ISSN : 0974 - 7451 Volume 7 Issue 3

Environmental Science
An Indian Journal

Trade Science Inc.

Current Research Paper

ESAIJ, 7(3), 2012 [103-107]

An experimental study on impacts of temperature and salinity on dissolved oxygen in water: Correlation and regression technique

Sanjay Kumar Sundaray[1,2,3]

[1]Faculty of Earth Systems and Environmental Science, Chonnam National University, Gwangju - 500757, (SOUTH KOREA)

[2]Institute of Oceanography, National Taiwan University, Taipei, 10617, (TAIWAN)

[3]Department of Chemistry, S.C.S.(Autonomous) College, Puri-752 001, Orissa, (INDIA)

E-mail : sksundaray@yahoo.com

Received: 23rd December, 2011 ; Accepted: 17th January, 2012

ABSTRACT

Dissolved oxygen (DO) in an aquatic environment is an important indicator of the environment's water quality and a vital to the existence of most aquatic organisms. Its concentration and distribution in the aquatic environment are dependent on chemical and physical factors and are greatly affected by biological and chemical processes. Dissolved oxygen of aerated distilled water was investigated with different temperature and different salinity. The results show large negative correlation between temperature and DO (r = – 0.9988) and for salinity and DO r = – 0.9986. The very usefulness of these correlation study has been tested by obtaining a linear relation of the form $Y = A + BX + CX^2$ for temperature-DO and $Y = A + BX$ for salinity- DO to predict the values of dissolved oxygen as a function of temperature and salinity, which are found to be good agreement with observed values.

KEYWORDS

DO;
Temperature;
Salinity;
Correlation coefficient;
Regression analysis.

INTRODUCTION

Oxygen is critical to the maintenance of the life processes of nearly all organisms. It is one of several dissolved gases important to aquatic systems. Oxygen gas dissolved in water is vital to the existence of most aquatic organisms. It is a component in cellular respiration for both aquatic and terrestrial life. The concentration of dissolved oxygen (DO) in an aquatic environment is an important indicator of the environment's water quality. DO is necessary to maintain aerobic conditions in surface waters and is considered a primary indicator when assessing the suitability of surface waters to support aquatic life.

The introduction of excess organic matter may result in a depletion of oxygen from an aquatic system. Prolonged exposure to low dissolved oxygen levels (<5–6 mg/1) may not directly kill an organism, but will increase its susceptibility to other environmental stresses. Exposure to less than 30% saturation (<2 mg/l) of oxygen for one to four days may kill most of the biota in a system[12].

Oxygen gas is dissolved in water by a variety of processes - diffusion between the atmosphere and water at its surface, aeration as water flows over rocks and other debris, churning of water by waves and winds, and photosynthesis of aquatic plants. There are many factors that affect the concentration of dissolved oxygen in an aquatic environment. These factors include: temperature, stream flow, air pressure, aquatic plants, decaying organic matter and human activities. Churning waters and natural diffusion of oxygen from the atmosphere also cause an increase in dissolved oxygen.

Its concentration and distribution in the aquatic environment are dependent on chemical and physical factors and are greatly affected by biological and chemical processes. Chemical and physical factors which affect the DO concentration researched in the present study are salinity and temperature

The correlation provides an excellent tool for the prediction of parameter values within reasonable degree of accuracy. The term correlation indicates the relationship between two such variables. Correlation coefficient and regression studies among various water quality parameters were reported by many researchers[1, 5, 6, 8, 9, 10, 11], but no attempt was made to correlate DO with temperature and salinity. As chemistry of DO changes from time to time, temperature to temperature and salinity to salinity depending upon their effect on it. Moreover, an advantage in such type of study lies in the fact that these results of correlation coefficients and linear regression equations can be successfully extrapolated to others.

MATERIALS AND METHODS

Sampling and analytical methods

The analysis of dissolved oxygen in water was done by adopting the iodometric (Modified Winkler's) method of analysis[2]. The analytical data quality was ensured through careful standardisation, procedural blank measurements, spiked and duplicate samples.

To study the variation of dissolved oxygen with respect to temperature and salinity, aerated distilled water were taken with different temperature and different salinity.

Data treatment and statistical methods

Correlation coefficient (r) and regression analysis of DO with temperature and DO with salinity were performed by applying the experimental data. Correlation coefficient determines the relationship between two parameters (in our case DO-temperature and DO salinity). Let x and y any two variables and let (x_i y_i) be n pairs of observed variables (i = 1, 2, 3,……n), then the correlation coefficient 'r' between the variables x and y is given by the relation:

$$r = \frac{\sum_{i=1}^{n} X_i Y_i}{\left[\sum_{i=1}^{n} X_i^2 \sum_{i=1}^{n} Y_i^2\right]^{1/2}} \qquad (1)$$

where

$$X_i = (x_i - \bar{x}), \quad Y_i = (y_i - \bar{y}) \qquad (2, 3)$$

And

$$\bar{x} = \frac{\sum_{i=1}^{n} x_i}{n}, \quad \bar{y} = \frac{\sum_{i=1}^{n} y_i}{n} \qquad (4, 5)$$

and all the summation are to be taken from 1 to n (the number of observations).

Parameters of straight line

If the correlation coefficient (r) between two variables x and y is fairly large, it implies that these two variables are highly correlated. In such cases it is feasible to try linear relation of the form

$$y = Ax + B \qquad (6)$$

to correlate x and y, where A and B are constants to be determined by fitting the experimental data on the variables x and y to the above equation 6. According to well known method of least squares[9], the values of the constants A and B were calculated by the relations:

$$A = \frac{\sum_{i=1}^{n}(X_i Y_i) - (\sum_{i=1}^{n} X_i).(\sum_{i=1}^{n} Y_i)}{\sum_{i=1}^{n}(X_i - \bar{x})^2} \qquad (7)$$

$$B = \bar{y} - A\,\bar{x} \tag{8}$$

Where the symbols have their own meaning as mentioned in the previous section.

All the parameter values were computed to calculate correlation coefficient for all possible linear relationship from software package Excel in PC Pentium IV and SPSS-10.0 statistical software.

RESULT AND DISCUSSION

The analyses have been divided into two parts (with results in parentheses):

(I) Impacts of temperature on DO [i.e. Variations and correlations (coefficients) between DO & temperature].

(II) Impacts of salinity on DO [i.e. Variations and correlations (coefficients) between dissolved oxygen & salinity]

Impacts of temperature on DO

Variations of dissolved oxygen with temperature

Temperature is a significant factor in determining the concentration at dissolved oxygen. The variations of dissolved oxygen in aerated distilled water with respect to different temperature ranging from 1^0C to 90^0C are shown in Figure 1. DO is found to 14.15 mg/l in 1^0C, 4.65 mg/l at 50^0C and 0.41 mg/l at 90^0C. From Figure 1 it is found that there is an inversely relationship between temperature and dissolved oxygen in water i.e. when temperature increases the amount of dissolved oxygen decreases. This is due to temperature inversely controls the solubility of oxygen in water as temperature increases, oxygen is less soluble. When the water boils, the dissolved oxygen is ejected, thus warmer water contains less DO. Warmer water is able to hold less oxygen than cooler water, and this experiment supported this conclusion.

Because large fluctuations of DO are possible with respect to temperature, DO tests should be performed at a given temperature for different samples to study its variations.

Applebaum et al.[3] observed in Corpus Christi Bay, Texas, U.S.A., that a significant decrease in surface water DO with increase in surface water temperature.

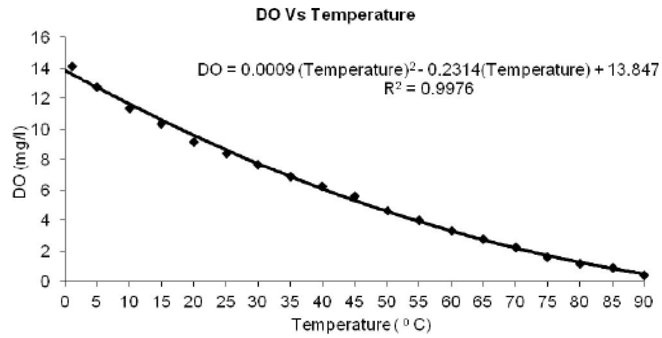

Figure 1 : Variation of DO with Temperature along with Regression equation

Correlation coefficient between DO and temperature

Greater the numerical value of the correlation coefficient (r), greater is extent to which a linear relationship holds well between two variables X and Y. The value of correlation coefficient (r) for temperature and DO is found to be negative (r = - 0.9988) indicates that there is a perfect negative correlation between temperature and DO. The corresponding regression equation was calculated for the temperature and D.O.

Linear relationship between DO and temperature is shown in Figure 1, which reflects the parabolic variability (Curve nature than line) of DO with temperature. By applying polynomial regression of power 2 ($y = Ax^2 + BX + C$), the values of A, B, C and r can be calculated, which gives better value for polynomial relation than linear.

For this, the best fitted equation is:

DO = [0.0009 x (Temperature) ^{2}] + (-0.2314 x Temperature) + 13.847

Using the above regression equation the amount of DO are calculated and compared with experimentally observed values. The results of the above calculation are shown in TABLE 1. According to the TABLE 1, percentage of error varies from 0.01% to 7.25 % within the temperature range of 1 to 80 ^{0} C. However, the percentage of error is more for > 80 ^{0}C, this is because of very low value of DO (< 1 mg/l).

Impacts of salinity on DO

Variations of dissolved oxygen with salinity

Dissolved oxygen concentration in aerated distilled (salinity is zero) water is found to be 7.62 mg/l at 30°C (Room temperature). The concentration of DO of water with salinity 25 ppt. is found to be 6.62 mg/l at 30°C,

TABLE 1 : Observed and predicted values of DO with respect to different temperature along with % of error

Temperature	DO		% of error
	Observed	Predicted	
^{0} C	mg/l	mg/l	
1	14.15	13.62	3.77
5	12.75	12.71	0.29
10	11.38	11.62	2.14
15	10.35	10.58	2.21
20	9.18	9.58	4.35
25	8.45	8.62	2.07
30	7.68	7.72	0.46
35	6.850	6.851	0.01
40	6.25	6.03	3.50
45	5.53	5.26	4.95
50	4.65	4.53	2.65
55	4.01	3.84	4.18
60	3.32	3.20	3.52
65	2.75	2.61	5.15
70	2.22	2.06	7.25
75	1.61	1.55	3.45
80	1.15	1.10	4.78
85	0.88	0.68	22.67
90	0.41	0.31	24.15

which decreases to 5.65 mg/l when salinity increased to 50 ppt. at the same temperature (Figure 2). Thus it is evident that there is also an inversely relationship between salinity and dissolved oxygen in water i.e. when salinity increases the amount of dissolved oxygen decreases. This is because when salts are dissolved in a unit volume of water, there is less room for oxygen to dissolve. Further oxygen is less soluble than most salts. Thus freshwater can hold more oxygen than saltwater. This experiment concludes that the amount oxygen present in a given volume of water is a function of the amount of other dissolved substances (such as salts) in the water.

Similar reports were made in different Indian estuaries by many authors showing that the solubility of oxygen in the water decreases with increase in salinity and temperature[4, 7, 10].

Correlation Coefficient (r) between DO & salinity

The value of correlation coefficient (r) for salinity and DO at a given temperature (30^{0}C) was found to be negative (r = – 0.9986) indicates that there is a highly negative correlation between salinity and DO. Figure 2

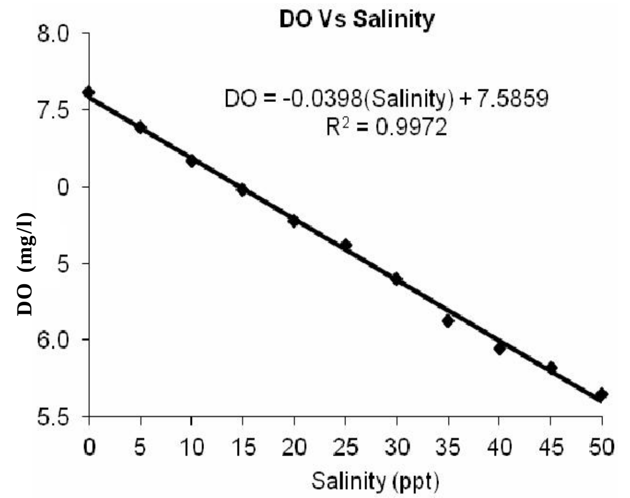

Figure 2 : Variation of DO with Salinity along with Regression equation

TABLE 2 : Observed and predicted values of DO with respect to different salinities along with % of error

Salinity	DO		% of error
	Observed	Predicted	
ppt	mg/l	mg/l	
0	7.62	7.59	0.45
5	7.39	7.39	0.04
10	7.17	7.19	0.25
15	6.98	6.99	0.13
20	6.78	6.79	0.15
25	6.62	6.59	0.44
30	6.40	6.39	0.13
35	6.13	6.19	1.03
40	5.95	5.99	0.74
45	5.82	5.79	0.43
50	5.65	5.60	0.96

shows the linear regression correlation between DO and salinity. The linear correlation coefficient r = – 0.9986 and the best fitted linear equation (Y = AX + B) for this correlation is:

Dissolved Oxygen (DO) = (–0.0398 x Salinity) + 7.5859

Further, the value for regression analysis constant (A) for salinity-DO was negative (-0.0398) indicates that the dissolved oxygen in water decreases with increase in salinity. Using the above regression equation the amount of DO are calculated and compared with experimentally observed values. The results of the above calculation are shown in TABLE 2. The percent (%) error between predict value and observed value is minimum i.e. from 0.04 % to 1.03 %.

CONCLUSION

The present study reveals that the amount of oxygen present in a given volume of water is a function of the temperature of the water; and the amount of the other dissolved substances (such as salts) in the water. There is an inversely relationship between (i) temperature and dissolved oxygen and (ii) salinity and dissolved oxygen in water. Temperature bears a highly negative correlation with DO, which is reflected from their negative correlation coefficient ($r = -0.9988$). The highly negative correlation between DO and salinity is reflected from their negative correlation coefficient value ($r = -0.9986$), which is further confirmed by the negative regression analysis constant (A) value (-0.0398).

The linear regression analysis reflects that the parabolic variability (Curve nature than line) of DO with temperature and for this the best fitted equation is

$$DO = [0.0009 \times (Temperature)^2] + (-0.2314 \times Temperature) + 13.847$$

However, for DO and salinity, the best fitted linear regression equation is

$$\text{Dissolved Oxygen (DO)} = (-0.0398 \times Salinity) + 7.5859$$

Because large fluctuations of DO are possible with respect to temperature, DO tests should be performed at a given temperature for different samples to study its variations among the samples.

Thus, an inverse relationship describes a situation in which a change in one thing (e.g. temperature/salinity) causes something else (e.g. dissolved oxygen) to change in the opposite direction.

ACKNOWLEDGEMENT

The author is grateful to Prof. D. Bhatta, Professor of Chemistry, Utkal University, Bhubaneswar, Dr. B. B. Nayak, Institute of Minerals and Materials Technology, Bhubaneswar, India and Prof Saulwood Lin, Institute of Oceanography, National Taiwan University, Taipei, Taiwan, for much of their proper guidance and encouragement. The author is thankful to Principal, S. C. S. (Autonomous) College, Puri, India for providing necessary facilities.

REFERENCES

[1] M.D.Adak, K.M.Purohit; Pollution Research, **20(2)**, 227-232 **(2001)**.

[2] APHA. AWWA, WEF; Standard Methods for The Examination of Water and Waste Water. 20^{th} Edition, American Public Health Association. Washington DC. USA., **(1998)**.

[3] S.Applebaum, P.A.Montanga, C.Rifler; Environmental Monitoring and Assessment, **107(1-3)**, 297-311 **(2000)**.

[4] J.Das, S.N.Das, R.K.Sahoo; Indian Journal of Marine Sciences, **26**, 323-326 **(1997)**.

[5] R.W.Gaikwad; Indian Journal of Environmental Protection, **24(2)**, 13 43 **(2004)**.

[6] N.Jain, S.Saxena, R.K.Shrivastava; Indian Journal of Environmental Protection, **24(1)**, 57-59 **(2004)**.

[7] D.Padmavathi, D.Satyanarayana; Indian Journal of Marine Sciences, **28**, 345-354 **(1999)**.

[8] B.Sarangi, S.K.Biswal, S.C.Pradhan; Pollution Research, **20(3)**, 481-485 **(2001)**.

[9] R.K.Somashekar, V.Rameshaiah, A.C.Suvarna; Journal of Environment and Pollution, **7(2)**, 101-109 **(2000)**.

[10] S.K.Sundaray, U.C.Panda, B.B.Nayak, D.Bhatta; Environmental Geochemistry and Health, **28**, 317-330 **(2006)**.

[11] V.L.Verma, H.S.Bhatia, D.Kahal; Indian Journal of Environmental Protection, **23(6)**, 601-606 **(2003)**.

[12] Water Quality Assessments, A Guide to The Use of Biota, Sediments and Water in Environmental Modelling, Ed.D., Chapman. Published on Behalf of UNESCO (United Nations Education, Scientific. and Cultural Organisation); WHO (World Health Organization); UNEP (United Nations Environmental Programme), Chapman & Hall, London, **(1996)**.