PHYSICOCHEMISTRY AND RELATION BETWEEN TEMPERATURE AND DISSOLVED OXYGEN OF STREAM WATER IN SOUTHERN NIGERIA

ISSN: 2141 – 3290
www.wojast.com

ATAT, J. G.[1], UKO, M. I.[1] AND ATAT, A. G.[2]
[1]*Department of Physics, University of Uyo, Uyo, Akwa Ibom State, Nigeria*
[2]*Department of Geology and Mineral Sciences, University of Ilorin, Kwara State, Nigeria*
josephatat@uniuyo.edu.ng

ABSTRACT

Water samples were collected from Ikot Inyang Abia stream in Ukanafun LGA for four days. These samples were analysed in Biomedical Technology Laboratory, University of Port Harcourt, Rivers State. The average results from day one to day four of Dissolved Oxygen (DO) are 6.99mgL^{-1}, 7.07mgL^{-1}, 7.14mgL^{-1} and 6.05mgL^{-1} respectively; Water Temperature (WT) are 27.80℃, 28.17℃, 28.36℃, and 29.09℃ respectively; pH are 5.44, 7.51, 6.34 and 6.71 respectively; Electrical Conductivity (CND) are 26.76 mScm^{-1}, 24.94 mScm^{-1}, 28.55 mScm^{-1} and 16.88 mScm^{-1}. We were able to correlate WT and DO to know how these parameters relate with each other. The results obtained from day one, three and four show strong correlations as 0.891, 0.995 and 0.948 respectively. The practical implication of this strong correlation indicates that the amount of oxygen that water can hold strongly varies with temperature. Also, it helps or permits researchers to examine naturally occurring parameters such as DO or WT (if either is known) in other case studies that may be difficult to test experimentally. The coefficients of determination are 0.79, 0.99 and 0.90. Day two correlation coefficient is 0.785 (≈ 0.8) which is still strong and coefficient of determination as 0.62. Coefficients of determination indicate that 79%, 62%, 99% and 90% of the total variation in DO can be explained by the linear relationship between them. Cold water hold more oxygen than warm water. The toxicity of many toxicants may double when the DO reduces from 10mg/L to 5mg/L. Generally, pH and DO values stated in these abstract above showed that water from this stream is not recommended for human consumption and should be improved for aquatic life as the values are under tolerance.

INTRODUCTION

Dissolved oxygen is the amount of oxygen present in water; it defines the living condition for oxygen requiring (aerobic) aquatic organisms. In fresh water systems such as lakes, rivers and streams, DO concentration varies by season, location and water depth. Oxygen has limited solubility in water, usually ranging from 6 to 14mgL^{-1}. DO concentration reflects an equilibrium between oxygen producing processes (example, photosynthesis) and oxygen consuming processes (aerobic respiration, nitrification, chemical oxidation) and the rate at which DO is added or removed from the system by atmospheric exchange (aeration and degassing) and hydrodynamic processes (accrual/addition from rivers and tides against export to ocean). DO concentrations vary over 24 hours period due to tidal exchange and net production of oxygen by plants during the day when photosynthesis occurs. Plants only respire at night; this process consumes oxygen. Highly productive systems are expected to have large diurnal fluctuation that occurs each day. Among the many things that affect the health of natural streams, none is more important than DO. DO provides a suitable environment for the aerobic microorganisms that consume dissolved and suspended organic matter. In addition, the steady growth of aquatic recreation is demanding that in most areas, oxygen levels be maintained high enough to satisfy the needs of a plentiful fish population (Hoak and Bramer, 1961). Most aquatic organisms require oxygen in specified metabolism. DO concentration changes above or below this can have adverse

physiological effect (Anzecc and Armcanz, 2000). Even short lived anoxic and hypoxic events can cause major deaths of aquatic organisms. The toxicity of many toxicants (lead, zinc, copper, cyanide, ammonia, Hydrogen Sulphide and pentachlorophenol) can double when DO is reduced from 10 to $5mgL^{-1}$ (Anzecc and Armcanz, 2000). The death of immobile organisms and avoidance of low oxygen conditions by mobile organisms can also cause changes in the structure and diversity of aquatic communities. Moreso, if DO becomes depleted in bottom waters (or sediments), nitrification, and therefore, denitrification may be terminated and bioavailable orthophosphate and ammonia may be released from the sediment to the water column. These recycled nutrients can give rise to or reinforce gas; also result of anaerobic respiration can be toxic to benthic organism and fish assemblages in high concentration (Connell and Miller, 1984). Temperature is the property of the body that determines the direction of heat flow. Water temperature is measured with a thermometer. Thermometer has a liquid that expands as the temperature increases. Water temperature can make aquatic life sensitive to disease. Thermal pollution [due to hot water introduced into the stream after cooling of equipment] and increased erosion [as the sediments in water absorb heat from sunlight] could lead to increase in water temperature. Warm water is less capable of holding dissolved oxygen; it can be fatal to aquatic life or make them weak and more susceptible to diseases and pollutant.

Coefficient of determination (r^2) gives the proportion of the variance (fluctuation of one variable that is predictable from the other variable). It is a measure that allows for the determination of how certain predictions can be made from a certain model or graph. The value of r^2 is such that $0 \leq r^2 \leq 1$. It denotes the strength of the linear association between WT and DO and represents the percent of the data that is the closest to the line of best fit. For instance, if $r = 0.922$ and $r^2 = 0.850$. This means that 85% of the total variation in DO can be explained by the linear relationship between WT and DO. The other 15% of the total variation in DO remains unexplained. How well does a regression equation truly represent a set of data, may be answered as coefficient of determination is the measure of how well the regression line represents the data (Stigler, 1999).

The linear correlation coefficient (r) measures the strength and the direction of a linear relationship between two variables. It is sometimes referred to as the Pearson product moment correlation coefficient. The value of r is such that it ranges from $-1 \leq r \leq 1$. The positive and negative signs are used for positive linear correlation and negative linear correlation respectively. If dissolved oxygen (DO) and water temperature (WT) have a strong positive linear correlation, r is close to +1; if r is exactly +1, it indicates a perfect positive fit. This positive value indicates a relationship between WT and DO variables such that as values of WT increase, values of DO also increase. Moreso, if WT and DO have a strong negative linear correlation, r is also close to -1. If r is exactly -1, it indicates a perfect negative fit. Negative values indicate a relationship between WT and DO such that as value of WT increases, value of DO decreases (Pearson, 1895). If there is no linear correlation or a weak linear correlation, r is close to zero. A value near zero means that there is a random, nonlinear relationship between the two variables. A correlation greater than 0.8 is generally described as strong whereas a correlation less than 0.5 is weak.

Linear correlation coefficient (r) measures the strength and direction of a linear relationship between two variables. It can be determined using expression of Spearman's rank. The coefficient of determination is also necessary as it gives the proportion of one variance that is predictable from the other variable.

The mathematical formula for Pearson product moment (linear correlation coefficient) is given by

$$r = \frac{n\sum xy - \sum x \sum y}{\sqrt{(n\sum x^2 - (\sum x)^2 .\ n\sum y^2 - (\sum y)^2)}} \qquad 1$$

The value of r is such that $-1 \leq r \leq 1$. The positive and negative signs are used for positive linear correlations and negative linear correlations respectively. r is a dimensionless quantity.

Perfect correlation of ±1 occurs only when the data points, all lie exactly on a straight line. If r = +1, the slope of this line is positive; if r = -1, the slope is negative (Pearson, 1895; Stigler, 1989).

The Spearman's rank for determination of correlation coefficient is expressed mathematically as

$$r_s = \frac{1-6\sum d_i^2}{n(n^2)-1)} \quad 2$$

Where: r_s is Spearman's rank correlation coefficient
d_i is difference in paired ranks
n is number of cases.

Table 1: Standards for fresh water

S/N	Parameters	Tanzanian	WHO	UNECE
1	Dissolved Oxygen (mgL^{-1})			Greater than 7.0 for class one (UNECE, 1994).
2	pH		6.5 to 8.5 (Ojija, 2015).	6.5 to 9.0 for class one (UNECE, 1994).
3	Temperature (^0C)	20 to 35 (Ojija, 2015).		

Study Location and Geology

The study area (Ikot Inyang Abia) is located in the southern part of Ukanafun within latitude 4^055^1N to 5^000^1N and longitude 7^030^1E to 7^040^1E (Figure 1). The area is characterized by two distinct seasons: rainy (March to October) and dry [November to February] (Evans *et al*., 2010). The mean monthly rainfall is about 135mm during the rainy season and falls to 65mm during the dry season (George *et al*., 2010). The maximum daily mean temperature is between 28^0C to 30^0C (Akpan *et al*., 2006). The formation [which comprises continental sand and gravel deposited in an upper deltaic plain environment] is Benin of Niger Delta. The grain size range from coarse to fine in texture and poorly sorted (Reijers *et al*., 1997). The area is drained by Kwa Ibo River (Okereke *et al*., 1998).

Figure 1: Location of study (George *et al*., 2010)

MATERIALS AND METHOD

Beakers were used to collect water samples from the stream at time interval of two hours from 8am to 5pm for four days. Thermometer was used to measure the temperature of the samples.

Other materials and reagents used, and methods of analyses were carried out in biomedical technology laboratory, University of Port Harcourt. Nigeria.

RESULT AND DISCUSSION

The results of the analysis are presented in Tables 2 to 5. These were used to evaluate correlation coefficient and coefficient of determination. Equation 1 was used to compute the Correlation coefficient (r) as

Day one: $r = 0.8913267$ (This implies $r^2 = 0.79445$)

Day two: $r = 0.7850500$ and $r^2 = 0.6163$

Day three: $r = 0.9954690$ and $r^2 = 0.9910$

Day four: $r = 0.9481030$ and $r^2 = 0.8989$

Considering Table 1,
DO falls within the standards but the first class value (that is water that is not polluted) in most of the measurements are not met. The first class value is greater than 7.0 mgL^{-1} (UNECE, 1994). This class of water may not require treatment before use. Second class water is slightly polluted; requires adequate treatment and may be used for suitable recreational activities and irrigation. Third class is also polluted; it requires treatment and can be used for industrial supply except in food and textile industries. The fourth class is one that the water quality is very poor. The amount of oxygen that water can hold varies with temperature. Cold water hold more oxygen than warm water. The toxicity of many toxicants may double when the DO reduces from 10mg/L to 5mg/L. Temperature is within the standard range of 20^0C to 35^0C. Increase in WT increases DO, as the temperature gets closer to the maximum allowed value, it leads to lower DO but still linearly related. If the standard limit is exceeded, the relationship may be inversely proportional.

pH is fluctuating between acidic and standard values. This could be due to exposure of the stream to pollutant (impurities) from extrinsic sources. This stream is not good for human consumption though it partly satisfies tolerance limit for aquatic life.

Table 2: Result for day one

S/N	WT (^{o}C)	DO (mgL^{-1})	pH	CND ($mScm^{-1}$)	TDS (ppm)
1	26.0	6.68	6.41	31.95	20.00
2	30.0	7.95	6.83	29.83	20.00
3	28.5	6.95	4.53	20.14	13.39
4	27.0	6.65	4.62	27.98	19.00
5	27.5	6.70	4.79	23.90	16.43
Average	27.80	6.99	5.44	26.76	17.76

Table 3: Result of measurement for day two

S/N	WT (^{o}C)	DO (mgL^{-1})	pH	CND ($mScm^{-1}$)	TDS (ppm)
1	27.90	6.53	6.23	32.03	21.49
2	27.95	6.63	6.91	29.83	20.00
3	28.00	7.50	7.64	20.13	14.03
4	29.00	7.82	8.53	20.00	14.03
5	28.00	6.89	8.25	22.7	13.82
Average	28.17	7.07	7.51	24.94	16.67

Table 4.0: Result of measurement for day three

S/N	WT (^oC)	DO (mgL^{-1})	pH	CND ($mScm^{-1}$)	TDS (ppm)
1	26.93	6.37	5.58	31.71	20.33
2	28.30	7.11	6.19	31.26	21.00
3	29.30	7.70	7.76	25.76	17.80
4	29.17	7.50	6.96	24.64	16.55
5	28.10	7.03	5.23	29.36	19.02
Average	28.36	7.14	6.34	28.55	18.94

Table 5.0: Result of measurement for day four

S/N	WT (^oC)	DO (mgL^{-1})	pH	CND ($mScm^{-1}$)	TDS (ppm)
1	28.35	5.8	6.68	19.41	12.51
2	32.40	6.5	4.72	15.30	12.00
3	25.20	5.7	7.63	15.29	10.50
4	30.40	6.2	7.80	17.50	11.91
Average	29.09	6.05	6.71	16.88	11.73

CONCLUSION

Water samples were collected and analysed for temperature, dissolved oxygen and pH. The result of the correlation coefficients showed there is a linear relationship between water temperature that is within the standard range and dissolved oxygen. The coefficients of determination were determined for the samples obtained. These showed that 79%, 62%, 99% and 90% of the total variation in dissolved oxygen can be explained by the linear relationship between the two parameters. The values of pH fluctuate between acidic and tolerance. This stream is not recommended for human consumption though it partly satisfies tolerance limit for aquatic life.

REFERENCES

Akpan, F. S., Etim O. N. and Akpan, A. E. (2006). Geophysical Studies of Groundwater Potential of Parts of Etim Ekpo Local Government Area of Akwa Ibom State, Nigeria. Nigerian Journal of Physics, 18(1): 39 – 44.

ANZECC and ARMCANZ, 2000. Australian Guidelines for Water Quality Monitoring and Reporting. National Water Quality Management Strategy Paper No 7, Australian and New Zealand Environment and Conservation Council, Agriculture and Resource Management Council of Australia and New Zealand, Canberra.

Connell, D. W. and Miller, G. J. (1984). *Chemistry and Ecotoxicology of Pollution*. New York: John Wiley and Sons.

Evans, U. F. Akpan, A. E., George, N. J., Obot, I. B. and Ikot, A. N. (2010). A Study of the Superficial Sediments and Aquifers in Parts of Uyo Local Government Area, Akwa Ibom State, Southern Nigeria Using Electrical Sounding Method. E-journal of Chemistry India, 7(3), 1016 – 1022.

George, N. J., Akpan, A. E., George, A. M. and Obot, I. B. (2010). Determination of elastic properties of the over burden materials in parts of Akamkpa, Southern Nigeria using seismic refraction studies. *Scholars Research library.Archives of Physics Research*, 1(2): 58 – 71.

Hoak, R. C. and Bramer, S. L. (1961). Recovery and Identification of Organics in Water. *International Journal of Air and Water Pollution*. 6: 521.

Ojija, F. (2015). Analysis of Water quality Parameters and Ecosystem Services of Nzovwe Stream. *International Journal of Biological Sciences and Technology*, 7(1): 1 – 10.

Okereke, C. S., Esu, E. O. and Edet, A. E. (1998). Determination of Potential Groundwater Sites using Geological and Geophysical Techniques in the Cross River State, Southeastern Nigeria. Journal of African Earth Sciences, 27(1): 149 – 163.

Reijers, T. J. A., Petters, S. W. and Nwajide, C. S. (1997). The Niger Delta Basin. In: Selly, R. C. Edition, *African Basins - Sedimentary Basin of the World 3*. Amsterdam: Elsevier Science, pp. 151 – 172.

Pearson, K. (1895). *Mathematical Contributions to the Theory of Evolution II: Skew Variation in Homogenous Material*. London: Cambridge University Press. pp. 343 – 414.

Stigler, S. M. (1999). *Statistical on the Table*. Cambridge: Harvard University Press.

United Nation Economic Commission for Europe, United Nations, New York and Geneva (1994). Standard Statistical Classification of Surface Fresh Water Quality for the Maintenance of Aquatic Life.