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Seasonal evaluation of groundwater quality around Igando dumpsites in Lagos metropolis using correlation and regression analysis.

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ABSTRACT: Correlation and Multiple linear regression analysis was used to establish the degree of relationship and variability of groundwater quality parameters around Solous 1 and 2 Dumpsites, in Igando, Lagos, for the wet and the dry seasons. The correlation between TDS and other hydrochemical parameters which constituted the independent variables were positive, with significantly high positive correlation exhibited between TDS and EC for the wet season. For the dry season, the correlation between TDS and other groundwater quality parameters (EC, NO_3^- and Cl^-) was positive, while its correlation with Zn^{2+} and Fe^{2+} was negative. The results of the multiple linear regressions for the wet and the dry seasons indicate that the model accounts for 96.8 percent and 93.9 percent, respectively of the variance of TDS concentration of groundwater around the dumpsites.@JASEM

Dumpsites and landfills alike may pose a myriad of environmental problems, the most prominent of which is groundwater contamination. This risk is particularly high for groundwater within and around dumpsites with no leachate control and collection facilities. This situation is however not restricted to dumpsites that lack leachate control facilities, as groundwater around landfills with bottom liners and leachate collection systems are also vulnerable to contamination from leachate especially if there are issues of inadequate design and construction, or problems of maintenance (Bjerg, Albrechtsen, Kjelsen & Christensen, 2003).

At the Solous dumpsites in the Igando area of Lagos Metropolis, there are no environmental cautionary measures put in place by the Lagos State Waste Management Authority (LAWMA), hence the need for information on the status of groundwater quality around the dumpsites. One of the ways in which this can be achieved is through the characterisation of groundwater quality and the establishment of the degree of relationship among different water quality parameters in order to assist in groundwater quality monitoring and prediction. Due to the multivariate nature of groundwater quality and the need to obtain pertinent information from the available hydrochemical datasets, correlation and multiple linear regression analysis were used as statistical tools for this study.

MATERIALS AND METHODS

Study Area: Solous 1 and 2 Dumpsites (Fig. 1) are located between 6^0 34′17.47′′N; 3^0 15′16.93′′E and 6^0 34′ 13.94′′N; 3^0 15′ 08.94′′E and between 6^0 34′19.37′′N; 3^0 15′05.96′′E and 6^0 34′ 15.68′′N; 3^0 15′ 01.31′′E, respectively. Both dumpsites are located opposite each other along LASU-Igando road, in the Alimosho Local Government Area of Lagos.

Climate: The climate of Igando and its environs is of the warm tropical type, having little seasonal variation. Mean annual temperature is around 30^0C with narrow diurnal and annual ranges while humidity is about 75 percent with a steady vapour pressure.

Hydrogeology and Groundwater Supply: Solous dumpsites and environs are made up semi-permeable to impermeable materials of variable thickness. The area's hydrogeological profile is composed of a top layer of lateritic clay and thick strata of clay underlain by fine grained sand. The basal sand and the first aquifer horizon are underlain by clayey sand of extensive thickness.

At Igando, the Solous dumpsites environs in particular, groundwater constitutes the main source of water supply. This is due to the inadequate coverage of the area by the Igando mini-waterworks supply network, and the demand for water outweighing the supply from the mini-waterworks. The inadequate supply of water by the mini-waterworks (which also depends on groundwater) is attributed to its inability to produce at the installed capacity. The mini-water works has an installed capacity of $1.0x10^6$litres/day but is only able to produce $0.4x10^6$litres/day, i.e., 40% of installed capacity.

Groundwater Sampling and Analytical Methods: In order to determine seasonal variations of groundwater quality in the vicinity of the two dumpsites, fifteen groundwater samples each were collected for the wet and dry seasons, in November, 2010 and March, 2011 respectively. Sampling and analytical procedures of the groundwater were done in accordance with standard methods of water and waste water analysis (APHA, 1992). The analysed hydrochemical parameters include Total Dissolved Solids (TDS), Electrical Conductivity (EC), Nitrate (NO_3^-), Chloride (Cl^-), Zinc (Zn^{2+}) and Iron (Fe^{2+}). TDS and EC were measured in-situ using HM Digital EC/TDS/TEMP COM-100 Meter. Cl^- was analysed in the laboratory through silver-nitrate titration with

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potassium chromate as an indicator, while NO_3^- was analysed using spectronic 20D+. Zn^{2+} and Fe^{2+} was analysed using Perkin-Elmer atomic absorption spectrophotometer (AAS).

Statistical Techniques: The correlation and regression analysis module of Statistical Package for the Social Sciences Version 17 (SPSS Inc, 2008) was utilised. For correlation analysis, Pearson's product moment correlation was employed while for the regression analysis, the Simultaneous Method (i.e., the Enter Method in SPSS) of the multiple linear regression was adopted.

Pearson's product moment correlation coefficient is stated as:

$$r = \frac{\Sigma xy}{N\sigma_x\sigma_y} \quad \text{----------} \ (1)$$

Where

r = product moment correlation coefficient x = (X-X); y = (Y-Y); σ_x = Standard deviation of series x; σ_y = Standard deviation of series y; N= No of pairs of observations.

The multiple linear regression model is stated as:

$$Y_i = \beta_0 + \beta_1 x_{1i} + \beta_2 x_{2i} + \text{-------} \ \beta_q x_{qi} + \varepsilon_i \ \text{------------} \ (2)$$

where:

Y_i = dependent variable predicted by regression model. β_0 = intercept. β_1 = ith coefficient of xi

xi= ith independent variable from total set of q variables. ε_i = random errors

The correlation and multiple linear regression analysis was conducted to investigate the relationship between TDS and other groundwater quality parameters. EC, NO_3^-, Cl^-, Zn^{2+} and Fe^{2+} constituents of the groundwater were considered as independent or predictor variables while TDS was considered as the dependent or criterion variable.

RESULTS AND DISCUSSION

The summary of the statistics of the groundwater quality parameters utilised for the correlation and multiple regression analysis is presented in Table 1. The degree of linear relationship between any pair of the hydrochemical parameters as computed by the Pearson's product moment correlation for the wet and dry seasons is presented in the correlation matrix shown in Tables 2 and 3, while in Table 4, the summary of the multiple linear regression for both seasons are presented.

As shown in Table 1, the concentration of TDS in the groundwater varied between 13 and 488mg/L during the wet season and between 12.80 and 382mg/L during the dry season. For Electrical Conductivity (EC), the values ranged between 26.00 and 712µS/cm during the wet season and between 26.40 and 690µS/cm during the dry season.

For NO_3^- the mean concentration was 2.67mg/L during the wet season and 15.12mg/L during the dry season. For Zn^{2+}, Cl^- and Fe^{2+}, the mean concentration was of the order wet season >dry season, with Zn^{2+} recording a mean concentration of 3.43mg/L during the wet season and 0.35mg/L during the dry season. Mean Cl^- concentration in the groundwater, was 121.27mg/L and 161.33mg/L for the wet and dry seasons, respectively. Wet season mean Fe^{2+} was 0.71mg/L while it was 0.28mg/L in the dry season.

As shown in Table 2, the correlation between TDS and other groundwater quality parameters around the dumpsites was positive, with a significantly high positive correlation exhibited between TDS and EC (r = 0.976) during the wet season. In the dry season, significantly high positive correlation was also recorded between TDS and EC, with r=0.969.

For NO_3^- the degree of positive correlation with TDS ranged from weak (r = 0.263) in the wet season to very weak (r = 0.039) in the dry season. Association between TDS and Zn^{2+}, and TDS and Fe^{2+}, was positive in the wet season but negative in the dry season. In the wet season, a weak positive correlation was established between TDS and Zn^{2+}, while a very weak positive correlation was established between TDS and Fe^{2+}. Association between TDS and Zn^{2+}, in the dry season, was weak at r = -0.210, while the negative relationship between TDS and Fe^{2+} was moderate.

Furthermore, the r value (0.976) between TDS and EC (Table 2) and the coefficient of determination (r^2 = 0.95) indicate that 95 percent of the variability in TDS for the wet season can be attributed to the variability of the electrical conductivity of groundwater around the dumpsites. Similarly, the 0.969 correlation coefficient value for EC (Table 3), and the coefficient of determination (r^2 = 0.94) indicate that 94 percent of the variability in TDS during the dry season is due to the electrical conductivity of the groundwater, while 40 percent of the variability is attributable to Cl^- (r = 0.607; r^2 = 0.40)

From the summary of the multiple linear regression model for predicting TDS of the groundwater around the Solous dumpsites (Table 4), the linear regression equation for the wet and dry seasons, respectively are:

$TDS = -2.099 + 1.037EC - 0.381NO_3^- + 0.337\ Cl^- - 0.006\ Zn^{2+} + 0.112\ Fe^{2+} + \varepsilon_i$ ------- (3)

$TDS = 0.547 + 0.852EC - 0.069NO_3^- + 0.187\ Cl^- - 0.039Zn^{2+} + 0.030\ Fe^{2+} + \varepsilon_i$ ------- (4)

As also shown in Table 4 and Equation 3, the positive sign of the beta coefficients and the t-values of EC, Cl^- and Fe^{2+} indicate that a positive relationship exists between TDS and EC of the groundwater, as well as between TDS and Cl^- and Fe^{2+} constituents of the groundwater for the wet season. The high absolute value of EC (19.819) and the small P- value (0.000) suggest that EC is very important variable in the prediction of the TDS of the groundwater. Furthermore, the adjusted R Square, which is the most useful measure of the success of the model when compared with the multiple R or R Square, indicate that the model accounts for 96.8 percent of the variance in the TDS concentration of the groundwater for the wet season.

For the dry season (Table 4 and Equation 4), a positive relationship was maintained between TDS and EC, and between TDS and Cl^-, while a negative relationship was maintained between TDS and other hydrochemical parameters (NO_3^-, Zn^{2+} and Fe^{2+}). In predicting TDS for the wet season, the absolute value of t and the small P-value of the EC emphasise the major impact of EC in predicting TDS of the groundwater for the season. With regards to the variability of TDS in the groundwater during the dry season, the model indicates that 93.9 percent of the variability is due to the combined influence of EC, (NO_3^-, Cl^-, Zn^{2+} and Fe^{2+}.

In conclusion, this study has shown that significant information can be obtained from groundwater quality data through the use of correlation and multiple linear regression statistical methods. Similarly, utilisation of the regression model's power of prediction and information on the degree of association between TDS and other hydrochemical parameters provided by the correlation analysis could assist in the implementation of seasonal groundwater quality monitoring programmes around the dumpsites.

Table 1: Statistical Summary of Groundwater Quality Parameters for the Vicinity of Solous 1 and Solous 2 Dumpsites

Groundwater Quality Parameter	Minimum		Maximum		Mean		Standard Deviation		Variance	
	Wet Season	Dry Season	Wet Season	Dry Season	Wet Season	Dry Season	Wet Season	Dry Season	Wet Season	Dry Season
TDS (mg/L)	13.00	12.80	488.0	382.0	117.46	122.27	131.88	111.60	17393.51	12453.14
EC (µS/cm)	26.00	26.40	712.0	690.00	202.00	223.95	207.98	194.74	43257.28	37923.16
Cl^- (mg/L)	0.05	0.04	9.09	86.40	2.67	15.12	2.99	23.11	8.96	533.93
NO_3^- (mg/L)	30.00	16.00	470.0	548.00	121.27	161.33	140.12	171.50	19632.92	29411.81
Zn^{2+} (mg/L)	1.10	0.12	10.30	0.72	3.43	0.35	2.73	0.20	7.48	0.04
Fe^{2+} (mg/L)	0.05	0.17	2.20	0.39	0.71	0.28	0.55	0.07	0.30	0.01

Table 2: Correlation Matrix for Groundwater Quality Parameters in the Vicinity of Solous 1 and 2 Dumpsites for the Wet Season

	TDS	EC	NO_3^-	Cl^-	Zn^{2+}	Fe^{2+}
TDS	1					
EC	0.976	1				
NO_3^-	0.263	0.282	1			
Cl^-	0.205	0.172	0.925**	1		
Zn^{2+}	0.182	0.165	0.823**	0.816**	1	
Fe^{2+}	0.02	-0.097	0.397	0.415	0.492	1

** *Correlation is significant at the 0.01 level*

Table 3: Correlation Matrix for Groundwater Quality Parameters in the Vicinity of Solous 1 and 2 Dumpsites for the Dry Season

*** Correlation is significant at the 0.01 level (2-tailed)*
** Correlation is significant at the 0.05 level (2-tailed)*

	TDS	EC	NO_3^-	Cl^-	Zn^{2+}	Fe^{2+}
TDS	1					
EC	0.969**	1				
NO_3^-	0.039	0.022	1			
Cl^-	0.607*	0.516*	0.470	1		
Zn^{2+}	-0.210	-0.181	0.268	0.023	1	
Fe^{2+}	-0.510	-0.482	-0.289	-0.459	0.067	1

Table 4: Regression Statistics for Predicting Total Dissolved Solids in Groundwater within Solous 1 and 2 Dumpsites Vicinity for the Wet and Dry Seasons

Water Quality Independent/ Predictor Variable	Beta Coefficients		t-Values		Significance of t at 5% level (P-values)	
	Wet Season	Dry Season	Wet Season	Dry Season	Wet Season	Dry Season
EC	1.037	0.852	19.819	9.765	0.000	0.000
NO_3^-	-0.381	-0.069	-2.736	0.833	0.023	0.426
Cl^-	0.337	0.187	2.543	2.027	0.032	0.073
Zn^{2+}	-0.006	-0.039	-0.063	-0.562	0.951	0.588
Fe^{2+}	0.112	-0.030	2.010	-0.374	0.075	0.717
Constant			-2.099	0.547		
Multiple R			0.990	0.980		
R Square			0.980	0.961		
Adjusted R Square			0.968	0.939		
Standard Error			23.48	27.59		
F-Test Statistics			86.505	44.016		
Overall Significance			0.000	0.000		

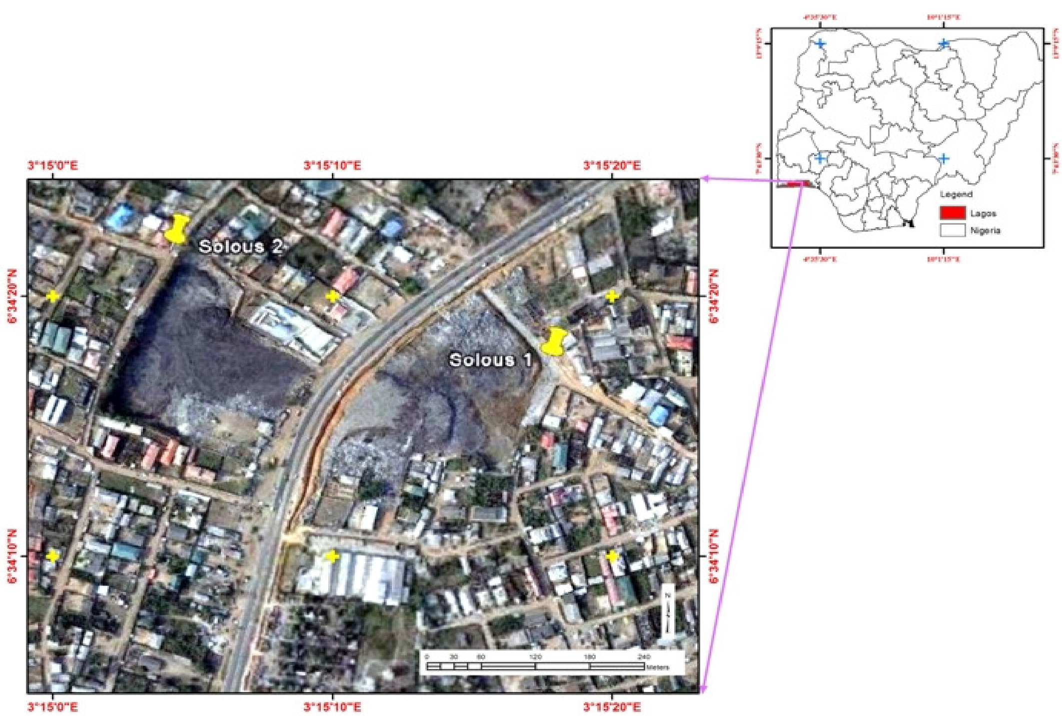

Fig.1: Solous 1 and 2 Dumpsites and Environs

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