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Physico-chemical Characterization of Water Quality of Eutrophied Surface Water Body and Ground Water around the Field Crop Research Station, Burdwan, West Bengal

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Abstract: A study on water quality of eutrophied surface water body of Kalna farm as well as ground water quality of the area was done to investigate the level of pollution and contamination that have occurred in these two sources of fresh water systems. Several physicochemical parameters viz., pH, temperature, TDS, turbidity, nitrate nitrogen, phosphate, sodium and potassium content were measured in groundwater samples. For surface water analysis, DO, BOD and COD were mediated to evaluate the pollution load of the surface water bodies surrounding the Kalna farm. Results indicate that all the surface water body was nutrient enriched in terms of sodium (14.73-27.98), potassium (6.59-10.31 mg/L) and phosphate content (0.52-0.73 mg/L) in the water whereas ground water contains more salt content than its surface water counterpart. Surface water body was found to be alkaline in nature (8.09-8.68) whereas ground water was found to be little acidic to neutral range (6.52-7.89). COD values (142-224 mg/L) were found to be higher than BOD values (2.42-5.64 mg/L) indicating presence of higher load of non-biodegradable wastes in the surface water bodies around Kalna farm.

Key words: Surface water body, water quality, crop field, eutrophication.

Introduction

Water quality monitoring has one of the highest priorities in environmental protection policy (Simeonov et al., 2002). The main objective is to control and minimize the incidence of pollution oriented problems, and to provide water appropriate quality to serve various purposes such as drinking water supply, irrigation water, etc.

The quality of water is identified in terms of its physical, chemical and biological parameters (Sargaonkar and Deshpande, 2003). The particular problem in the case of water quality monitoring is the complexity associated with analyzing the large number of measured variables (Saffran, 2001).

Water eutrophication is one of the most challenging environmental problem in the world. The increasing severity of water eutrophication has been brought to the attention of both the governments and public in recent years (Xiao-e Yang et al., 2008). The mechanism of water eutrophication is not fully understood, but excessive nutrient loading into surface water system is considered to be one of the major factors (Fang, 2004; Tong, 2002. The nutrient level of many lakes and rivers have increased

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dramatically over the past 50 years in response to increased discharge of domestic wastes and non-point pollution from agricultural practices and urban development (Mainstone and Parr, 2000). Increasing deterioration of water quality since last few years due to human waste, excessive use of fertilizers and pesticides in agriculture and unplanned industrialization is a serious matter to be studied for better environmental conservation. According to a reported work (Jha, 2001) use of agrochemicals have resulted in increased productivity and has caused the imbalances in nature. On the basis of literature survey, the present work was undertaken to have a comparative account of the water quality of eutrophied surface water body and ground water in and around the field crop research station, Burdwan, West Bengal.

Materials and Methods

Study Area

The study was carried out at different places of Field Crop Research Station, Kalna Road, Burdwan District, West Bengal situated almost 10 km away from Burdwan town, 23°14′ North (latitude) and 87°53′ East (longitude) which is under Department of Agriculture, Govt of West Bengal, India. Water samples (surface water body and groundwater samples) were collected from six different locations of Field Crop Research Station.

The main morphometric factors that influence the water quality in surface water bodies include area, depth etc. In Kalna farm all the three sampling spots are shallower in depth and sources of water include precipitation during monsoon periods and excess agricultural run-off. During the monsoon periods the water level rises and remains lower in rest of the season. The people use most of the area for agricultural practices by extracting water from those water bodies. Regarding the groundwater sampling three tubewells of about 200 ft, 120 ft and 80 ft depth respectively were selected which are situated adjacent to the Kalna farm. These tubewells are used for domestic purposes by the local people (Figures 1 and 2).

Various parameters viz., temp, pH, turbidity, dissolved oxygen (DO), biochemical oxygen demand (BOD), chemical oxygen demand (COD), total alkalinity, hardness, ammonia nitrogen, nitrate nitrogen, sodium, potassium, phosphate, sulphate, chloride, fluoride, total dissolved solids (TDS), electrical conductivity (EC), and primary productivity, of water were analysed by using standard methodologies [APHA (American Public Health Association), 1998]. To analyze the tabulated data of

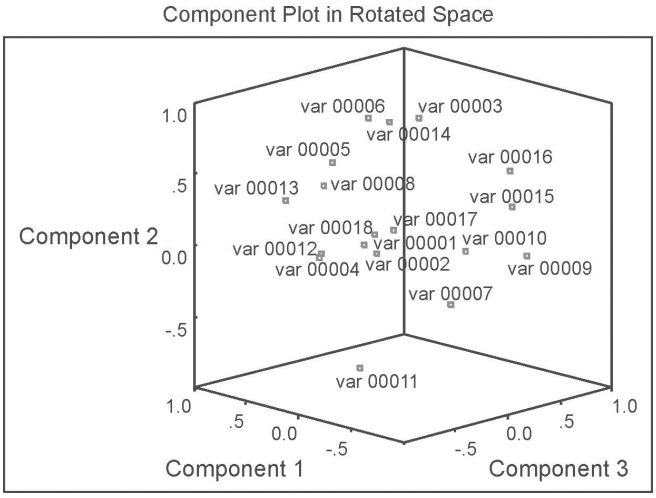

Figure 1: The loading plot of factor scores for water quality of surface water body around Kalna farm.

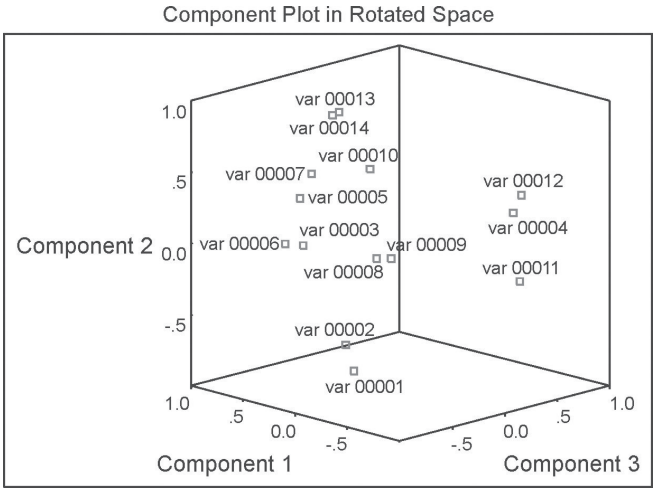

Figure 2: The loading plot of factor scores for water quality of ground water around Kalna farm.

observed experiment and laboratory analysis in different aspects, the methods adopted by Coehran and Cox (1959), Fisher (1960), Panse et al. (1967) and Gomez et al. (1984) were followed. From the factor analysis correlation matrix of variables was generated and factors extracted by the centroid method, rotated by varimax rotation (Ahmed et. al., 2005). Statistical calculations were done through SPSS-10(2000) package.

Results and Discussion

From the physico-chemical analysis of water samples (Tables 1 and 2), it was found that water temperature is the most important factor which affects the chemical and biological reactions in water. Measured temperature showed variation as per the seasonal variation. The

Table 1: Physico-chemical analysis of water of eutrophied surface water body, Field Crop Research Station, Kalna Farm, Burdwan

Parameters	*Seasons*								
	Pre-winter			*Winter*			*Post-winter*		
	S1	*S2*	*S3*	*S1*	*S2*	*S3*	*S1*	*S2*	*S3*
Temperature (°C)	28	27	30.1	21.2	20.8	20.7	27.1	26.9	26.0
pH	8.68	8.51	8.39	8.12	8.6	8.32	8.45	8.09	8.16
Turbidity (NTU)	48	38	42	42	27	47	39	31	51
DO (mg/L)	8.86	7.25	6.85	9.26	8.86	7.25	8.05	7.65	6 04
BOD (mg/L)	4.84	3.22	3.62	5.64	3.62	4.03	4.83	2.42	2.82
COD (mg/L)	224	142	224	192	160	192	192	160	192
Alkalinity (mg/L)	12	16	12	16	16	16	16	16	16
Hardness (mg/L as $CaCO_3$)	82	58	44	88	60	58	90	58	82
Ammonical Nitrogen (mg/L as $CaCO_3$)	0.59	0.88	0.82	0.5	0.63	0.97	0.52	0.79	0.87
Nitrate nitrogen (mg/L)	0.21	0.2	0.27	0.35	0.46	0.49	0.34	0.33	0.18
Sodium (mg/L)	20.38	25.12	14.73	22.14	27.98	16.13	22.0	25.93	15.99
Potassium (mg/L)	9.49	9.32	6.32	10.31	8.53	7.41	9.33	7.23	6.59
Phosphate (mg/L)	0.7	0.61	0.73	0.72	0.63	0.52	0.63	0.6	0.7
Sulphate (mg/L)	30.0	14.78	35.56	24.12	13.33	26.66	34.56	16.11	38.33
Chloride (mg/L)	12.5	15.6	21.73	10.32	15.0	22.9	11.31	13.94	20.99
Fluoride(mg/L)	0.06	0.02	ND	0.11	ND	0.38	0.09	0.08	0.12
TDS (mg/L)	446	503	391	412	227	405	591	489	421
Conductivity (µS)	0.78	0.8	0.53	0.69	0.39	0.62	0.99	0.8	0.68

Table 2: Physico-chemical analysis of ground water in and around Field Crop Research Station, Kalna Farm, Burdwan

Parameters	*Seasons*								
	Pre-winter			*Winter*			*Post-winter*		
	S1	*S2*	*S3*	*S1*	*S2*	*S3*	*S1*	*S2*	*S3*
Temperature (°C)	29	28.3	29.6	22.1	21.8	22.3	27.6	28.0	27.1
pH	7.08	7.26	7.16	6.97	6.52	7.02	7.3	7.07	7.89
Turbidity (NTU)	41	14	46	45	02	20	42	07	34
Alkalinity (mg/L)	20	20	20	24	24	20	20	28	28
Hardness (mg/L as $CaCO_3$)	132	76	92	136	104	106	130	92	148
Nitrate nitrogen (mg/L)	3.66	3.49	3.31	4.09	4.24	0.39	3.67	3.59	3.9
Sodium (mg/L)	19.18	11.24	13.13	20.12	12.19	14.67	19.23	11.92	13.99
Potassium (mg/L)	2.42	2.14	2.61	3.12	2.52	3.01	9.33	7.23	2.62
Phosphate (mg/L)	0.06	0.04	0.09	0.08	0.05	0.12	0.06	0.03	0.17
Sulphate (mg/L)	17.22	9.11	15.56	25.11	10.56	21.11	19.99	15.24	14.44
Chloride (mg/L)	11	31.32	20.14	13.72	26.98	31.87	12.11	37.29	20.99
Fluoride (mg/L)	0.23	0.29	0.29	0.21	0.39	0.37	0.2	0.25	0.16
TDS (mg/L)	320	192	197	530	444	236	310	234	265
Conductivity (µS)	0.53	0.39	0.39	0.81	0.72	0.4	0.59	0.39	0.44

temperature of the water samples of both underground and surface water body remains lower in the winter season than that in the pre-winter and post-winter seasons. The surface water body was slightly alkaline in nature which indicates towards the anthropogenic influence in terms of on-farm inputs as well as due to the buffering capacity of water.

Turbidity generates in water due to dissolved salt content, biological pollutants and high plankton population. Since the surface water body is eutrophied, the turbidity values were more than that of the groundwater samples. In the present study, generally lower alkalinity values were due to dilution effect as reported by Patil et al. (2004). From the experimental results it was found that groundwater samples showed higher hardness than that of surface water in the present study. This may be due to natural accumulation of salt in contact with soil and nature of geological formation of the aquifer as reported by some workers (Mueller et al., 1995).

The dissolved oxygen and biological productivity are indirect indicators of waste water pollution. Dissolved oxygen has inverse relationship with temperature. As the temperature was slightly lower in pre-winter, winter, and post-winter, the dissolved oxygen content was found to be higher in surface water body samples. Value of high dissolved oxygen content was supported by lower BOD value. Chemical oxygen demand (COD) test is useful with respect to toxic conditions and presence of biochemical resistant substances.

In the present study overall COD values are higher than that of BOD values indicating minimum organic load compared to that of higher inorganic load (Table 3). This is probably due to excessive use of chemical fertilizers which may have found their way to the surface water body as agricultural run-off and thereby increasing the inorganic load. Presence of ammoniacal nitrogen in the eutrophied surface water body may be probably due to run off from agricultural fields containing ammonia plus fertilizers viz., DAP. The nitrate nitrogen is one of the most oxidisable forms of nitrogen and is essential plant nutrient. Due to its higher mobility in water and utilization by plants, it is also regulated by waste loading, through agricultural runoff (Indian Specification for drinking water: IS-10500). Groundwater nitrate nitrogen values are very high as compared to the surface water body. This result corroborates with the findings of some workers (Kler et al., 2002), who similarly reported that ground water has higher nitrate content than surface water.

Both the sodium and potassium content of surface water bodies were higher with respect to the groundwater samples which may be a cause of future threat. High concentration of sodium and potassium can reduce the suitability of water for irrigation and can alter the soil chemistry absorbtion properties as was reported by Mueller et al., 1995) which is very much harmful for agriculture. Phosphate content lies well below the acceptable range in case of surface water body. This may be due to lower doses of application of phosphate

Table 3: Descriptive statistics of water quality of ground water around Kalna farm

Variable	*Unit*	*No. of obs*	*Range*	*Minimum*	*Maximum*	*Mean*	*SE*	*SD*	*V*
Temperature	(°C)	9	7.80	21.80	29.60	26.20	1.06	3.18	10.15
pH		9	1.37	6.52	7.89	7.14	0.12	0.36	0.13
Turbidity	(NTU)	9	44	2.00	46.00	27.88	5.76	17.28	298.86
Alkalinity	(mg/L)	9	2000	20.00	2020.00	223.20	199.64	631.34	398591.3
Hardness	(mg/L as $CaCO_3$)	9	72	76.00	148.00	112.88	8.15	24.45	598.111
Nitrate nitrogen	(mg/L)	9	3.85	0.39	4.24	3.37	0.38	1.15	1.33
Sodium	(mg/L)	9	8.88	11.24	20.12	15.07	1.16	3.49	12.20
Potassium	(mg/L)	9	7.19	2.14	9.33	3.88	0.85	2.56	6.55
Phosphate	(mg/L)	9	0.14	0.03	0.17	0.077	0.014	0.044	0.001
Sulphate	(mg/L)	9	16.0	9.11	25.11	16.48	1.68	5.05	25.58
Chloride	(mg/L)	9	26.29	11.00	37.29	22.82	3.18	9.54	91.08
Fluoride	(mg/L)	9	0.23	0.16	0.39	0.26	0.025	0.077	0.005
TDS	(mg/L)	9	338	192.00	530.00	303.11	38.36	115.10	13249.86
Conductivity	(µS)	9	0.42	0.39	0.81	0.52	0.052	0.15	0.02

SE = standard error; SD = standard deviation; V = variance.

fertilizer in the agricultural field. But there is a probability of causing further eutrophication in the surface water body due to higher nutrient load as well as the contamination of the groundwater aquifer through subsurface leaching. Chloride content in the present study showed much variation in both surface water bodies and groundwater samples. The chloride content was found to be higher in the ground water in comparison to surface water but well within the acceptable range of 1 mg/L as prescribed by IS: 10500 (Indian Specification for drinking water). The conductivity value for both ground water and surface water was found to be lower whereas TDS value was found to be higher which may be probably due to addition of sediments in the receiving water bodies in terms of agricultural runoff.

Regarding surface water quality the factor analysis (Tables 4 and 5) (Figure 1) generated five significant factors which explained % of total variance in the data sets. The following factors were indicated considering the hydrochemical aspects of water.

Factor 1: DO, BOD, K
Factor 2: Turbidity, COD, Sulphate
Factor 3: Nitrate nitrogen, fluoride
Factor 4: TDS, Conductivity, Temperature
Factor 5: pH

Factor 1 (F1) explained 26.76% of the variance. These factors have a high positive loading of 0.88, 0.85 and 0.86 indicating towards the different domestic sources of surface water pollution. Factor 2 (F2) explained 24.62% of the variance. These factors have a high positive loading of 0.88, 0.89 and 0.90 indicating towards the surface runoff sources. Factor 3 (F3) explained 16.14% of the variance. These factors have a high positive loading of 0.73 and 0.86 indicating towards the various nitrogenous sources such as chemicals, soaps, detergents of surface water pollution. Factor (F4) explained 15.45% of the variance. These factors have a high positive loading of 0.96, 0.95 and 0.500. Factor 5 (F5) explained 0.86% of the variance among all the data sets.

Regarding groundwater quality the factor analysis generated four significant factors (Table 6) which explained % of total variance in the data sets. The following factors were indicated considering the hydrochemical aspects of water.

Factor 1: Turbidity, Hardness, Na, Sulphate
Factor 2: TDS, Conductivity
Factor 3: Alkalinity
Factor 4: pH

Factor 1 (F1) explained 34.29% of the variance. These factors have a high positive loading of 0.86, 0.86, 0.88 and 0.75 indicating towards the higher leachability of

Table 4: Descriptive statistics of water quality of surface water body around Kalna farm

Variable	*Unit*	*No. of obs*	*Range*	*Minimum*	*Maximum*	*Mean*	*SE*	*SD*	*V*
Temperature	(°C)	9	9.40	20.70	30.10	25.31	1.16	3.49	12.22
pH		9	0.59	8.09	8.68	8.36	0.07	0.21	0.04
Turbidity	(NTU)	9	24	27	51	40.55	2.62	7.85	61.77
DO	(mg/L)	9	3.22	6.04	9.26	7.78	0.35	1.06	1.13
BOD	(mg/L)	9	3.22	2.42	5.64	3.89	0.34	1.04	1.09
COD	(mg/L)	9	82	142	224	186.44	9.36	28.10	789.77
Alkalinity	(mg/L)	9	4	12	16	15.11	0.58	1.76	3.11
Hardness	(mg/L as $CaCO_3$)	9	46	44	90	68.88	5.53	16.61	276.11
Ammonical nitrogen	(mg/L as $CaCO_3$)	9	.47	0.50	0.97	0.73	0.05	.17	0.02
Nitrate nitrogen	(mg/L)	9	.31	0.18	0.49	0.31	0.03	.11	0.01
Sodium	(mg/L)	9	13.25	14.73	27.98	21.15	1.58	4.75	22.57
Potassium	(mg/L)	9	3.99	6.32	10.31	8.28	0.47	1.43	2.04
Phosphate	(mg/L)	9	0.21	.52	0.73	0.64	0.02	0.06	0.004
Sulphate	(mg/L)	9	25	13.33	38.33	25.93	3.16	9.49	90.10
Chloride	(mg/L)	9	12.58	10.32	22.90	16.03	1.56	4.70	22.15
Fluoride	(mg/L)	9	0.38	0	0.38	0.009	0.03	0.11	0.01
TDS	(mg/L)	9	364	227	591	431.66	33.06	99.19	9840.25
Conductivity	(μS)	9	0.60	0.39	0.99	0.69	0.05	0.17	0.03

SE = standard error; SD = standard deviation; V = variance.

Table 5: Factor loading matrix and total variance explained for water quality of surface water body around Kalna farm

Variable	*Factor*				
	1	*2*	*3*	*4*	*5*
Temperature	–0.308	0.191	–0.689	0.500	0.329
pH	0.197	–0.086	–0.046	–0.043	0.866
Turbidity	–0.077	0.886	0.064	0.233	0.087
DO	0.880	–0.267	0.084	–0.223	0.222
BOD	0.854	0.385	0.182	–0.018	0.155
COD	0.159	0.896	–0.179	–0.113	0.252
Alkalinity	0.026	–0.504	0.472	0.128	–0.657
Hardness	0.729	0.286	–0.032	0.350	–0.372
Ammonical nitrogen	–0.930	0.049	0.255	0.023	–0.022
Nitrate nitrogen	0.147	–0.217	0.739	–0.462	0.009
Sodium	0.163	–0.922	–0.045	0.015	0.029
Potassium	0.868	–0.239	0.088	0.224	0.132
Phosphate	0.305	0.406	–0.819	–0.210	–0.098
Sulphate	0.057	0.902	–0.195	0.182	–0.093
Chloride	–0.840	0.390	0.208	–0.275	0.186
Fluoride	–0.145	0.382	0.868	0.08	–0.210
TDS	0.054	0.099	–0.037	0.965	–0.06
Conductivity	0.244	0.025	–0.023	0.958	–0.081
% total variance	26.769	24.621	16.146	15.454	83.201
Cumulative %	26.769	51.600	67.746	83.201	92.447

Table 6: Factor loading matrix and total variance explained for water quality of groundwater body around Kalna farm

Variable	*Factor*			
	1	*2*	*3*	*4*
Temperature	0.048	–0.824	–0.395	–0.255
pH	0.429	–0.778	–0.094	0.314
Turbidity	0.868	–0.169	–0.057	0.018
Alkalinity	–0.09	0.047	0.979	0.129
Hardness	0.864	0.161	–0.087	0.275
Nitrate nitrogen	0.125	0.155	–0.970	–0.035
Sodium	0.886	0.312	0.039	–0.023
Potassium	0.225	0.154	0.034	–0.798
Phosphate	0.432	–0.254	0.339	0.747
Sulphate	0.753	0.282	0.469	–0.221
Chloride	–0.839	–0.164	0.301	0.004
Fluoride	–0.739	0.396	0.417	0.041
TDS	0.349	0.894	–0.235	0.056
Conductivity	0.348	0.878	–0.289	–0.023
% total variance	34.294	24.160	20.096	11.139
Cumulative %	34.294	58.454	78.550	89.689

soluble salts in the ground water. Factor 2 (F2) explained 24.16% of the variance of all data sets. These factors have a high positive loading of 0.89 and 0.87. Factor 3 (F3) explained 20.09% of the variance. These factors have a high positive loading of 0.97 indicating towards the various surface runoff sources in terms of chemical fertilizers, pesticides etc. leading towards subsequent eutrophication and alkaline nature of the ground water. Factor (F4) explained 11.13% of the variance of all the data samples of ground water. These factors have a lower positive loading of 0.31 and 0.27.

Conclusion

From our present study it can be concluded that agricultural runoff from the fields is probably the reason for nutrient enrichment of the surface waterbody in the Kalna farm. The groundwater quality is more or less harmless in terms of drinking or irrigation purpose. Regarding management of such problems in the adjacent waterbodies of agricultural field, the method of application of chemical fertilizers should be reduced properly in order to check the nutrient flow from the nearby agricultural land to the receiving waterbodies of Kalna farm, Burdwan District.

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