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STATISTICAL ANALYSIS OF PHYSICOCHEMICAL PARAMETERS OF WATER OF RIVER GANGA IN HARIDWAR DISTRICT

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ABSTRACT

The present study deals with the study of physico-chemical parameters of Ganga river water in Haridwar (Uttarakhand). Systematic calculation of correlation coefficient between water quality parameters has been done with the objective of minimizing the complexity and dimensionality of large set of data. The significant correlation has been further verified by using t-test.The water samples were collected and analysed for two consecutive years 2007 and 2008 from five sampling stations during three seasons(winter, summer and rainy). In the present study, an appreciable significant positive correlation was found for Free CO_2 with Cl^- , TDSD, TSSD; turbidity with Cl^- ,Ec, TSSD; Cl^- with Ec, Free CO_2, TSSD ;Ec with Cl^- , TDSD, TSSD. A significant negative correlation was found for DO with Free CO_2, COD, turbidity. Cl^- , Ec, TDSD and TSSD.

Key words : statistical analysis, correlation , t- test, physico-chemical parameters, river water.

INTRODUCTION

In spite of India's spectacular achievements in some areas of Science and Technology since independence, most of our rural areas and even many of urban areas do not have access to safe drinking water. The Government of India is determined to rectify this situation and, consequently, supplying safe drinking water to rural and urban populations has been identified as one of the "Technology Missions" to be pursued by the nation[1].

Even now most of the towns do not have a pipelined water supply. Even if there is one, water is obtained from ponds and rivers. This water is also used for domestic and agricultural purposes. The quality of water may be described according to its physico-chemical and micro-biological characteristics [2] .In order that the water quality is effectively maintained through appropriate control measures, it is essential to monitor a large number of quality parameters continuously. The quality of water is identified by its physical, chemical and biological properties; the particulate problem in case of water quality monitoring is the complexity associated with analysis of the large number of measured variables[3], the data sets contain large information about the behavior of the water body. The classification, modeling and interpretations of monitoring data are the most important steps in the assessment of water quality. Water quality parameters interact with each other. To define the resource water quality many researchers treated water quality parameters individually by describing the seasonal variability and their causes. It is a very difficult and laborious task to regularly monitor all the parameters even if adequate manpower and laboratory facilities are available. For this reason, in recent years an easier and simpler approach based on statistical correlation, has been developed using mathematical relationship for comparison of physico-chemical parameters[4-7].

Interrelationship studies between different variables are very helpful tools in promoting research and opening new frontiers of knowledge. The study of correlation reduces the range of uncertainty associated with decision making.The significance of the observed correlation coefficients have been tested by using't' test[8].

The present study deals with the study of physico-chemical parameters of Ganga river water in Haridwar (Uttarakhand, India). Haridwar is a fast growing industrial area and a sacred city of Northern Indian state of Uttarakhand situated at about 285.56 meters above sea level. This study was performed at five stations on the stretch of 10 Kms starting from sampling station A (Bhooma Niketan), sampling station B (Jai Ram Ashram), Sampling station C (Har-ki-Pauri), Sampling station D (Prem Nagar Ashram and Sampling station E (Pul Jatwara).

Statistical studies have been carried out by calculating correlation coefficients between different pairs of parameters and *t*- test applied for checking significance.

EXPERIMENTAL

A total of 90 water samples were collected from five different spots during different seasons(winter, summer and rainy) over a period of two years (November 2006 to October 2008).Water samples were collected in plastic jerry canes. Grab sampling was generally applied during the sampling. Water samples were analyzed by standard methods[9-16]. The chemicals used in the present investigation were procured by E. Merck India, S.D fine chemicals and B.D.H., India of analytical grade. All the glassware used was of corning grade, manufactured by Borosil India Ltd. The statistical analysis has been performed using standard methods[16]. Statistical studies have been carried out by calculating correlation coefficients between different pairs of parameters and *t*- test applied for checking significance.

Coefficient of correlation (r):

$$r = \sqrt{\frac{\Sigma(x-\bar{x})(y-\bar{y})}{\Sigma(x-x)^2\Sigma(y-y)^2}}$$

Where, x = Individual reading of 1st parameter
x =Mean of Σ x
y = Individual reading of 2nd parameter
y = Mean of Σ y

The correlation among the different parameters will be true when the value of correlation coefficient (r) is high and approaching to one. **Correlation**, the relationship between two variables, is closely related to prediction.The greater the association between variables, the more accurately we can predict the outcome of events[17-19].

RESULTS AND DISCUSSION

Different pairs of water quality parameters with significant correlation coefficients are given in Table 1.

The dissolved oxygen in water is often attributed to the fact that the oxygen is dissolved more during the period of high catabolic activity by photosynthesis. D.O. decreases as turbidity, TDSD, TSSD increase because of retarded photosynthetic activity of biota. In the present study D.O. has strong significant negative correlation with free CO_2 (r= -0.9405, t=11.0971) B.O.D. (r= -0.8983, t= 16.0419), turbidity (r= -0.8672, t= 4.3137), Cl^- (r= -0.8794, t=3.1959), TDSD (r= -0.9226, t=5.8326), and TSSD (r= -0.8836, t=4.7913). This shows that with any increase or decrease in the values of D.O.; free CO_2, B.O.D., turbidity, Cl^-, TDSD and TSSD also exhibit decrease or increase in their values.

Free CO_2 is released during the decomposition of certain substances and metabolic activity of the living organisms. The D.O. and free CO_2 are inversely related to one another because of the photosynthetic and respiratory activities of biota. Free CO_2 shows significant positive correlation with B.O.D. (r=0.8397, t=2.6060), turbidity (r=0.9485, t=4.4937), Na (r=0.8639, t=10.9542), K (r=0.8392, t=5.7425),NO_3^- (r=0.8360, t=11.5501),PO_4^{3-} (r=0.8016, t=11.5637), Cl^- (r=0.9567, t=4.6610),Ec (r=0.9355, t=9.6397), TDSD (r=0.9589, t=5.9848), and TSSD (r=0.9570, t=4.8282).

Chloride ion bears significant positive correlation with Free CO_2 (r=0.9567, t=4.6610), turbidity (r=0.9982, t=4.4911), Na (r=0.9313, t=15.0362), K (r=0.9129, t=5.1718), NO_3^- (r=0.9176, t=6.9479), Ec

(r=0.9921, t=9.7788) and TDSD(r=0.9472, t=5.9924), TSSD (r=0.9978, t=4.8285) and SO_4^{2-}ion does not bear significant positive correlation with Na and K. It shows that Na^+ and K^+ are mainly present as chlorides.

The turbidity is a striking characteristic to know the physical status of a river. The suspended particles, soil particles, discharged effluents, decomposed organic matter, total dissolved solids as well as the microscopic organisms increase the turbidity of water, which interferes with the penetration of light. Turbidity shows strong positive significant correlation with Free CO_2 (r=0.9485, t=4.4937), Cl^- (r=0.9982, t=4.911), Na (r=0.9388, t=4.3344), K (r=0.9255, t=4.5020), NO_3^- (r=0.9275, t=4.5348), PO_4^{3-} (r=0.8738, t=4.5342), TDSD(r=0.9407, t=6.6467) and TSSD (r=0.9976, t=4.9073); and strong negative correlation with D.O. (r=-0.8672,t=4.3137).

B.O.D. is defined as the amount of oxygen required by the bacteria while stabilizing decomposable organic matter under aerobic conditions. A quantitative relationship exists between the amount of oxygen required to convert a definite amount of any organic matter to CO_2, water and NH_3. A negative relationship has been observed between B.O.D. and D.O. (r= -0.8983, t=16.0419).

TSSD shows strong positive significant correlation with Free CO_2 (r=0.9570, t=4.8282), turbidity (r=0.9976, t=4.9073), Na (r=0.9416, t=4.7985), K (r=0.9119, t=4.8296), NO_3^- (r=0.9144, t=4.8360), PO_4^{3-} (r=0.8646,t=4.8359), Cl^- (r=0.9978, t=4.8285) Ec (r=0.9858, t=4.3568), TDSD(r=0.9598, t=4.3405); and strong negative correlation with D.O. (r= -0.8836,t=4.7913).

Nitrate has significant positive correlation with Free CO_2 (r=0.8360, t=11.5501), turbidity (r=0.9275, t=4.5348), Na (r=0.9389, t=11.4740), K (r=0.9240, t=17.2300), PO_4^{3-} (r=0.9420,t=7.4921), Cl^- (r=0.9176, t=6.9749), Ec (r=0.8988, t=9.6720), TDSD(r=0.8106, t=6.0099) and TSSD (r=0.9144,t=4.8360).

Phosphate has strong positive significant correlation with Free CO_2 (r=0.8016, t=11.5637), turbidity (r=0.8738, t=4.5342), Na (r=0.9462, t=11.4867), K (r=0.9095, t=17.5958), NO_3^- (r=0.9420, t=7.4921), Cl^- (r=0.8647, t=6.9572), Ec (r=0.8263, t=9.6718), TDSD(r=0.8063, t=6.0095) and TSSD (r=0.8646,t=4.8359).

Calcium is essential for metabolic processes in all living organisms and as a structural or skeletal material in many. Magnesium serves mainly as a transition metal at the heart of reactive centre in the chlorophyll molecule and therefore plays a major role in algal photosynthesis. Calcium shows strong positive correlation with Mg (r=0.8472, t=30.1587).

TDSD has strong significant positive correlation with Free CO_2 (r=0.9589, t=5.9848), turbidity (r=0.9407, t=6.6467), Na (r=0.9116, t=5.8832), K (r=0.8303, t=5.9863), NO_3^- (r=0.8106, t=6.0099), PO_4^{3-} (r=0.8063,t=6.0095), Cl^- (r=0.9472, t=5.9924) Ec (r=0.9224, t=3.8769) and TSSD (r=0.9598,t=4.3405); and significant negative correlation with D.O. (r= -0.9226, t=5.8326).

Sodium has strong positive significant correlation with Free CO_2 (r=0.8639, t=10.9542), turbidity (r=0.9388, t=4.3344), K (r=0.9398, t=10.8089), Ec (r=0.9006, t=9. 4912), NO_3^- (r=0.9389, t=11.4740) PO_4^{3-}(r=0.9462, t=11.4867), Cl^-(r=0.9313,t=15.0362) TDSD(r=0.9116,t=5.8832) andTSSD r=0.9416,t=4.7985).

Potassium shows strong positive correlation with Free CO_2 (r=0.8392, t=5.7425), turbidity (r=0.9255, t=4.5020), Na (r=0.9389, t=11.4740), NO_3^- (r=0.9240, t=17.2300), PO_4^{3-}(r=0.9095,t=17.5985), Cl^- (r=0.9129, t=5.1718) Ec (r=0.8889, t=9.6231), TDSD(r=0.8303, t=5.9863) and TSSD (r=0.9119,t=4.8296).

The electrical conductivity of water depends upon the concentration of ions and its nutrient load. Ec is a measure of capacity of a substance or solution to conduct electricity. It is an excellent indicator of total dissolved solids which is a measure of salinity which affects taste of potable water. Ec shows significant positive correlation with Free CO_2 (r=0.9355, t=9.6397), Na (r=0.9006, t=9.4912), K (r=0.8889, t=9.6231), NO_3^- (r=0.8988, t=9.6720) and PO_4^{3-} (r=0.8263, t=9.6718). Significant negative correlation was found between Ec and D.O. (r=-0.8696, t=9.1163).

CONCLUSIONS

An appreciable significant positive correlation was found for Free CO_2 with Cl^- , TDSD, TSSD; turbidity with Cl^- ,Ec, TSSD; Cl^- with Ec, Free CO_2, TSSD ;Ec with Cl^- , TDSD, TSSD. A significant negative correlation was found for DO with Free CO_2, COD, turbidity.Cl^- , Ec, TDSD and TSSD. These correlation coefficient values can be used in calculating the other parameters of the particular area without analyzing with the help of equation of linearity. The values of correlation coefficients and their significance levels will help in selecting the proper treatments to minimize the contaminations of Ganga river water in Haridwar. There is an increasing awareness among the people to maintain the river water at their highest quality and purity levels and the present study may prove to be useful in achieving the same.

Table-1 : Correlation between different pairs of parameters

	Pairs of Parameters	Correlation	ItI
1	pH & DO	-0.6323	5.1313
2	pH & Free CO_2	0.5576	18.6413
3	pH & COD	-0.9111	0.6619
4	pH & BOD	0.5152	45.0367
5	pH & CO_3^{2-}	0.7290	52.3544
6	pH & HCO_3^-	0.0667	13.7060
7	pH & Total Alkalinity	0.2927	16.5281
8	pH & Hardness	-0.0801	30.0021
9	pH & Turbidity	0.5907	4.3792
10	pH & Ca	0.1995	17.2678
11	pH & Mg	0.0560	11.0476
12	pH & Na	0.3559	5.6751
13	pH & K	0.5447	52.9659
14	pH & NO_3^-	0.3997	108.5718
15	pH & PO_4^{3-}	0.2550	108.0239
16	pH & Cl^-	0.5886	2.1971
17	pH & SO_4^{2-}	0.7399	19.5212
18	pH & Ec	0.6199	9.3333
19	pH & TDSD	0.4813	-5.8910
20	pH & TSSD	0.5724	4.8050
21	DO & Free CO_2	-0.9405	11.0971
22	DO & COD	0.6909	3.0277
23	DO & BOD	-0.8983	16.0419
24	DO & CO_3^{2-}	-0.1508	23.7325
25	DO & HCO_3^-	0.0492	13.1421
26	DO & Total Alkalinity	-0.0067	15.6789
27	DO & Hardness	-0.3117	28.6404
28	DO & Turbidity	-0.8672	4.3137
29	DO & Ca	-0.4209	10.7133
30	DO & Mg	-0.4081	9.8437
31	DO & Na	-0.7360	3.5301
32	DO & K	-0.6913	18.3975

33	DO & NO_3^-	-0.6865	30.6975
34	DO & PO_4^{3-}	-0.6354	30.1846
35	DO & Cl^-	-0.8794	3.1959
36	DO & SO_4^{2-}	0.7399	13.0129
37	DO & Ec	-0.8696	9.1163
38	DO & TDSD	-0.9226	5.8326
39	DO & TSSD	-0.8836	4.7913
40	Free CO_2 & COD	-0.5679	6.2297
41	Free CO_2 & BOD	0.8397	2.6060
42	Free CO_2 & CO_3^-	0.1105	8.3073
43	Free CO_2 & HCO_3^-	-0.2779	14.6707
44	Free CO_2 & Total Alkalinity	-0.2239	17.5322
45	Free CO_2 & Hardness	0.2982	32.0410
46	Free CO_2 & Turbidity	0.9485	4.4937
47	Free CO_2 & Ca	0.4292	27.1496
48	Free CO_2 & Mg	0.3870	6.8397
49	Free CO_2 & Na	0.8639	10.9542
50	Free CO_2 & K	0.8392	5.7425
51	Free CO_2 & NO_3^-	0.8360	11.5501
52	Free CO_2 & PO_4^{3-}	0.8016	11.5637
53	Free CO_2 & Cl^-	0.9567	4.6610
54	Free CO_2 & SO_4^{2-}	0.7720	29.4291
55	Free CO_2 & Ec	0.9355	9.6397
56	Free CO_2 & TDSD	0.9589	5.9848
57	Free CO_2 & TSSD	0.9570	4.8282
58	COD & BOD	-0.5544	7.9033
59	COD & CO_3^{2-}	-0.5805	10.3923
60	COD & HCO_3^-	-0.2627	12.7487
61	COD & Total Alkalinity	-0.4203	14.7035
62	COD & Hardness	-0.0290	29.3280
63	COD & Turbidity	-0.5533	4.3355
64	COD & Ca	-0.1223	10.7386
65	COD & Mg	-0.0384	4.6285
66	COD & Na	-0.3420	4.2194
67	COD & K	-0.4555	8.9239
68	COD & NO_3-	-0.2962	13.2801
69	COD & PO_4^{3-}	-0.2077	13.1815
70	COD & Cl^-	-0.5546	1.7229
71	COD & SO_4^{2-}	-0.6668	11.7833
72	COD & Ec	-0.5648	9.1445
73	COD & TDSD	-0.5510	5.8492
74	COD & TSSD	-0.5518	4.7957

75	BOD & CO_3^{2-}	0.1600	10.4000
76	BOD & HCO_3^-	0.0227	15.2001
77	BOD & Total Alkalinity	0.0978	18.2080
78	BOD & Hardness	0.3956	31.9646
79	BOD & Turbidity	0.6667	4.4871
80	BOD & Ca	0.4593	27.4980
81	BOD & Mg	0.3987	11.2826
82	BOD & Na	0.5134	9.8583
83	BOD & K	0.4914	4.5222
84	BOD & NO_3^-	0.5004	20.9898
85	BOD & PO_4^{3-}	0.4593	20.9708
86	BOD & Cl^-	0.6940	4.2168
87	BOD & SO_4^{2-}	0.7231	26.3684
88	BOD & Ec	0.6933	9.5860
89	BOD & TDSD	0.7602	5.9765
90	BOD & TSSD	0.6882	4.8267
91	CO_3^{2-} & HCO_3^-	-0.1796	15.6633
92	CO_3^{2-} & Total Alkalinity	0.1167	18.9830
93	CO_3^{2-} & Hardness	-0.1465	31.8394
94	CO_3^{2-} & Turbidity	0.1322	4.5253
95	CO_3^{2-} & Ca	-0.0183	27.5110
96	CO_3^{2-} & Mg	-0.2214	14.1237
97	CO_3^{2-} & Na	-0.1241	10.7353
98	CO_3^{2-} & K	0.1388	7.5275
99	CO_3^{2-} & NO_3^-	0.0089	3.0268
100	CO_3^{2-} & PO_4^{3-}	-0.1589	2.7227
101	CO_3^{2-} & Cl^-	0.1260	6.3226
102	CO_3^{2-} & SO_4^{2-}	0.5060	28.4912
103	CO_3^{2-} & Ec	0.1665	9.6577
104	CO_3^{2-} & TDSD	-0.0487	6.0000
105	CO_3^{2-} & TSSD	0.0932	4.8340
106	HCO_3^- & Total Alkalinity	0.9024	1.3515
107	HCO_3^- & Hardness	0.0117	12.2596
108	HCO_3^- & Turbidity	-0.3591	3.3446
109	HCO_3^- & Ca	-0.0384	10.3830
110	HCO_3^- & Mg	0.0005	14.4404
111	HCO_3^- & Na	-0.3879	9.5040
112	HCO_3^- & K	-0.4224	15.1229
113	HCO_3^- & NO_3^-	-0.4882	15.9893
114	HCO_3^- & PO_4^{3-}	-0.4484	15.9626
115	HCO_3^- & Cl^-	-0.3388	12.7787

116	HCO_3^- & SO_4^{2-}	-0.1291	7.9839
117	HCO_3^- & Ec	-0.3167	6.8057
118	HCO_3^- & TDSD	-0.1858	5.1103
119	HCO_3^- & TSSD	-0.3293	4.5954
120	Total Alkalinity & Hardness	-0.0172	12.4338
121	Total Alkalinity & Turbidity	-0.2816	3.3323
122	Total Alkalinity & Ca	-0.0216	12.5610
123	Total Alkalinity & Mg	-0.0309	17.2179
124	Total Alkalinity & Na	-0.3993	11.0867
125	Total Alkalinity & K	-0.3812	18.0341
126	Total Alkalinity & NO_3^-	-0.4502	19.0545
127	Total Alkalinity & PO_4^{3-}	-0.4845	19.0171
128	Total Alkalinity & Cl^-	-0.2562	15.3054
129	Total Alkalinity & SO_4^{2-}	0.0243	10.0839
130	Total Alkalinity & Ec	-0.1990	6.8758
131	Total Alkalinity & TDSD	-0.1723	5.0910
132	Total Alkalinity & TSSD	-0.2602	4.5940
133	Hardness & Turbidity	0.2033	2.2516
134	Hardness & Ca	0.3426	28.4022
135	Hardness & Mg	0.1060	30.9633
136	Hardness & Na	0.2234	28.3123
137	Hardness & K	0.1537	31.8356
138	Hardness & NO_3^-	0.1966	32.2911
139	Hardness & PO_4^{3-}	0.2468	32.2931
140	Hardness & Cl^-	0.2145	31.2862
141	Hardness & SO_4^{2-}	0.3183	26.4709
142	Hardness & Ec	0.2118	4.5966
143	Hardness & TDSD	0.2935	4.3044
144	Hardness & TSSD	0.2189	4.3887
145	Turbidity & Ca	0.3808	4.1839
146	Turbidity & Mg	0.3264	4.4361
147	Turbidity & Na	0.9388	4.3344
148	Turbidity & K	0.9255	4.5020
149	Turbidity & NO_3^-	0.9275	4.5348
150	Turbidity & PO_4^{3-}	0.8738	4.5342
151	Turbidity & Cl^-	0.9982	4.4911
152	Turbidity & SO_4^{2-}	0.7334	4.0795
153	Turbidity & Ec	0.9870	0.3815
154	Turbidity & TDSD	0.9407	6.6467
155	Turbidity & TSSD	0.9976	4.9073
156	Ca & Mg	0.8472	30.1587
157	Ca & Na	0.3978	2.3958
158	Ca & K	0.3660	27.8670
159	Ca & NO_3^-	0.4709	29.8932

160	Ca & PO_4^{3-}	0.3452	29.8780
161	Ca & Cl^-	0.3832	14.3796
162	Ca & SO_4^{2-}	0.5321	8.6614
163	Ca & Ec	0.3812	8.9334
164	Ca & TDSD	0.3773	5.7466
165	Ca & TSSD	0.3890	4.7667
166	Mg & Na	0.3536	7.9378
167	Mg & K	0.2329	12.7752
168	Mg & NO_3^-	0.3499	22.3661
169	Mg & PO_4^{3-}	0.2492	22.2245
170	Mg & Cl^-	0.3347	1.0291
171	Mg & SO_4^{2-}	0.2942	22.1895
172	Mg & Ec	0.3261	9.4670
173	Mg & TDSD	0.3889	5.9374
174	Mg & TSSD	0.3503	4.8166
175	Na & K	0.9398	10.8089
176	Na & NO_3^-	0.9389	11.4740
177	Na & PO_4^{3-}	0.9462	11.4867
178	Na & Cl^-	0.9313	15.0362
179	Na & SO_4^{2-}	0.5555	8.7911
180	Na & Ec	0.9006	9.4912
181	Na & TDSD	0.9116	5.8832
182	Na & TSSD	0.9416	4.7985
183	K & NO_3^-	0.9240	17.2300
184	K & PO_4^{3-}	0.9095	17.5958
185	K & Cl^-	0.9129	5.1718
186	K & SO_4^{2-}	0.6805	26.7978
187	K & Ec	0.8889	9.6231
188	K & TDSD	0.8303	5.9863
189	K & TSSD	0.9119	4.8296
190	NO_3^- & PO_4^{3-}	0.9420	7.4921
191	NO_3^- & Cl^-	0.9176	6.9749
192	NO_3^- & SO_4^{2-}	0.6667	26.8184
193	NO_3^- & Ec	0.8988	9.6720
194	NO_3^- & TDSD	0.8106	6.0099
195	NO_3^- & TSSD	0.9144	4.8360
196	PO_4^{3-} & Cl^-	0.8647	6.9572
197	PO_4^{3-} & SO_4^{2-}	0.5451	26.8407
198	PO_4^{3-} & Ec	0.8263	9.6718
199	PO_4^{3-} & TDSD	0.8063	6.0095
200	PO_4^{3-} & TSSD	0.8646	4.8359
201	Cl^- & SO_4^{2-}	0.7427	29.3693

202	Cl^- & Ec	0.9921	9.7788
203	Cl^- & TDSD	0.9472	5.9924
204	Cl^- & TSSD	0.9978	4.8285
205	SO_4^{2-} & Ec	0.7541	8.8053
206	SO_4^{2-} & TDSD	0.6334	5.6700
207	SO_4^{2-} & TSSD	0.7163	4.7469
208	Ec & TDSD	0.9224	3.8769
209	Ec & TSSD	0.9858	4.3568
210	TDSD & TSSD	0.9598	4.3405

$t_{10\ ,\ 0.05} > 2.23$ is significant

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