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Modelling Reaeration Coefficient of Stream using Regression Analytical Method - A case of Mmubete Stream, Rivers State Nigeria

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***Abstract:** Surface water pollution is a major problem/ occurrence in the Niger Delta region of Nigeria. Mmubete stream is never an exception. Mmubete stream is significant to the people of Rivers State owing to its usefulness in terms fishing activities and domestic usage. The modelling of Mmubete stream using regression analytical method with emphasis on incorporating mixing properties of stream in stream reaeration prediction was carried out. Water samples were collected and analysed for dissolved oxygen (DO) and temperature. The hydrodynamic data (depth, velocity, surface area, kinematic viscosity and dispersion) of the stream were measured while re-aeration coefficient using empirical models developed using regression analytical approach was determined. The results revealed that the field reaeration coefficient of Mmubete stream ranges from 2.4432d^{-1} to 3.7568d^{-1} in the wet season and 0.96d^{-1} to 2.712d^{-1} in the dry season. The reaeration coefficient of the stream ranges from 1.983^{d-1} to 3.088d^{-1} using the model 1 for the prediction, 1.983d^{-1} to 3.5065d^{-1} using the model 2 and 3.0221d^{-1} to d^{-1} 4.1817 using the model 3. The R^2 of the models are 0.934, 0.934 and 0.998 for models 1, 2 and 3 respectively and the standard errors are 0.11135, 0.549694 and 0.022008 for model 1,2 and 3 respectively. The models developed are reliable considering the root mean square and standard error values.*

***Keywords:** Modelling, Stream, Reaeration, Regression Analysis, Hydrodynamic Data.*

I. INTRODUCTION

The degrading or pollution of our streams is on the increase due to population explosion and rapid industrialization. The quality of our stream water has been adversely affected by the actions of the industries and human activities. These actions have not only affected the water quality but also adversely affects the aquatic environment [1][2]. Having an indebt knowledge of the water quality in order to avoid pollution of the stream has been the major concern of environmentalists.

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Environmentalists believe in the preservation and sustainability of the water environment rather than treatment, hence their interest in self-purification of stream. Self-purification of surface water bodies allows the surface water to rid themselves of waste through natural processes [3][4]. Self-purification complements artificial methods and processes of maintaining water quality [5]. The process of self-purification is a complicated one that involves the simultaneous occurrences of processes in the physical, chemical and biological states [6]. The determination of the self-purification abilities of streams depends on deoxygenation and reaeration processes. The deoxygenation and reaeration processes are determined as deoxygenation coefficient and reaeration coefficient respectively. The reaeration coefficient is measure of the rate at which surface water bodies take oxygen from the surrounding atmosphere [7][8][9].

Prediction of water quality and reaeration rate depends on the relationship between water quality indicators and factors affecting reaeration of streams. Many methods are employed in predicting water quality and reaeration. The methods include certain mathematical models and stochastic methods [10][4]. The mathematical models and statistical methods include limited unit method, finite difference method, wave analysis, time series analysis, probability method regression analysis [10][11]. Regression analysis method is a statistical method to deal with relationship among variables. Regression analysis can provide both mathematical expressions among variables and basis for effective judgment and conclusion [12]. The mathematical expressions (models) formed from the regression analysis are used to forecast (predict) and control the value of the dependent variable.

II. METHODOLOGY

A. Study Area and Sampling Stations

The Mmubete stream is in Aleto, Eleme Local Government Area in Rivers State, Nigeria. The stream is in the Atlantic coast of Southern Nigeria with a coastline of about 450km which terminates at Imo River entrance. It is along the East-West Road and beside the Petrochemical Company. The stream is black freshwater. It is located on the coordinates of between Latitude 5^0 04' 06''N and Longitude 6^0 38' 56''E and 8^0E. In the study, 12 sampling points were used. The co-ordinates of the sampling stations are given in Table 1.

Table 1: Co-ordinates of Sampling Stations

S/N.	Easting	Northing	Point
1	290646	532405	P1
2	290632	532422	P2
3	290628	532246	P3
4	290547	532084	P4
5	290359	532007	P5
6	290229	531945	P6
7	290085	531850	P7
8	289971	531769	P8
9	289837	531674	P9
10	289728	531643	P10
11	289584	531634	P11
12	289539	531599	P12

B. Laboratory and Field Measurement

Water samples were collected and analysed for dissolved oxygen (DO) and temperature using iodometric method and digital laboratory thermometer respectively. The hydrodynamic properties (depth, surface area and volume of water, dispersion coefficient and kinematic viscosity) of were measured using standard methods.

III. MATHEMATICAL DETERMINATION

The field reaeration coefficient values were obtained using equation 1.

$$K_2 = \frac{K_L A}{V} \quad (1)$$

$$K_2 = \frac{K_L}{H} \quad (2)$$

$$K_L = H(DO_s - DO) \quad (3)$$

Where: K_L = mass transfer coefficient for DO

A	=	Surface area of stream
V	=	Volume of water in the stream
H	=	Depth of stream or river.
DOs	=	Saturated dissolved oxygen of water
DO	=	Dissolved Oxygen content of water

Re-Aeration Models Development

Model 1

Model for the prediction of K_2 using stream hydrodynamic data was obtained. The K_2 model was developed using Multiple Linear Regression with K_2 (dependent variable) measured in the field. U and H were used as independent variables to the model.

$K_2 = \frac{CU^n}{H^m}$, hence the choice of velocity (U) and depth (H) only.

The K_2 was computed based on the general form of the reaeration coefficient equation:

$$K_2 = f(U, H) \quad (4)$$

The above relationship can be written as:

$$K21 = \frac{aU^{a_1}}{H^{a_2}} \quad (5)$$

Where; K_{21} = reaeration coefficient determined in the field, U = Velocity of flow; H = Depth of flow or stream and a, a1 and a2 = constants obtained by multiple linear regression analysis;

Therefore, writing equation (5) in multiple linear regression equation form,

$$Y = a_0 + a_1x_1 + a_2x_2 \quad (6)$$

the equation becomes;

$$\text{In } K_{21} = \text{Ina} + a_1\text{InU} - a_2\text{InH} \quad (7)$$

The least square normal equations were derived from equation 6 and are given as

$$\sum y = na_0 + a_1 \sum x_1 - a_2 \sum x_2 \quad (8)$$

$$\sum y\, x_1 = a_0 \sum x_1 + a_1 \sum x_1^2 - a_2 \sum x_1\, x_2 \quad (9)$$

$$\sum y\, x_2 = a_0 \sum x_2 + a_1 \sum x_2\, x_1 - a_2 \sum x_2^2 \quad (10)$$

Equations 8 to 10, are solved using generated data for solving values of the variables for derivation of the model as presented in Appendix A1. From the data generated, equations 8 to 10 becomes;

$$20a_0 - 13.662a_1 + 11.108a_2 == 18.120 \quad (11)$$

$$-13.662a_0 + 10.527a_1 - 9.463a_2 = -13.056 \quad (12)$$

$$11.108a_0 - 9.463a_1 + 10.593a_2 = 10.838 \quad (13)$$

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Solving equations 11 to 13 using MATLAB software, the following results were obtained

$a_o = 0.4167$, $a_1 = -0.8760$ and $a_2 = 0.1963$, $a = 1.516$

Substituting the values of a, a_o, a_1 and a_2 in equation 5, we obtain

$$K21 = \frac{1.5169U^{-0.8760}}{H^{0.1963}} \quad (14)$$

Model 2

Model 2 is developed with the aim of incorporating mixing properties and air – water molecular interactions into the reaeration coefficient model. This concept led to the choice of velocity, depth, surface area, dispersion coefficient and kinematic viscosity in the model. The K_2 was computed based on the general form of the equation:

Then, the equation becomes;

$$K_{22} = f(U, H, As, D, \mu) \quad (15)$$

The above relationship can be written as:

$$K_{22} = \frac{aU^{a_1}A_s^{a_4}D^{a_3}}{H^{a_2}\mu^{a_6}} \quad (16)$$

Where; K_{22} = reaeration coefficient determined in the field, U = Velocity of flow; H = Depth of flow or stream; As = Surface area of Stream; D = Dispersion Coefficient of stream; μ = Kinematics viscosity and a, a_1, a_2, a_5, a4 and a_6 = = constants obtained by multiple linear regression analysis

Therefore, writing equation (8) in multiple linear regression equation form,

$$Y = a_0 + a_1X_1 + a_2X_2 + a_4X_4 + a_5X_5 + a_6X_6, \quad (17)$$

$$In\, k_2 = Ina + a_1\, InU - a_2\, InH + a_4\, In\, A_s + a_5\, InD - a_6\, In\mu \quad (18)$$

$$where\ y = Ink_2;\ x_1 = InV;\ x_2 = InH;\ x_4 = InA_s;\ x_5 = InD;\ x_6 = In\, V_k$$

The least square normal equations were derived from equation 17 and are given as

$$\sum y = na_0 + a_1\sum x_1 + a_2\sum x_2 + a_4\sum x_4 + a_5\sum x_5 + a_6\sum x_6 \quad (19)$$

$$\sum y\, x_1 = a_0\sum x_1 + a_1 \sum x_1^2 + a_2\sum x_1 x_2 + a_4\sum x_1 x_4 + a_5\sum x_1 x_5 + a_6\sum x_1 x_6 \quad (20)$$

$$\sum y\, x_2 = a_0\sum x_2 + a_1 \sum x_2 x_1 + a_2\sum x_2^2 + a_4\sum x_2 x_4 + a_5\sum x_2 x_5 + a_6\sum x_2 x_6 \quad (21)$$

$$\sum y\, x_4 = a_0\sum x_4 + a_1 \sum x_4x_1 + a_2\sum x_4 x_2 + a_4\sum x_4^2 + a_5\sum x_4 x_5 + a_6\sum x_4 x_6 \quad (22)$$

$$\sum y\, x_5 = a_0\sum x_5 + a_1 \sum x_5x_1 + a_2\sum x_5 x_2 + a_4\sum x_5 x_4 + a_5\sum x_5^2 + a_6\sum x_5 x_6 \quad (23)$$

$$\sum y\, x_6 = a_0\sum x_6 + a_1 \sum x_6x_1 + a_2\sum x_6 x_2 + a_4\sum x_6 x_4 + a_6\sum x_5 x_6 + a_6\sum x_6^2 \quad (24)$$

Equations 19 to 24 are solved using generated data for solving values of the variables for derivation of the model as presented in Appendix A2. From the data generated, equations 19 to 24 becomes;

$$10a_0 - 6.831a_1 - 5.554a_2 + 69.24a_4 - 55.759a_5 + 1.601a_6 == 11.269 \quad (25)$$

$$-6.831a_0 + 5.264a_1 + 4.732a_2 - 48.878a_4 + 38.686a_5 - 1.091a_6 == -7.563; \quad (26)$$

$$5.554a_0 - 4.732a_1 - 5.297a_2 + 41.842a_4 - 31.906a_5 + 0.875a_6 = 6.10 \quad (27)$$

$$69.24a_0 - 48.878a_1 - 41.842a_2 + 484.907a_4 - 387.658a_5 + 11.062a_6 = 77.653 \quad (28)$$

$$-55.759a_0 + 38.686a_1 + 31.906a_2 - 387.658a_4 + 311.509a_5 - 8.925a_6 = -62.699 \quad (29)$$

$$-1.601a_0 + 1.091a_1 + 0.875a_2 - 11.062a_4 + 8.925a_5 - 0.258a_6 = -1.803 \quad (30)$$

Solving equations 25 to 30 using MATLAB software, the following results were obtained

$a_o = 2.7653$, $a_1 = 0.2746$ and $a_2 = -0.5943$, $a_4 = -0.4493$, $a_5 = -0.2956$, $a_6 = -1.9878$, $a = 15.8833$

Substituting the values of a, a_o, a_1, a_2, a_4, a_5 and a_6 in equation 16, we obtained

$$K_{22} = \frac{15.8833U^{0.2746.}A_s^{-0.4493}D^{-0.2956}}{H^{-0.5943}\mu^{-1.9878}} \quad (31)$$

Model 3

Model 3 is developed with the aim of incorporating mixing properties into the re-aeration constant calculation. This was the major focus of the study. The K_2 was computed based on the general form of the equation:

$$K_{22} = f(U, H, D, \mu) \quad (32)$$

The above relationship can be written as:

$$K_{23} = \frac{aU^{a_1}D^{a_3}}{H^{a_2}\mu^{a_4}} \quad (33)$$

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where; K_{23} = reaeration coefficient determined in the field, U = Velocity of flow; H = Depth of flow or stream; D = Dispersion Coefficient of stream; μ = Kinematics viscosity.
Therefore, writing equation (33) in multiple linear regression equation form,

$$Y = a_0 + a_1X_1 + a_2X_2 + a_3X_3 + a_4X_4 \quad (34)$$

Equation (34) becomes

$$\text{In}K_2 = \text{Ina} + a_1\text{In}U - a_2\text{In}H + a_3\text{In}D - a_4\text{In}\mu \quad (35)$$

$where\ y = Ink_2;\ x_1 = InU;\ x_2 = InH;\ x_4 = InA_s;\ x_5 = InD;\ x_6 = In\mu$ The least square normal equations were derived from equation 17 and are given as

$$\sum y = na_0 + a_1\sum x_1 + a_2\sum x_2 + a_5\sum x_5 + a_6\sum x_6 \quad (37)$$

$$\sum y\, x_1 = a_0\sum x_1 + a_1\sum x_1^2 + a_2\sum x_1\, x_2 + a_5\sum x_1\, x_5 + a_6\sum x_1\, x_6 \quad (38)$$

$$\sum y\, x_2 = a_0\sum x_2 + a_1\sum x_2\, x_1 + a_2\sum x_2^2 + a_5\sum x_2\, x_5 + a_6\sum x_2\, x_6 \quad (39)$$

$$\sum y\, x_5 = a_0\sum x_5 + a_1\sum x_5 x_1 + a_2\sum x_5\, x_2 + a_5\sum x_5^2 + a_6\sum x_5\, x_6 \quad (40)$$

$$\sum y\, x_6 = a_0\sum x_6 + a_1\sum x_6 x_1 + a_2\sum x_6\, x_2 + a_5\sum x_6\, x_5 + a_6\sum x_6^2 \quad (41)$$

Equations 37 to 41 are solved using generated data for solving values of the variables for derivation of the model as presented in Appendix A3. From the data generated, equations 37 to 41 becomes;

$$10a_0 - 6.831a_1 + 5.554a_2 - 55.759a_5 - 1.601a_6 == 11.269 \quad (42)$$

$$-6.831a_0 + 5.264a_1 - 4.732a_2 + 38.686a_5 - 1.091a_6 == -7.563; \quad (43)$$

$$5.554a_0 - 4.732a_1 + 5.297a_2 - 31.906a_5 - 0.875a_6 = 6.10 \quad (44)$$

$$-55.759a_0 + 38.686a_1 - 31.906a_2 + 311.509a_5 + 8.925a_6 = -62.699 \quad (45)$$

$$-1.601a_0 + 1.091a_1 - 0.875a_2 + 8.925a_5 + 0.258a_6 = -1.803 \quad (46)$$

Solving equations 42 to 46 using MATLAB software, the following results were obtained
a_o = 2.7653, a_1 = 0.2746 and a_2 = -0.5943, a4 = -0.4493, a5 = -0.2956, a6 = -1.9878, a = 15.8833
Substituting the values of a, a_o, a_1, a_2, a_5 and a_6 in equation 33, we obtained

$$K_{23} = \frac{7.62U^{0.2017}.D^{0.1255}}{H^{0.0629}\mu^{0.6312}} \quad (47)$$

A. Calibration and Validation of K_2 Models

Statistical approaches were used to find the goodness/adequacy of the formulated model. The commonly used performance evaluation statistics (root mean square error (*RMSE*) and coefficient of determination (CoD) were used in this work to calibrate the model. The root mean square error (*RMSE*) and coefficient of determination (CoD) of the models were solved using the SPSS software.

IV. RESULTS AND DISCUSSION

Table 2. A: Reaeration Constant of Mmubete Stream at The Different Sampling Stations from Field Investigation (Wet Season)

Temp	DO	DOs	DOs-DO	Depth	K_L	Surf area	Volume	K_2
28.4	4.55	7.866	3.316	0.700	2.3212	235.000	164.5	3.316
27.9	5.09	7.946	2.856	0.810	2.31336	396.000	320.76	2.856
27.33	4.48	8.0372	3.5572	1.420	5.051224	610.000	866.2	3.5572
26.77	4.37	8.1268	3.7568	1.830	6.874944	815.000	1491.45	3.7568
27.07	4.82	8.0788	3.2588	1.770	5.768076	1050.000	1858.5	3.2588
26.5	5.37	8.17	2.8	1.960	5.488	1395.000	2734.2	2.8
26.33	5.39	8.1972	2.8072	2.690	7.551368	1585.000	4263.65	2.8072
27.23	5.61	8.0532	2.4432	2.510	6.132432	2065.000	5183.15	2.4432
27.57	4.49	7.9988	3.5088	2.580	9.052704	2125.000	5482.5	3.5088
27.07	5.26	8.0788	2.8188	2.900	8.17452	2495.000	7235.5	2.8188

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Table 2. B: Reaeration Constant of Mmubete Stream at The Different Sampling Stations from Field Investigation (Dry Season)

Temp	DO	DOs	DOs-DO	Depth	K_L	Surf area	Volume	K_2
29.17	5.34	7.7428	2.4028	0.700	1.68196	235.000	164.5	2.4028
28.43	6.87	7.8612	0.9912	0.810	0.802872	396.000	320.76	0.9912
27.9	6.48	7.946	1.466	1.420	2.08172	610.000	866.2	1.466
28	6.97	7.93	0.96	1.830	1.7568	815.000	1491.45	0.96
26.83	6.03	8.1172	2.0872	1.770	3.694344	1050.000	1858.5	2.0872
27.4	5.41	8.026	2.616	1.960	5.12736	1395.000	2734.2	2.616
27.5	5.33	8.01	2.68	2.690	7.2092	1585.000	4263.65	2.68
27.8	5.25	7.962	2.712	2.510	6.80712	2065.000	5183.15	2.712
27.27	5.49	8.0468	2.5568	2.580	6.596544	2125.000	5482.5	2.5568
28	5.15	7.93	2.78	2.900	8.062	2495.000	7235.5	2.78

Table 3: Reaeration Constant of Mmubete Stream at the Different Sampling Stations Using Newly Developed Model 1

Velocity	Depth	K2
0.6	0.7	2.545261
0.739	0.81	2.060713
0.681	1.42	1.982689
0.634	1.83	2.008335
0.51	1.77	2.446115
0.45	1.96	2.675479
0.44	2.69	2.564252
0.42	2.51	2.707467
0.38	2.58	2.93964
0.35	2.9	3.087545

Table 4: Reaeration Constant of Mmubete Stream at the Different Sampling Stations using Newly Developed Model 2

Surface Area (m2)	Velocity (m/s)	Depth (m)	Dispersion coefficient (m/s^2)	Kinematic Viscosity (m/s^2)	K_2
235.000	0.600	0.700	0.005	0.836	3.320455
396.000	0.739	0.810	0.006	0.854	2.978175
610.000	0.681	1.420	0.005	0.854	3.429917
815.000	0.634	1.830	0.005	0.854	3.506479
1050.000	0.510	1.770	0.004	0.854	3.081873
1395.000	0.450	1.960	0.003	0.873	3.018804
1585.000	0.440	2.690	0.003	0.854	3.29488
2065.000	0.420	2.510	0.003	0.836	2.6913
2125.000	0.380	2.580	0.003	0.854	2.826124
2495.000	0.350	2.900	0.003	0.854	2.823562

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Table 5: Reaeration constant of Mmubete stream at the different sampling stations using newly developed model 3

VEL (m/s)	DEPTH (m)	DISP (m/s^2)	K. VIS (m/s^2)	K2
0.600	0.700	0.005	0.836	3.996657943
0.739	0.810	0.006	0.854	4.181651209
0.681	1.420	0.005	0.854	3.930047967
0.634	1.830	0.005	0.854	3.778387402
0.510	1.770	0.004	0.854	3.526066479
0.450	1.960	0.003	0.873	3.316550383
0.440	2.690	0.003	0.854	3.272482632
0.420	2.510	0.003	0.836	3.281937065
0.380	2.580	0.003	0.854	3.12741393
0.350	2.900	0.003	0.854	3.022075312

The reaeration coefficient of the stream as determined using the field methods and empirical models are presented in the Tables 2 to 5. The reaeration coefficient of the stream as determined in the field is presented in Tables 2a and 2b. The reaeration coefficient of the stream as determined by the newly developed model I is presented in table 3. The reaeration coefficient of the stream as determined by the newly developed model II is presented in table 4. The reaeration coefficient of the stream as determined by the newly developed model III is presented in table 5. From tables 2a and 2b above, the field reaeration coefficient of Mmubete stream ranges from 2.4432d-1 to 3.7568d-1 in the wet season and 0.96d-1 to 2.712d-1 in the dry season. From table 3, the reaeration coefficient of the stream ranges from 1.983d-1 to 3.088d-1 using the model 1. From table 4, the reaeration coefficient of the stream ranges from 1.983d-1 to 3.5065d-1 using the model 2. From table 4, the reaeration coefficient of the stream ranges from 3.0221d-1 to d-1 4.1817using the model 3.

Table 6: Regression analysis of data for the prediction of K2 result using model 1

Variables	B	SE	t	P	95%CI
Constant	5.119	.465	11.008	.000	[4.020,6.219]
Velocity	-4.014	.560	-7.173	.000	[-5.338, -2.691]
Depth	-.276	.098	-2.819	.026	[-0.507, -0.044]

Table 7: Model summary of regression analysis of data for predicting K2 using Model 1

Model Summary[c]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
Velocity	.927[a]	.860	.842	.15221	
2	.967[b]	.934	.916	.11135	.754

Tables 6 and 7 show the impact of velocity and depth in predicting K_2. The R^2 value of 0.934 reveals that the predictor explained 93% variance in the dependent variable (K_2) with $F(2, 7)= 49.88$, $\rho=0.000$ with standard error of 0.11135. The findings reveal that velocity and depth negatively predicted K_2 ($\beta=-1.409$, $\rho<0.05$, $\rho=0.000$) ($\beta=-0.554$, $\rho<0.05$, $\rho=0.026$) respectively and they are statistically significant.

Table 8: Regression Analysis of Data for the Prediction of K2 result using Model 2

Variable	β	SE	T	ρ	95%CI	
(Constant)	55	16.411	1.557	.194	-20.008	71.118
Surface area(m^2)	0.000	.001	-.427	.691	-.003	.002
Velocity (m/s)	-9.084	7.321	-1.241	.282	-29.411	11.242
Depth (m)	-1.704	.843	-2.020	.113	-4.045	.638
Dispersion coefficient (m/s^2)	710.918	769.640	.924	.408	-1425.946	2847.782
Kinematic viscosity (m/s^2)	-21.035	19.272	-1.091	.336	-74.543	32.474

Table 9: Model summary of regression analysis of data for predicting K2 using Model 2

Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics					Durbin-Watson
					R Square Change	F Change	df1	df2	Sig. F Change	
1	.966[a]	.934	.851	.549694	.934	11.314	5	4	.018	1.726

a. Predictors: (Constant), kinematic viscosity (m/s2), velocity (m/s), depth (m), surface area(m2), dispersion coe (m/s2); b. dependent variable: k2

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Tables 8 and 9 above show the impact of surface area, velocity, depth, dispersion coefficient and kinematic viscosity in predicting K_2. The R^2 value of 0.934 revealed that the predictors explained 93.4% variance in the dependent variable (K_2) with F(5, 9)= 11.314, ρ=0.018.The R^2 value of 0 .934 and standard error of 0.549694 revealed that all the variables contributed to the prediction of K_2. The findings revealed that the predictors positively predicted $K_2$and it is statistically significant P-value less than 0.05.

Table 10: Regression Analysis of Data for the Prediction of K_2 Result using Model 3

Variable		SE	T	ρ	95%CI	
(Constant)	6.038	.552	10.933	.000	4.687	7.390
Velocity (m/s)	1.991	.102	19.519	.000	1.742	2.241
Depth (m)	-.181	.018	-10.052	.000	-.225	-.137
Kinematic Viscosity	-3.736	.658	-5.680	.001	-5.345	-2.126

Table 11: Model Summary of Regression Analysis of Data for Predicting K_2 using Model 3

Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics					Durbin-Watson
					R Square Change	F Change	df1	df2	Sig. F Change	
1	.999[a]	.998	.997	.022008	.998	750.233	4	5	.000	2.267

a. predictors: (constant), kinematic viscosity (m/s^2), velocity (m/s), depth (m), dispersion coefficient (m/s^2)
b. dependent variable: k_2

Tables 10 and 11 show the impact of Velocity, depth and Kinematic viscosity in predicting K_2 (Other variables are forced as constants). The R^2 value of 0.998 revealed that the predictors explained 99.8% variance in the dependent variable (K_2) with F(3, 9)= 1199.698, ρ=0.000.. The R^2 value of 0.998 revealed that the predictors explained 99.8% variance in the dependent variable (K_2) with F(5, 9).The R^2 value of 0 .998 and standard error of .022008 revealed that all the variables contributed to the prediction of K_2. The findings revealed that the predictors positively predicted K_2 and it is statistically significant P-value less than 0.05.

V. CONCLUSION

The hydrodynamic properties of the stream (kinematic viscosity, dispersion coefficient, surface area and velocity are important stream properties for the determination of reaeration coefficient of the streams. Most studies make use of only velocity and depth or hydraulic radius to predict reaeration coefficient of streams. Besides velocity and depth, kinematic viscosity, surface area and dispersion coefficient of a stream are the major contributors for the prediction of re-aeration coefficient of streams. Also, statistical analysis of the results of the various newly developed models indicates that the kinematic viscosity, surface area and dispersion coefficient have significant impact on the re-aeration coefficient.

DECLARATION

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Ethical Approval and Consent to Participate	The article does not require ethical approval and consent to participate with evidence.
Availability of Data and Material/ Data Access Statement	Not relevant.
Authors Contributions	All authors have equal participation in this article.

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Appendix A

A1: Table1: Data for the derivation of model 1

D.1: DATA FOR DERIVATION OF MODEL 1 FOR PREDICTING K2											
	K2	VEL	DEPTH	LNK2(Y)	LNV(X1)	LNH(X2)	YX1	YX2	X1X1	X2X2	X2X1
	3.316	0.600	0.700	1.199	-0.511	-0.357	-0.612	-0.428	0.261	0.127	0.182
	2.856	0.739	0.810	1.049	-0.302	-0.211	-0.317	-0.221	0.091	0.044	0.064
	3.557	0.681	1.420	1.269	-0.384	0.351	-0.488	0.445	0.148	0.123	-0.135
	3.757	0.634	1.830	1.324	-0.456	0.604	-0.603	0.800	0.208	0.365	-0.275
	3.259	0.510	1.770	1.181	-0.673	0.571	-0.795	0.675	0.453	0.326	-0.384
	2.800	0.450	1.960	1.030	-0.799	0.673	-0.822	0.693	0.638	0.453	-0.537
	2.807	0.440	2.690	1.032	-0.821	0.990	-0.847	1.021	0.674	0.979	-0.812
	2.443	0.420	2.510	0.893	-0.868	0.920	-0.775	0.822	0.753	0.847	-0.798
	3.509	0.380	2.580	1.255	-0.968	0.948	-1.215	1.190	0.936	0.898	-0.917
	2.819	0.350	2.900	1.036	-1.050	1.065	-1.088	1.103	1.102	1.134	-1.118
	2.403	**0.600**	**0.700**	**0.877**	**-0.511**	**-0.357**	**-0.448**	**-0.313**	**0.261**	**0.127**	**0.182**
	0.991	**0.739**	**0.810**	**-0.009**	**-0.302**	**-0.211**	**0.003**	**0.002**	**0.091**	**0.044**	**0.064**
	1.466	**0.681**	**1.420**	**0.383**	**-0.384**	**0.351**	**-0.147**	**0.134**	**0.148**	**0.123**	**-0.135**
	0.960	**0.634**	**1.830**	**-0.041**	**-0.456**	**0.604**	**0.019**	**-0.025**	**0.208**	**0.365**	**-0.275**
	2.087	**0.510**	**1.770**	**0.736**	**-0.673**	**0.571**	**-0.495**	**0.420**	**0.453**	**0.326**	**-0.384**
	2.616	**0.450**	**1.960**	**0.962**	**-0.799**	**0.673**	**-0.768**	**0.647**	**0.638**	**0.453**	**-0.537**
	2.680	**0.440**	**2.690**	**0.986**	**-0.821**	**0.990**	**-0.809**	**0.976**	**0.674**	**0.979**	**-0.812**
	2.712	**0.420**	**2.510**	**0.998**	**-0.868**	**0.920**	**-0.865**	**0.918**	**0.753**	**0.847**	**-0.798**
	2.557	**0.380**	**2.580**	**0.939**	**-0.968**	**0.948**	**-0.908**	**0.890**	**0.936**	**0.898**	**-0.917**
	2.780	**0.350**	**2.900**	**1.022**	**-1.050**	**1.065**	**-1.073**	**1.089**	**1.102**	**1.134**	**-1.118**
SUM	*52.375*	*10.408*	*38.340*	*18.120*	*-13.662*	*11.108*	*-13.056*	*10.838*	*10.527*	*10.593*	*-9.463*

A2: Table 2: Data for the derivation of model 2

	K2 (Y)	As (X4)	VEL (X1)	DEPTH (X2)	DISPERSION (X5)	K. VISCOSTY (X6)	LNK(Y)	LNU(X1)	LNH(X2)	LNAs(X4)	LND(X5)	LNVk(X6)	X1X1	X2X2	X4X4	X5X5
	3.316	235.000	0.600	0.700	0.005	0.836	1.199	-0.511	-0.357	5.460	-5.404	-0.180	0.261	0.127	29.807	29.200
	2.856	396.000	0.739	0.810	0.006	0.854	1.049	-0.302	-0.211	5.981	-5.195	-0.158	0.091	0.044	35.777	26.991
	3.557	610.000	0.681	1.420	0.005	0.854	1.269	-0.384	0.351	6.413	-5.277	-0.158	0.148	0.123	41.132	27.847
	3.757	815.000	0.634	1.830	0.005	0.854	1.324	-0.456	0.604	6.703	-5.349	-0.158	0.208	0.365	44.933	28.607
	3.259	1050.000	0.510	1.770	0.004	0.854	1.181	-0.673	0.571	6.957	-5.566	-0.158	0.453	0.326	48.394	30.983
	2.800	1395.000	0.450	1.960	0.003	0.873	1.030	-0.799	0.673	7.241	-5.691	-0.136	0.638	0.453	52.427	32.392
	2.807	1585.000	0.440	2.690	0.003	0.854	1.032	-0.821	0.990	7.368	-5.714	-0.158	0.674	0.979	54.292	32.648
	2.443	2065.000	0.420	2.510	0.003	0.836	0.893	-0.868	0.920	7.633	-5.760	-0.180	0.753	0.847	58.261	33.182
	3.509	2125.000	0.380	2.580	0.003	0.854	1.255	-0.968	0.948	7.662	-5.860	-0.158	0.936	0.898	58.699	34.345
	2.819	2495.000	0.350	2.900	0.003	0.854	1.036	-1.050	1.065	7.822	-5.943	-0.158	1.102	1.134	61.184	35.315
SUM	***31.123***	**12771.000**	**5.204**	**19.170**	**0.039**	**8.521**	**11.269**	**-6.831**	**5.554**	**69.240**	**-55.759**	**-1.601**	**5.264**	**5.297**	**484.907**	**311.509**

X6X6	YX1	YX2	YX4	YX5	YX6	X1X2	X1X4	X1X5	X1X6	X2X4	X2X5	X2X6	X4X5	X4X6	X5X6
0.032301	-0.612357	-0.42757	6.544729	-6.47771	-0.21545	0.182199	-2.7889	2.760337	0.091808	-1.9473	1.927357	0.064103	-29.5018	-0.98122	0.971176
0.024945	-0.317405	-0.22114	6.277028	-5.45207	-0.16575	0.063734	-1.80912	1.57136	0.04777	-1.26041	1.094761	0.033282	-31.0753	-0.94471	0.820553
0.024945	-0.487531	0.444974	8.138511	-6.69643	-0.20042	-0.13472	-2.46401	2.027404	0.06068	2.248923	-1.85043	-0.05538	-33.8441	-1.01295	0.833463
0.024945	-0.603158	0.799853	8.872122	-7.07918	-0.20905	-0.27539	-3.05469	2.437372	0.071975	4.050844	-3.23222	-0.09545	-35.8524	-1.05871	0.844758
0.024945	-0.795462	0.674532	8.218178	-6.57568	-0.18659	-0.38447	-4.68415	3.747968	0.106349	3.972045	-3.17818	-0.09018	-38.7215	-1.09873	0.879132
0.018478	-0.822159	0.692877	7.455114	-5.85993	-0.13996	-0.53735	-5.78171	4.544595	0.108545	4.872555	-3.82997	-0.09148	-41.2091	-0.98425	0.773651
0.024945	-0.847406	1.021392	7.605508	-5.89775	-0.16302	-0.81239	-6.04926	4.690946	0.129667	7.291276	-5.65407	-0.15629	-42.1015	-1.16376	0.90245
0.032301	-0.774946	0.822097	6.818523	-5.14577	-0.16055	-0.79835	-6.62153	4.997109	0.155911	7.024413	-5.30115	-0.1654	-43.9681	-1.37182	1.035279
0.024945	-1.214583	1.189735	9.617317	-7.35645	-0.19826	-0.91707	-7.41317	5.670465	0.152821	7.261514	-5.55446	-0.14969	-44.8999	-1.21007	0.925604
0.024945	-1.087942	1.103372	8.106072	-6.15846	-0.16368	-1.11776	-8.21175	6.238751	0.16581	8.328214	-6.32723	-0.16816	-46.4839	-1.23542	0.938593
0.257698	**-7.562949**	**6.100129**	**77.6531**	**-62.6994**	**-1.80272**	**-4.73156**	**-48.8783**	**38.68631**	**1.091336**	**41.84208**	**-31.9056**	**-0.87465**	**-387.658**	**-11.0616**	**8.924658**

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A3: Table 3: Data for the derivation of model 3

D.3: DATA FOR DERIVATION OF MODEL 3 FOR PREDICTING K2

K2 (Y)	VEL (X1)	DEPTH (X2)	DISPERSION (X5)	K. VISCOSTY (X6)	LNK(Y)	LNU(X1)	LNH(X2)	LND(X5)	LNVK(X6)	X1X1	X2X2
3.316	0.600	0.700	0.005	0.836	1.199	-0.511	-0.357	-5.404	-0.180	0.261	0.127
2.856	0.739	0.810	0.006	0.854	1.049	-0.302	-0.211	-5.195	-0.158	0.091	0.044
3.557	0.681	1.420	0.005	0.854	1.269	-0.384	0.351	-5.277	-0.158	0.148	0.123
3.757	0.634	1.830	0.005	0.854	1.324	-0.456	0.604	-5.349	-0.158	0.208	0.365
3.259	0.510	1.770	0.004	0.854	1.181	-0.673	0.571	-5.566	-0.158	0.453	0.326
2.800	0.450	1.960	0.003	0.873	1.030	-0.799	0.673	-5.691	-0.136	0.638	0.453
2.807	0.440	2.690	0.003	0.854	1.032	-0.821	0.990	-5.714	-0.158	0.674	0.979
2.443	0.420	2.510	0.003	0.836	0.893	-0.868	0.920	-5.760	-0.180	0.753	0.847
3.509	0.380	2.580	0.003	0.854	1.255	-0.968	0.948	-5.860	-0.158	0.936	0.898
2.819	0.350	2.900	0.003	0.854	1.036	-1.050	1.065	-5.943	-0.158	1.102	1.134
31.123	**5.204**	**19.170**	**0.039**	**8.521**	**11.269**	**-6.831**	**5.554**	**-55.759**	**-1.601**	**5.264**	**5.297**

X5X5	X6X6	YX1	YX2	YX5	YX6	X1X2	X1X5	X1X6	X2X5	X2X6	X5X6
29.200	0.032	-0.612	-0.428	-6.478	-0.215	0.182	2.760	0.092	1.927	0.064	0.971
26.991	0.025	-0.317	-0.221	-5.452	-0.166	0.064	1.571	0.048	1.095	0.033	0.821
27.847	0.025	-0.488	0.445	-6.696	-0.200	-0.135	2.027	0.061	-1.850	-0.055	0.833
28.607	0.025	-0.603	0.800	-7.079	-0.209	-0.275	2.437	0.072	-3.232	-0.095	0.845
30.983	0.025	-0.795	0.675	-6.576	-0.187	-0.384	3.748	0.106	-3.178	-0.090	0.879
32.392	0.018	-0.822	0.693	-5.860	-0.140	-0.537	4.545	0.109	-3.830	-0.091	0.774
32.648	0.025	-0.847	1.021	-5.898	-0.163	-0.812	4.691	0.130	-5.654	-0.156	0.902
33.182	0.032	-0.775	0.822	-5.146	-0.161	-0.798	4.997	0.156	-5.301	-0.165	1.035
34.345	0.025	-1.215	1.190	-7.356	-0.198	-0.917	5.670	0.153	-5.554	-0.150	0.926
35.315	0.025	-1.088	1.103	-6.158	-0.164	-1.118	6.239	0.166	-6.327	-0.168	0.939
311.509	**0.258**	**-7.563**	**6.100**	**-62.699**	**-1.803**	**-4.732**	**38.686**	**1.091**	**-31.906**	**-0.875**	**8.925**

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