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A mathematical modeling with respect to DO for environmentally contaminated drinking water sources of Sagar city (M.P.), India: A case study

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Abstract. Dissolved oxygen is one of the most important parameters in aquatic systems. Oxygen gets into water by diffusion from the surrounding air, by aeration (rapid movement) and as a waste product of photosynthesis. Dissolved oxygen analysis measures the amount of gaseous oxygen (O_2) dissolved in an aqueous solution. DO is an absolute requirement for the metabolism of aerobic organisms and also influences inorganic chemical reactions. Therefore, knowledge of the solubility and interactions with other physico-chemical parameters is essential to interpreting both biological and chemical processes within water bodies. Water samples have been analyzed of 19 ground/municipal/reservoir sample collection places from March 2009 to February 2010 for their 15 physico - chemical parameters. Water temperature, colour, conductivity, turbidity, total solids, total dissolved solids, pH, alkalinity, chlorides, total hardness, dissolved oxygen, biological oxygen demand, chemical oxygen demand; iron and fluoride were analysed. From the results it is cleared that some parameters were beyond the limit of water quality standards led by WHO. The results thus obtained have been discussed in light of role and effect on DO, and influences of other parameter on DO. Keeping in view the composition of this standard resource an analysis of water samples of this city have been performed so as to derived a model for pollution and contamination with respect to DO and search their source as typical man made activities.

Keywords: ground water, physico-chemical parameters, mathematical model, multiregression analysis

1. Introduction

Good drinking water quality is essential for the well-being of all people. Unfortunately in many countries around the world, some drinking water supplies have become contaminated, which has affected the health and economic status of the populations. Stop dam are the main inland water resources for domestic, industrial and irrigation purposes. In Sagar city drinking water supplied by Municipal Corporation from Rajghat dam. The natural water analyses for physical and chemical properties are very important for public health studies [1]. In this study, for quality assessment of Ground/municipal water samples following physico-chemical parameters viz. water temperature, Colour, conductivity, Turbidity, Total solids, Total dissolved solids, pH, alkalinity, chlorides, Total hardness, Dissolved oxygen, Biological oxygen demand, chemical oxygen demand; Iron and fluoride were determined by using standard analytical methods [2]. The statistical tool such as Pearson correlation, regression and multiple regressions has been very important method to determine interrelationship among water quality parameters. It is also helpful to determine dominant parameter [3].

2. Experimental

Water samples were collected from in and around the Sagar city. Each water sample was taken every month during March 2009 to February 2010 (pre monsoon – March to June, monsoon – July to October and post monsoon – November to February). The samples were collected in prewashed (with detergent, diluted HNO_3 and doubly de-ionized distilled water respectively) clean polyethylene bottles without any air bubbles and

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tightly sealed after collection and labeled in the field.

The temperatures of the samples were measured in the field on the spot at the time of sample collection. The samples were immediately analysed in the chemistry lab to minimize physico-chemical changes. The error due to time has been omitted for the present study. Determinations of the major ions, physical and chemical properties of the water samples were performed on the same day of sampling [4]. Each sample was analysis for, using procedures outline in the standard methods for the examination of water and wastewater APHA [5].

All the chemicals used were of AR grade. Analysis was carried out for various water quality parameters such as: water temperature measured by using mercury-glass thermometer, colour by Pt-Co scale method, pH, conductivity and turbidity measured by using standard pH meter, conductivity meter and turbidity tube respectively, total solids (TS) by gravimetric method, total dissolved solids (TDS) by digital conductivity meter, chloride content by argentometric method. Total hardness was determined by complexometric titration using EDTA titrimetric method, alkalinity by titrimetric method, dissolved oxygen by Winkler method. Biological oxygen demand (BOD) has been measured using standard methods, chemical oxygen demand (COD) by open reflux method, iron and fluoride by colorimetric analysis. The value of the physico-chemical parameters were compared with desirable/ permissible limit of IS: 10500 drinking water specification [6]. The statistical analysis such as Pearson correlation matrix and curve estimation has been performed using by SPSS 11.0 [7] and linear interrelationship and multiple Regression analysis calculated by Winks SDA 6.0.5, Statistical Software [8].

3. Results and Discussions

Some of the obtained results are presented in **Tables 1-8**.

Table 1. Comparison of physicochemical parameters of ground/municipal water with standard values (IS: 10500), at pre-monsoon (March 2009 to June 2009)

Parameters	March	April	May	June	Mean	IS:10500 (Desirable limit)	IS:10500 (Permissible limit)
Water Temp., ^{O}C	23	25	27	29	26	-	-
Colour (Hz.u.)	20	21	23	19	20.75	5	25
Conductivity,(mS/cm)	.692	.708	.719	.677	0.698	-	-
Turbidity (N.T.U.)	17	20	23	23	20.75	5	10
Total solids (mg/L)	486.32	491.76	504.85	486.46	492.34	-	-
TDS (mg/L)	476.24	485.10	492.56	463.91	479.45	500	2000
pH	8.22	8.4	9.4	9.5	8.88	6.5-8.5	No Relaxation
Alkalinity, (mg/L)	285	279	315	327	301.5	200	600
Chloride, (mg/L)	55.67	51.08	72.45	64.90	61.02	250	1000
TH, (mg/L)	269.38	250.04	279.25	270.82	267.37	300	600
DO, (mg/L)	7.3	6.7	6.4	6.3	6.67	-	-
BOD, (mg/L)	8.43	9.11	13.54	11.21	10.57	-	-
COD, (mg/L)	18.46	20.14	24.10	19.23	20.48	-	-
Iron, (mg/L)	.97	1.10	1.23	1.42	1.18	0.3	1
Fluoride, (mg/L)	1.13	1.84	1.75	2.12	1.71	1	1.5

Table 2. Pearson correlation matrix for different parameters in the waters samples of ground/municipal water, Sagar district at pre-monsoon (March 2009 to June 2009)

Part- I

Parameters	**TDS**	**Temp.**	**Colour**	**Conductivity**	**Turbidity**	**Total Solids**	**pH**	**Alk.**
TDS	1.000	-.309	.958	0.976	.022	.843	-.139	-.343
Water Temp.	-.309	1.000	-.076	-.307	.944	.200	.942	.903
Colour	.958	-.076	1.000	.959	.255	.959	.135	-.063
Conductivity	0.976	-.307	.959	1.000	.024	.844	-.137	-.340
Turbidity	.022	.944	.255	.024	1.000	.505	.944	.834
Total solids	.843	.200	.959	.844	.505	1.000	.410	.217
pH	-.139	.942	.135	-.137	.944	.410	1.000	.965
Alkalinity	-.343	.903	-.063	-.340	.834	.217	.965	1.000
Chloride	.143	.664	.418	.145	.754	.634	.877	.852
TH	-.005	.351	.235	-.003	.375	.391	.623	.705
DO	.021	-.947	-.184	.019	-.986	-.426	-.893	-.772
BOD	.324	.715	.576	.326	.868	.782	.884	.777
COD	.771	.323	.916	.772	.609	.992	.522	.333
Iron	-.402	.995	-.173	-.400	.907	.105	.920	.903
Fluoride	-.211	.890	-.075	-.209	.859	.138	.716	.608

Part- II

Parameters	**Chloride**	**TH**	**DO**	**BOD**	**COD**	**Iron**	**Fluoride**
Water Temp.	.143	-.005	.021	.324	.771	-.402	-.211
Colour	.664	.351	-.947	.715	.323	.995	.890
Conductivity	.418	.235	-.184	.576	.916	-.173	-.075
Turbidity	.145	-.003	.019	.326	.772	-.400	-.209
Total solids	.754	.375	-.986	.868	.609	.907	.859
TDS	.634	.391	-.426	.782	.992	.105	.138
pH	.877	.623	-.893	.884	.522	.920	.716
Alkalinity	.852	.705	-.772	.777	.333	.903	.608
Chloride	1.000	.879	-.636	.946	.707	.623	.323
TH	.879	1.000	-.224	.685	.436	.336	-.099
DO	-.636	-.224	1.000	-.781	-.531	-.914	-.930
BOD	.946	.685	-.781	1.000	.852	.654	.496
COD	.707	.436	-.531	.852	1.000	.230	.242
Iron	.623	.336	-.914	.654	.230	1.000	.881
Fluoride	.323	-.099	-.930	.496	.242	.881	1.000

Table 3. Multiple regression analysis of different parameters in the waters samples of ground/municipal, Sagar district at pre-monsoon (March 2009 to June 2009)

R-Square = 0.0 Adjusted R-Square = 1.2727
Cohen's f-square = 0.0, a small effect size.

Variable	**Coefficient**
Intercept	-1457202.75
COLOUR	253018.94
CONDUCTIVITY	-1.87E+06
TURBIDITY	217513.16
TS	-2909.066
TDS	-7820.605
pH	-70109.17
ALKALINITY	9227.498
CHLORIDE	-25043.67
TH	-165.7053
DO	43619.141
BOD	-243769.6
COD	4042.3125
IRON	1503836.8
FLUORIDE	-1.22E+06

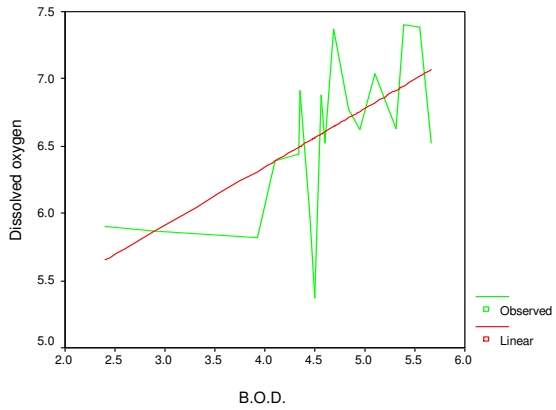
Table 4. Analysis of variance to test regression relation

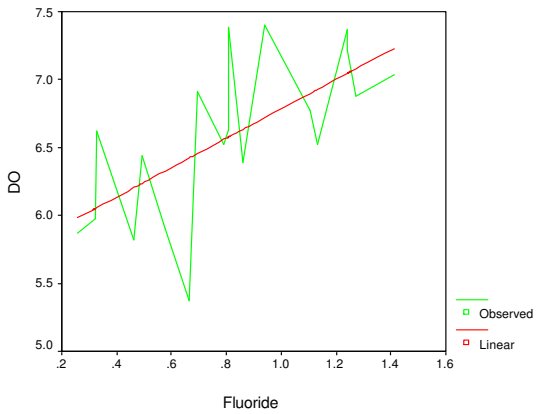
Source	Sum of Sqs	df	Mean Sq	F	p-value
Regression	-2.21E+08	14	-1.58+07	.	N.A.
Error	2.21E+08	-11	.		
Total	455.5903	3			

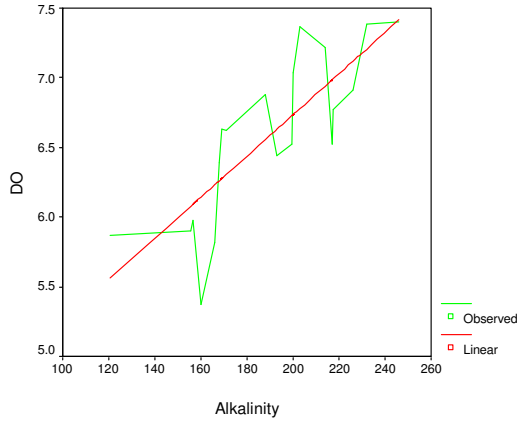
Table 5. Interrelationship between DO and other water quality parameter
Let linear equation is: $Y= m*b_1+b_{o,}$ and Independent variable is DO

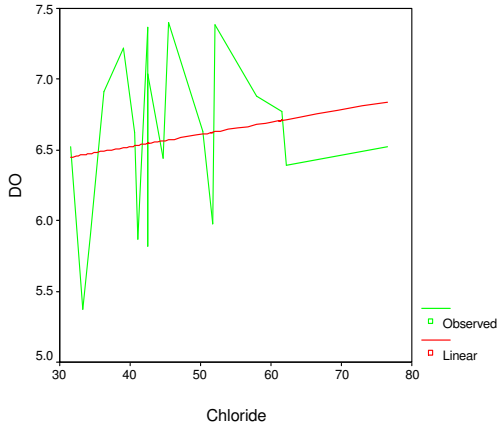
Parameter	**Rsq**	**d.f.**	**F**	**Sigf**	**b0**	**b1**
Temperature	.096	2	.21	.691	57.0767	-.0648
Colour	.919	2	22.56	.042	-42.932	.1328
Conductivity	1.000	2	400770	.000	-.0030	.0015
Turbidity	.000	2	9.7E-04	.978	18.2953	.0051
TS	.710	2	4.90	.157	206.703	.5958
pH	.019	2	.04	.861	12.4697	-.0075
Alkalinity	.117	2	.27	.657	610.315	-.6441
Chloride	.021	2	.04	.857	7.8121	.1110
TH	.000	2	4.8E-05	.995	269.722	-.0049
DO	.000	2	9.2E-04	.979	6.2990	.0008
BOD	.105	2	.23	.676	-18.485	.0606
COD	.594	2	2.93	.229	-54.706	.1568
Iron	.161	2	.38	.598	4.1814	-.0063
Fluoride	.044	2	.09	.789	5.1310	-.0071

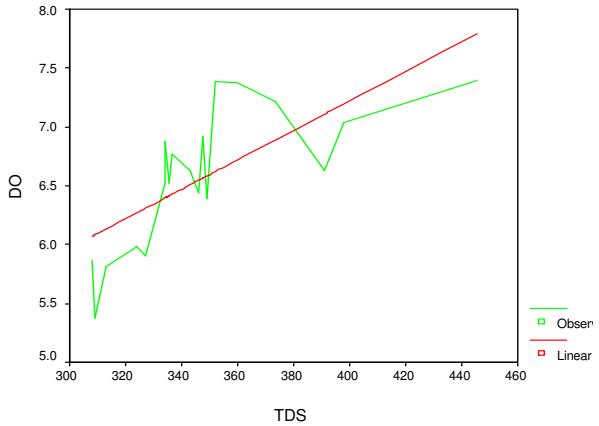
Table 6. Curve estimation by regression analysis between the mean chemical parameters (independent variables) and the mean dissolved oxygen parameter (dependent variable) in ground/municipal water samples of in and around Sagar city at pre-monsoon.











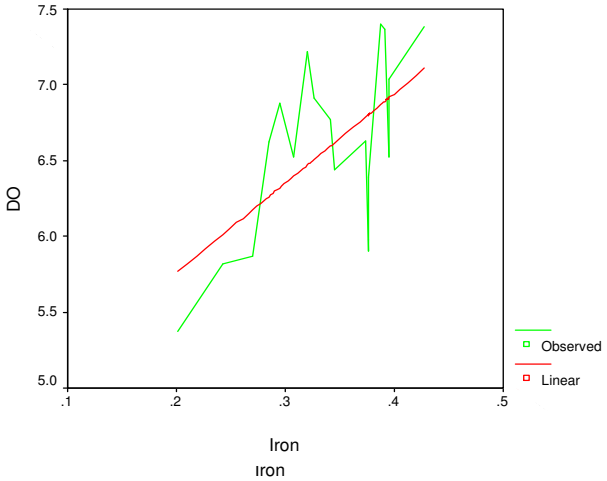


Table 7. Comparison of physico-chemical parameters of ground/municipal water with standard values (IS: 10500), at monsoon (July 2009 to October 2009)

Parameters	**July**	**August**	**September**	**October**	**Mean**	**IS:10500 (Desirable limit)**	**IS:10500 (Permissible limit)**
Water Temp., ^{O}C	22.5	24.2	23.4	25.1	23.8	-	-
Colour (Hz.u.)	18	17	15	16	16.5	5	25
Conductivity, (mS/cm)	.746	.771	.790	.758	0.764	-	-
Turbidity (N.T.U.)	16	22	25	18	20.25	5	10
Total solids (mg/L)	518.4	528.64	541.21	519.3	526.92	-	-
TDS (mg/L)	512.5	517.01	532.35	510.8	518.18	500	2000
pH	8.13	8.35	9.1	9.2	8.69	6.5-8.5	No Relaxation
Alkalinity (mg/L)	262	271	281	298	278	200	600
Chloride (mg/L)	52.51	47.21	66.21	62.78	57.17	250	1000
TH (mg/L)	251.1	262.18	269.43	273.8	264.13	300	600
DO (mg/L)	7.2	7.5	7.9	8.3	7.72	-	-
BOD (mg/L)	12.12	10.16	9.51	9.43	10.30	-	-
COD (mg/L)	16.73	14.23	13.32	14.51	14.69	-	-
Iron (mg/L)	1.02	0.88	0.93	1.05	0.97	0.3	1
Fluoride (mg/L)	1.06	1.25	1.31	1.92	1.385	1	1.5

Table 8. Comparison of physicochemical parameters of ground/municipal water with standard values (IS: 10500), at post monsoon (November 2009 to February 2010)

Parameters	**Nov.**	**Dec.**	**Jan.**	**Feb.**	**Mean**	**IS:10500 (Desirable limit)**	**IS:10500 (Permissible limit)**
Water Temp.,^{O}C	21.0	20.5	18.2	19.5	19.8	-	-
Colour (Hz.u.)	20	21	25	24	22.5	5	25
Conductivity (mS/cm)	.709	.702	.680	.691	0.695	-	-
Turbidity (N.T.U.)	18	21	26	19	21	5	10
Total solids (mg/L)	511.67	508.32	486.93	498.50	501.35	-	-
TDS (mg/L)	485.72	480.81	467.42	474.91	477.21	500	2000
pH	8.5	8.89	9.32	9.52	9.05	6.5-8.5	No Relaxation
Alkalinity (mg/L)	271	285	292	311	289.75	200	600
Chloride (mg/L)	43.36	39.32	41.57	52.62	44.21	250	1000
TH (mg/L)	242.45	250.08	257.48	268.46	254.61	300	600
DO (mg/L)	7.5	7.8	8.2	8.6	8.02	-	-
BOD (mg/L)	14.63	12.93	11.74	10.21	12.37	-	-
COD (mg/L)	17.65	16.62	15.39	13.93	15.84	-	-
Iron (mg/L)	1.1	0.92	0.96	1.13	1.0275	0.3	1
Fluoride (mg/L)	1.11	1.21	0.86	1.12	1.075	1	1.5

From the above all presented tables, it may be said that, Turbidity, BOD, COD and in some months, value of Iron is beyond the maximum permissible limit. The data revealed that, the month of January 2010 the value of fluoride was 0.86; there was requirement of additional amount of fluoride in drinking water. Throughout the sampling period's values of colour and alkalinity is more than desirable limit and within permissible limit. All correlation values positive, negative, strong, moderate, weak explained in table no. 2, 4 and 6 in detailed. Table of multiple regression analysis explained the effect of all water quality parameters on DO. We can determine the mathematical value of each parameters by relationship between DO and other water quality parameter and estimated curve.

4. Conclusions

Interrelationship between DO and other selected physico-chemical water quality parameters estimated by regression analysis and represented by curve modeling. Each model expressed variability in DO with different parameters. In some model decreasing value of DO indicated that, quality parameters are out of the highest desirable limit or maximum permissible limit set by IS:10500.

Model also represented that contamination level is higher at pre-monsoon compare to monsoon and post monsoon. Hence, these samples cannot be absolutely fit for directly drinking. Some essential treatment needed to convert in drinkable water. In conclusion, from the results of the present study it may be said that the ground/municipal water of Sagar is not absolutely fit for directly drinking purpose need treatments to minimize the contamination.

It is recommended that ground/municipal water monitoring should be carried out from time to time to assess the rate and kind of contamination. It is need of human to expand awareness among the people to maintain the cleanness of water at their highest quality and purity levels to achieve a healthy life.

5. References

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