reveals the magnitude and direction of the relationship. A pearson product- moment correlation coefficient has value ranging from -1 to 1 [2]. Regression is one of the very important statistical tools which are used in almost all sciences-natural, physical and social research. In regression analysis there are two types of variables. The variable whose value is influenced is called dependent variable and the variable which influences the dependent variable are called explanatory variables [15]. Cluster analysis is an explanatory data analysis technique that groups heterogeneous objects (multi–Dimensional/into homogeneous groups) [14].

The main objective of the statistical analysis was to evaluate trends in water quality parameters that are associated with tidal action and anthropogenic pollution.

Methodology

To fulfill the objective, total 72 samples were collected during May'08- April'09 and May'12- April'13 from below mentioned sites. Site 1 is the Jalalpore site which is the Marine water dominant (Estuarine) zone of the river and the domestic sewage is drained into the estuary which was most probably diluted with the sea water.

Site 2 is the Kasbapar site which is the fresh water dominant (Riverine) zone of the river. The Cremation ground is located on

the bank of the river. This site is also polluted by local village people as they wash their clothes at the river bank. Site 3 is the Viraval site which is the intermediate zone of the river. This site is mostly polluted due to the release of domestic sewage.

The water quality parameters were analyzed by using [1], [11]-[13] and "Soil, Plant, Water and Fertilizer Analysis" by [8]. The statistical analysis was carried out using SPSS and Microsoft excel.

Results and Discussion

To assess the water quality of Purna river estuary, water sample were collected during April'08- May'09 and April'12-May'13 from 3 different sites.

The parameters selected to assess the water quality during 2008-09 are pH, Temperature, Chloride and Dissolved oxygen while during 2012-13, the water samples was further analyzed by addition of parameters such as COD, BOD, Salinity, Sulphate, Nitrate, Nitrite, Phosphate, Ammonical nitrogen and Heavy metals (Copper, Nickel, Zinc, Cadmium and Lead). As per the theory of Aquatic Biology all the parameters observed for water are inter related and to identity the main parameter affecting each other, correlation, regressions analysis and also cluster analysis used to get a group of variables having similar (may be higher or lower) variation and which can represent majority of variation in the water quality.

The mean and standard deviation of physico-chemical parameters are tabulated in Table:1 (2008-09) and Table:2 (2012-13). During the study period, there was large variation in Chloride, Sulphate, COD and BOD were observed among the sites whereas Temperature, pH, DO, Ammonical nitrogen, Nitrite, Nitrate, Phosphorous and Heavy metal concentration shows the similar trends. The correlation is the mutual relationship between two variables. Direct correlation exists when increase or decrease in the value of one parameter is associated with a corresponding increase or decrease in the value of other parameter **[10].** The statistical value of correlation coefficient R for water quality parameters was put into a Table III and IV.

A. **Descriptive statistics**

Table IDescriptive statistics of water quality parameters during 2008-09

Sr. no.	Parameter	N	Minimum	Maximum	Mean	Standard deviation
1	Temp	36	25.50	34	28.66	1.923
2	pH	36	6.99	8.25	7.69	0.312
3	**Chloride**	**36**	**16.99**	**1249.61**	**118.58**	**222.210**
4	DO	36	2.20	11.3	6.76	2.043
	Valid N (list wise)	36				

Table II Descriptive statistics for water quality parameters during 2012-13

Parameters	N	Minimum	Maximum	Mean	Std. Deviation
Temperature	36	23	31	28.1806	2.21731
pH	36	7.63	8.42	8.0017	0.24411
Chloride	36	12.99	5598	395.3881	996.6301
DO	36	2.05	18.5	5.6442	2.85684
COD	**36**	**0**	**480**	**54.5617**	**78.69685**
BOD	**36**	**4.6**	**60**	**19.0472**	**11.64093**
Ammonical nitrogen	36	0.02	5.97	1.1261	1.08914
Nitrite	36	0	0.88	0.1236	0.19518
Nitrate	36	0.13	1.74	0.8961	0.42646
Phosphorous	36	0.9	3.95	1.7596	0.77585
Sulphate	**36**	**6.2**	**259**	**44.8511**	**54.58626**
Salinity	36	0.02	10.11	0.7135	1.80027
Copper	36	0	0.07	0.019	0.01416
Nickel	36	0.01	0.22	0.0382	0.03748
Zinc	36	0.01	0.56	0.0554	0.09048
Cadmium	36	0	0.01	0.0028	0.00279
Lead	36	0	0.01	0.0017	0.00299
Valid N (list wise)	36				

B. **Correlation**

Table III

Correlation of water quality parameters during 2008-09				
	Temp	pH	Chloride	DO
Temp	1.000			
pH	0.232	1.000		
Chloride	0.293	-0.274	1.000	
DO	0.276	**0.552****	-0.301	1.000
**. Correlation is significant at the 0.01 level (2-tailed).				
*. Correlation is significant at the 0.05 level (2-tailed).				

Table IV

Correlation of water quality parameters during 2012-13																	
	Temp	**pH**	**Chloride**	**DO**	**COD**	**BOD**	**ammonia**	**nitrite**	**nitrate**	**phosphate as po4**	**sulphate**	**salinity**	**copper**	**nickle**	**zinc**	**cadmium**	**lead**
Temp	1.000																
pH	-0.017	1.000															
Chloride	-0.300	-0.373*	1.000														
DO	0.028	0.107	0.043	1.000													
COD	0.036	0.110	0.024	-0.042	1.000												
BOD	0.030	-0.125	0.206	-0.103	0.835**	1.000											
ammonia	-0.099	-0.226	0.623**	0.029	-0.051	-0.021	1.000										
nitrite	-0.654**	-0.279	0.702**	-0.166	-0.043	0.036	0.527**	1.000									
nitrate	0.569**	0.060	-0.309	-0.129	0.224	0.171	-0.382*	-0.576**	1.000								
phosphate as po4	-0.142	-0.296	-0.004	-0.283	-0.126	-0.081	0.073	0.316	-0.240	1.000							
sulphate	-0.204	-0.436**	0.862**	0.086	0.097	0.423*	0.467**	0.511**	-0.223	-0.062	1.000						
salinity	-0.301	-0.373*	1.000**	0.043	0.024	0.206	0.623**	0.702**	-0.309	-0.004	0.861**	1.000					
copper	-0.269	-0.113	0.551**	-0.037	0.102	0.185	0.404*	0.620**	-0.304	0.208	0.401*	0.551**	1.000				
nickle	-0.437**	-0.265	0.927**	0.063	-0.054	0.048	0.663**	0.798**	-0.382*	0.054	0.678**	0.928**	0.657**	1.000			
zinc	-0.103	-0.137	-0.005	-0.064	-0.043	-0.033	-0.066	0.085	-0.114	0.113	-0.047	-0.004	0.020	0.010	1.000		
cadmium	-0.023	0.164	-0.272	-0.156	-0.015	-0.049	-0.164	-0.047	0.074	0.179	-0.171	-0.272	0.235	-0.179	-0.086	1.000	
lead	0.340*	0.021	-0.131	0.195	0.398*	0.176	-0.070	-0.258	0.199	-0.062	-0.130	-0.132	-0.200	-0.230	-0.103	-0.212	1.000
**. Correlation is significant at the 0.01 level (2-tailed).																	
*. Correlation is significant at the 0.05 level (2-tailed).																	

Regression

The regressions equations acquire by the analysis are shown in Table V and Table VI.

Table IVRegression coefficient, Model, S.E, Adjusted R^2

Model	S.E.	Adj R^2
pH=7.12+0.09DO	0.2644	0.285

Table VRegression coefficient, Model, S.E, Adjusted R^2

Model	S.E.	Adj R^2
Temperature =29.1-7.4 Nitrite	1.7017	0.811
pH=8.089-0.002Sulphate	0.22296	0.166
Chloride=0.7-6.4Nitrite+554Salinity	1.609	1
COD=-58.3+5.3BOD+6801Sulphate	**39.554**	**0.747**
BOD=9.274+0.12COD+0.074Sulphate	5.1534	0.815
Ammonical nitrogen=0.389+19.27Nickel	0.827	0.423
Nitrite=0.93-0.3 Temperature +3.25 Nickel	0.1001	0.737
Nitrate =1.052-1.25 Nitrite	0.353	0.313
Sulphate=38.6+0.08Chloride+0.7BOD-1031nickel	**21.0107**	**0.852**
Salinity=-0.001+0.002cl+0.012Nitrate	0.0029	1
copper=0.01+0.024Nickel	0.0108	0.415
Nickel=0.024+0.03Nitrite+0.02Salinity+0.3 Copper	0.0092	0.94

During 2008-09, the surface water pH was found in the range 6.99- 8.25, whereas during 2012-13, pH was found in the range 7.63-8.42, Thus, the pH of surface water remained alkaline throughout the investigation period. Reference [6] and [9] suggested that majority of flowing waters are neutral to alkaline in nature. During 2008-09, pH was positively correlated (r = 0.552) with Dissolved oxygen. The water temperature was found in the range 25.5˚C-34˚C during 2008-09. The maximum temperature was noticed during May'08 at site 1 while minimum was noticed during February'09 at same site. During 2012-13 the temperature was found in the range 23˚C -31˚C. The minimum temperature was observed during February'13 at site 2 while maximum temperature was noticed during May'12 and June'12 at site 2 whereas during June'12 at site 3. The seasonal variation in temperature was observed during the investigation period. The maximum Temperature was noticed in summer whereas minimum was noticed in winter season. During 2008-09 the minimum water DO was 2.2 mg/L found at site 1 during February '09 while maximum was 11.3 mg/L, found at site 2 during May'08. Both radiation and tidal inundation controlled temperature variation of estuarine water [19].During 2012-13, Temperature shows the negative correlation with nitrite (r = -0.654) and Nickel (r = -0.437) while positively correlated with Nitrate (r = 0.569).

During 2012-13 the minimum water DO was 2.05 at site 3 during February'13 while maximum DO was 18.5 mg/L at site 1 during March'13. The maximum Dissolved oxygen was attributed to mixing and circulation of water as well as may be presence of other oxidants [1] while minimum Dissolved oxygen concentration may be due to mixing of sewage water. Same was observed by [6]-[7]. During 2012-13, the BOD was found in the range of 10-60 mg/L, 4.6-18.2 mg/L and 4.9-22 mg/L at site 1, site 2 and site 3 respectively. Thus minimum concentration was 4.6 mg/L observed during August'13 at site 2 and maximum was 60 mg/L observed during September'12 at site 1. Reference [7] suggested that the rise in BOD at the sampling stations could be due to the entry of effluent from the dying, printing industries as well as domestic sewage of the town. During present study the rise in the BOD value may be due to the discharge of effluent as well as anthropogenic pollution.

During 2012-13, the COD was found in the range of 20-480 mg/L, ND-60.6 mg/L and 10-48 mg/L at site 1, site 2 and site 3 respectively. Thus minimum concentration was ND mg/L observed during July'13 to September'13 at Kasbapar site and maximum was 480 mg/L observed during September'12 at Jalalpore site. The maximum value of COD may be due to the discharges of flowers, flower garlands and burnt ashes as well as discharges of domestic and small scale industrial sewage. There was positive correlation (r = 0.835) found between COD and BOD during study period. During 2008-2009, the maximum Chloride concentration was 1249.6 mg/l noticed at Jalalpore site during April'09 while minimum was 16.99 mg/L found at Kasbapar site during September'08. During 2012-13 the maximum Chloride concentration was 5598 mg/L found at

Jalalpore site during January'13 whereas minimum was 12.99 mg/L observed at Kasbapar site during August'08. Presently wide variations in Chloride concentration were observed among the sites during different seasons. As compare within the sites lowest chloride and salinity was observed at site 2 as it was a freshwater zone and concentration was found increased towards the downstream. Chloride concentration shows positive correlation with ammonical nitrogen (r = 0.623), Nitrite (r = 0.702), Sulphate (r = 0.862), Salinity (r = 1.000) and Nickel (r = 0.927).

During 2012-13, the Nitrate as NO_3 concentration was in the range of 0.13-1.74 mg/l, 0.34-1.66 mg/l and 0.26-1.51 mg/l at site 1, site 2 and site 3 respectively. Thus minimum concentration was 0.13 mg/L observed during January'13 at site 1 and maximum was observed during August'12 at same site. Nitrate the major form of nitrogen in oxidizing water is the product of aerobic decomposition of organic nitrogenous matter, however main source of elevated nitrate concentration may be inorganic fertilizers used indiscriminately in and around the estuary [18].

The most important source of the nitrate is biological oxidation of organic nitrogenous substances, which come in sewage and industrial wastes. Atmospheric nitrogen fixed into nitrates by nitrogen-fixing organisms, is also adding a significant concentration to nitrates in the water [9].

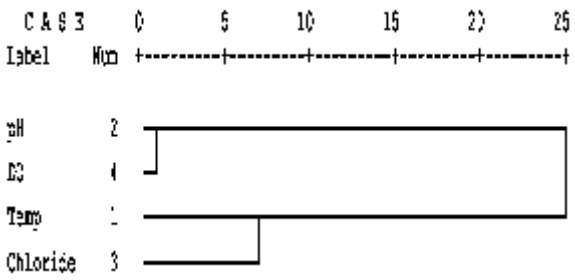
During 2012-2013, the Phosphorous as PO_4 concentration was in the range of 0.97-2.6 mg/l, 0.93-3.95 mg/l and 0.9-3.34 mg/l at site 1, site 2 and site 3 respectively. The minimum concentration was 0.9 mg/l found at site 3 during September'12 while maximum was 3.95 mg/l observed at site 2 during March'13. The high values of phosphate may be attributed to the formation or accumulation of inorganic phosphates and to the substantial addition of phosphate through agricultural drainage and sewage from the neighboring areas [9].

During 2012-2013, the Sulphate as SO_4 concentration was in the range of 8.89-259 mg/l, 6.2-48 mg/l and 6.4-125 mg/l at Jalalpore site, Kasbapar site and Viraval site respectively. The minimum concentration was 6.2 mg/l found at site 2 during August'12 while maximum was 259 mg/l observed at site 1 during January'13. Reference [17] suggested that temporal variation in sulphate can be attributed to several factors, more importantly the proportional physical mixing of sea water with fresh water , adsorption of reactive sulphate into suspended sedimentary particles in over lay waters and biological removal by phytoplankton especially by diatoms and silicofalgellates. Sulphate shoes the positive correlation with Salinity (r = 0.861) and nickel (r = 0.678), During 2012-2013, the Nitrite as NO_2 concentration was in the range of 0.0015-0.88 mg/l, ND-0.25 mg/l and ND-0.49 mg/l at site 1, site 2 and site 3 respectively. The nitrite form of nitrogen was found to be very low throughout the study period as it is intermediate and unstable state of nitrogen. The same was supported by [18]. Nitrite shows negative correlation with Nitrate (r = -0.576) and positively correlated with Sulphate (r = 0.511), Salinity (r = 0.702), Copper(r = 0.620) and Nickel(r = 0.798). During 2012-2013, the Ammonical nitrogen as NH_3 concentration was noticed in the range of 0.019-4.04 mg/l, 0.22-1.59 mg/l and 0.029-5.97 mg/l at site 1, site 2 and site 3 respectively. The minimum 0.019 mg/l was found at site 1 during July'12 and maximum 5.97 mg/l was found at site 3 during January'13. Ammonical nitrogen rapidly taken up by phytoplankton and other hydrophytes present naturally in surface water. However, high value of ammonia is a sign of pollution as in addition to aquatic animals in the form of excretory product it is also generated by degradation of organic nitrogenous matter and hydrolysis of urea [18]. Ammonical nitrogen shows positive correlation with Nitrite (r = 0.527), Sulphate(r = 0.467), Salinity(r = 0.623) and Nickel(r = 0.663). The water copper concentration was in the range of 0.006-0.067 mg/l, 0.0055-0.046 mg/l and 0.0032-0.025 mg/l at site 1, site 2 and site 3 respectively. The Nickel concentration was in the range of 0.0198-0.223 mg/l, 0.010-0.097 mg/l and 0.017-0.117 mg/l at site 1, site 2 and site 3 respectively. The Zinc concentration was in the range of 0.011-0.0836 mg/l, 0.0116-0.561 mg/l and 0.0208-0.046 mg/l at site 1, site 2 and site 3 respectively. The Cadmium concentration was in the range of ND-0.012 mg/l, ND-0.0045 mg/l and ND-0.008 mg/l at site 1, site 2 and site 3 respectively. The Lead concentration was in the range of ND-0.0098 mg/l, ND-0.0088 mg/l and ND-0.0091 mg/l at site 1, site 2 and site 3 respectively. It observed that the heavy metal concentration in water was found very low which may be due to the alkaline nature of water which induces precipitation of metals and their accumulation in sediment. This was also suggested by [4]. Among the heavy metals it observed that Zinc, Cadmium and Lead behave independently while copper and Nickel found interrelated.

C. **Cluster analysis**

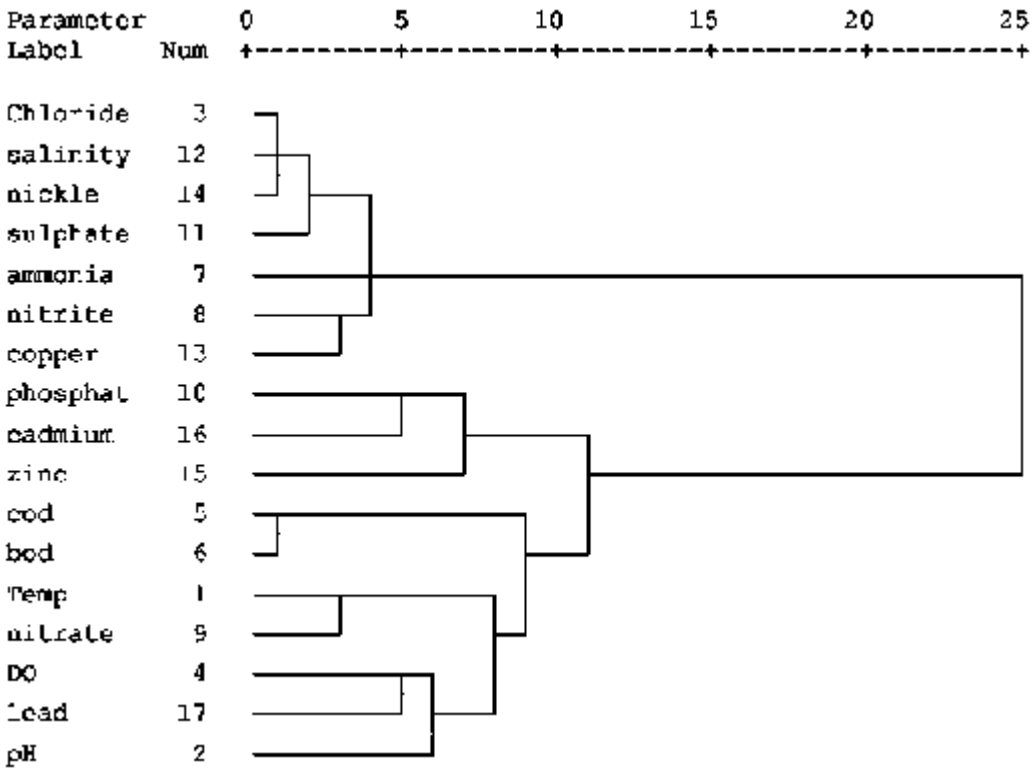
Cluster analysis (CA) groups the objects into classes (Clusters) on the basis of similarities within a class and dissimilarities between different classes. It also helps in interpreting the data and indicates the spatial and temporal patterns. In hierarchical clustering, clusters are formed sequentially by starting with the most similar pair of objects and forming higher clusters step by step [3].

Figure I



In the above dendrogram tree (Figure I) we can see that {pH and DO} is the cluster formed at the minimum distance level (i.e. at a distance less than 5). It indicates that this pair are highly related. {Temp and Chloride} is another cluster formed at distance level 7 (i.e. good relation). Finally the cluster at the levels 7 and a cluster at minimum level will merge into a new cluster at distance level 25.

Figure II



In the above dendrogram tree diagram (Figure 4.9), we can see that {chloride, salinity, nickel, sulphate, ammonical nitrogen, nitrite and copper}, {phosphate and cadmium}, {COD and BOD}, {temp and nitrite} and {DO and lead} are the cluster formed at the minimum distance level (i.e. at a distance less than 5). It indicates that these pairs are highly related. {Phosphate, cadmium and zinc} merges at distance level 7(i.e. good relation), {COD, BOD, temp, nitrate, DO, lead and pH} merges into one cluster at the distance level 9 (i.e. good relation). Now the clusters merged at the levels 7 and 9 will merge into one cluster at distance level 11(i.e. moderate relation). Finally the clusters merged at the levels 11 and a cluster {chloride, salinity, nickel, sulphate, ammonia, nitrite and copper} formed at level 4 , both will merge into a new cluster at distance level 25.

Conclusion

This study offers the statistical analysis for the water quality data of river and concluded that the water quality parameters are more or less interrelated with each other. The Statistical analysis such as Descriptive statistics, Correlation coefficient, Regression and Cluster analysis were applied to the water quality data of Purna river estuary. From the Descriptive statistics it conclude that there are large variation in Chloride and Sulphate as well as COD and BOD. The former is due the tidal action and seasonal variation while latter is due to the discharges of flowers, flower garlands and burnt ashes as well as discharges of domestic and small scale industrial sewage. This variation in the water quality also influences the biological communities of the river.

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