

Water Variables Analysis Using a Concept of Principal Component Statistics in Etim Ekpo River, Niger Delta Zone, Nigeria

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ABSTRACT

Water Variables Analysis through a concept of principal component statistics (PCS) was studied in Etim Ekpo River, Niger Delta Zone, Nigeria from January, 2020 - December, 2021 at three designated stations. Seventeen water variables were studied and analysed using various prescribed standards. A total of 34 samples were collected at all stations. The principal component statistics (PCS) was employed in the analysis of the water variables. The principal components adopted were that which contained the highest percentage of the total variance of information in the original data set. The results showed that the loading factors were basically, temperature, dissolved oxygen (DO), sodium (Na), Electrical Conductivity (Ec), total suspended solids (TSS), Acidity (A), Magnesium (Mg), Total Hardness (TA), Total Dissolved Solids (TDS) Sulphate (So₄), Phosphate (Po₄-P), Total Alkalinity (TA). These could be aligned as: nutrient loading factors, organic loading factors, domestic loading factors and chemo-physical loading factors. In a nutshell, the water variable analysis tickle within the prescribed standards of various organizations, which is perfect to sustain the aquatic biota. However, the quest of anthropogenic advancement should be checked, which might increase loading factors in the system.

INTRODUCTION

Water variables as a determinant of the health status of the aquatic environment is a pertinent issue and a subject of great concern (Akpan, 2021). This has led to evolution of novel strategies in the attainment of sustainable management and policy development with regards to water resources. The remote and immediate deviation in characteristics change in water variables, which is a function of data collection and interpretation, could be achieved through the use of Principal Component Statistic (PCS).

PCS is part of multivariate statistical analysis develop to sort out basic components that explain the most of the variances within a define system (Lin & Raiko, 2010), it permits reduction dimensionality in a set of data, however the characteristic of variables which caused most effect to the variation is upheld (Garcia, 2017).

In recent studies, the PCS analysis is effectively employed to different environmental research project, ranging from aqua-environmental variables indicators (Akpan, 2021; Akpan, 2013;) to other non-aqua-environmental variables (Robu and Istrate, 2015;).

The aim of this study is to employ the concept of PCS analysis procedures analyse water variables in Etim Ekpo River, Niger Delta Zone, this will enhance knowledge of determining the most pertinent variables in the aquatic environment of the area.

Sample Collection

The sample collection was carried out on three designated stationss along the waterbody (fig.1). The collection, preservation, transportation and analysis were done as prescribed by APHA (1998).

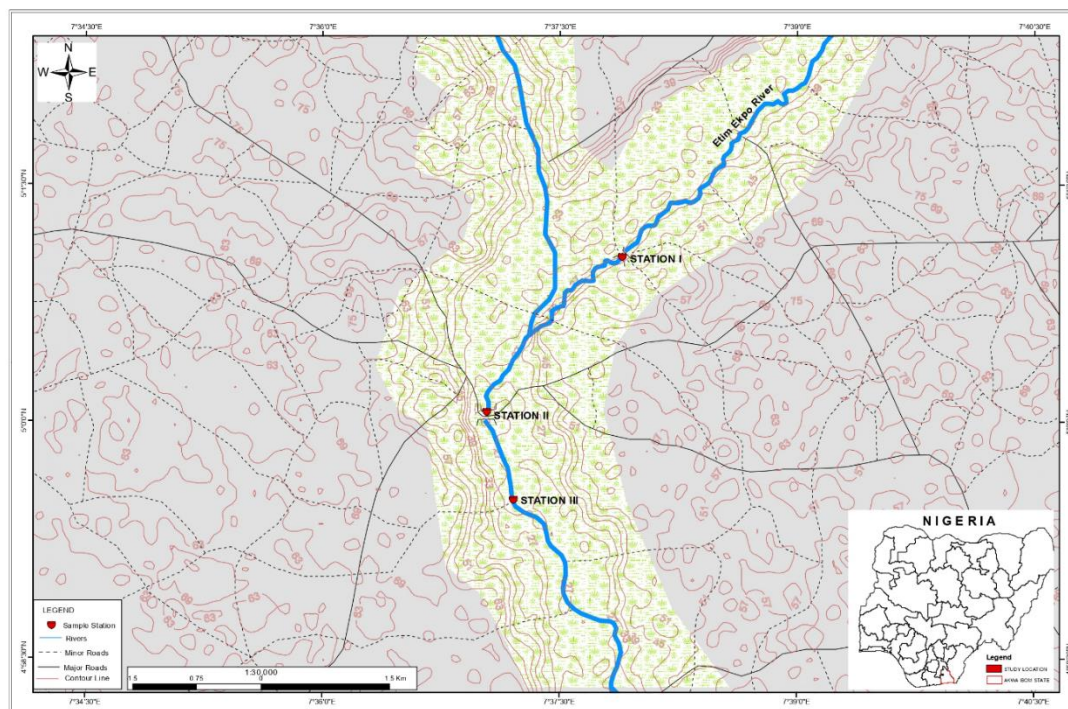


Fig 1: Map of Part of Etim Ekpo LGA showing Etim Ekpo River

Treatment of Data and Analysis

Prior to analysis, standardization was carried out because of various ranges of the concentrations each water variable. This was pertinent because the dimensions engaged to compute the distance between the object must be of similar magnitude. To minimize the dimensionality of data set and loss of vital information, the data set was sorted. The conversion of raw data into dimensionless values represented by mean zero and variance equals one was done (Garcia *et al*, 2007).

Pearson Correlation Coefficient was used to assessed the Linear Correlation between variables, this measures the degree of correlation and direction (chatfield and Collins 1980) and the PCS, which geared towards establishing the combination of some variables to know indices that describe the variation in the data with minimal loss of information (Chatfield and Collins 1980). The PCS was carried out using a statistical software, SPSS 1.5. Principal Components (PC) were ascertained to be significant with eigenvalues greater than unity and were extracted (Chatfield and Collins, 1980).

RESULT AND DISCUSSION

The result of the PCS of data gotten from the study on water variables of Etim Ekpo River is shown in Tables 1-6. PC with eigenvalues less than unity were discarded (Chatfield and Collins, 1980). Ascertained by this rule, only the first three PC (Table 1-3) were taken as it has an eigenvalue greater unity and a higher variance value, this invariably connotes that most of the variance of the original data set have been accounted for in these extracted PC.

Table 1: Seasonal Variation of Total Variance Explained in Station 1

Dry Season				Wet Season			
Component	Eigenvalues	Variance %	Cumulative %	Component	Eigenvalues	Variance %	Cumulative %
1	7.81	45.89	45.88	1	7.81	32.5	32.5
2	6.60	38.93	84.81	2	6.60	20.43	52.93
3	2.56	15.19	100.57	3	2.56	14.28	67.21
4	0.00	0.01	100.01	4	0.00	13.28	80.49
5	0.00	0.01	100.01	5	0.00	11.48	91.97
6	0.00	0.01	100.01	6	0.00	6.89	98.86
7	0.00	0.01	100.01	7	0.00	2.29	101.15
8	0.00	0.01	100.01	8	0.00	0.01	100.00
9	0.00	0.01	100.01	9	0.00	0.01	101.00
10	0.00	0.01	100.01	10	0.00	0.01	101.00
11	0.00	0.01	100.01	10	0.00	0.01	101.00
12	0.00	0.01	100.01	12	0.00	0.01	101.00
13	0.00	0.01	100.01	13	0.00	0.01	101.00
14	0.00	0.01	100.01	14	0.00	0.01	101.00
15	0.00	0.01	100.01	15	0.00	0.01	101.00
16	0.00	0.01	100.01	16	0.00	0.01	101.00
17	0.00	0.01	100.01	17	0.00	0.01	101.00

Table 2: Seasonal Variation of Total Variance Explained in Station II

Dry Season				Wet Season			
Component	Eigenvalues	Variance %	Cumulative %	Component	Eigenvalues	Variance %	Cumulative %
1	7.81	48.62	48.62	1	7.81	32.10	32.10
2	6.60	38.52	85.13	2	6.60	27.18	56.27
3	2.56	15.98	100.01	3	2.56	14.80	69.97
4	0.00	0.00	100.01	4	0.00	13.36	82.23
5	0.00	0.00	100.01	5	0.00	9.14	90.36
6	0.00	0.00	100.01	6	0.00	5.01	96.39
7	0.00	0.00	100.01	7	0.00	3.43	100
8	0.00	0.00	100.01	8	0.00	0.00	100
9	0.00	0.00	100.01	9	0.00	0.00	100
10	0.00	0.00	100.01	10	0.00	0.00	100
11	0.00	0.00	100.01	10	0.00	0.00	100
12	0.00	0.00	100.01	12	0.00	0.00	100
13	0.00	0.00	100.01	13	0.00	0.00	100
14	0.00	0.00	100.01	14	0.00	0.00	100
15	0.00	0.00	100.01	15	0.00	0.00	100
16	0.00	0.00	100.01	16	0.00	0.00	100
17	0.00	0.00	100.01	17	0.00	0.00	100

Table 3: Seasonal Variation of Total Variance Explained in Station III

Dry Season				Wet Season			
Component	Eigenvalues	Variance %	Cumulative %	Component	Eigenvalues	Variance %	Cumulative %
1	7.81	43.45	43.43	1	7.82	29.45	29.45
2	6.60	38.07	81.52	2	6.60	19.80	49.27
3	2.56	20.47	10.99	3	2.56	17.25	67.50
4	0.00	0.00	100	4	0.00	11.65	80.17
5	0.00	0.00	100	5	0.00	11.87	92.06
6	0.00	0.00	100	6	0.00	6.47	97.52
7	0.00	0.00	100	7	0.00	3.10	100.02
8	0.00	0.00	100	8	0.00	0.00	100.02
9	0.00	0.00	100	9	0.00	0.00	100.02
10	0.00	0.00	100	10	0.00	0.00	100.02
11	0.00	0.00	100	10	0.00	0.00	100.02
12	0.00	0.00	100	12	0.00	0.00	100.02
13	0.00	0.00	100	13	0.00	0.00	100.02
14	0.00	0.00	100	14	0.00	0.00	100.02
15	0.00	0.00	100	15	0.00	0.00	100.02
16	0.00	0.00	100	16	0.00	0.00	100.02
17	0.00	0.00	100	17	0.00	0.00	100.02

At station 1, at dry season, the first three components (PC₁, PC₂ and PC₃) which haboured the most variance variable had some degree of positive loadings on K, temperature BOD, TSS and

also some degree of negative loadings on TH, A, Na, Ec (Table 4). At wet season, the first three components (PC₁, PC₂ and PC₃) explained some level of positive loadings on Ca Do, TDS, A, TDS, TH and also some levels of negative loadings on TSS, Mg, Na, (Table 4).

Table 4: Seasonal Variation on Component Matrix on Station I

Dry Season				Wet Season			
Parameters	1	2	3	Parameters	1	2	3
DO (mg/l)	-0.320	0.199	-0.081	DO (mg/l)	0.348	-0.083	-0.015
BOD (mg/l)	-0.096	0.410	0.248	BOD (mg/l)	-0.170	0.238	0.320
TSS (mg/l)	-0.032	0.901	-0.012	TSS (mg/l)	-0.522	-0.141	-0.006
Mg (mg/l)	0.240	0.258	0.185	Mg (mg/l)	0.184	-0.960	-0.136
TH (mg/l)	0.231	-0.177	-0.421	TH (mg/l)	-0.051	-0.053	0.612
Cl ⁻¹ (mg/l)	0.320	0.183	0.008	Cl ⁻¹ (mg/l)	0.295	0.280	0.012
TA (mg/l)	0.335	0.128	-0.008	TA (mg/l)	0.261	-0.320	0.054
PO ₄ -P (mg/l)	0.324	-0.184	0.110	PO ₄ -P (mg/l)	0.085	-0.056	-0.461
A (mg/l)	-0.987	0.257	-0.390	A (mg/l)	0.405	-0.071	-0.125
TDS (mg/l)	-0.293	0.247	-0.041	TDS (mg/l)	-0.007	0.519	0.117
SO ₄ (mg/l)	0.328	0.130	0.077	SO ₄ (mg/l)	-0.078	-0.128	0.080
Na ⁺ (mg/l)	-0.042	-0.385	0.161	Na ⁺ (mg/l)	-0.215	-0.449	0.001
pH	-0.280	0.227	-0.185	pH	-0.280	-0.048	-0.323
Ec (μs/cm)	-0.541	-0.297	0.127	EC (μs/cm)	0.188	-0.279	0.192
K ⁺ (mg/l)	0.514	-0.196	0.100	K ⁺ (mg/l)	-0.125	-0.145	-0.326
Ca (mg/l)	0.318	0.199	0.015	Ca (mg/l)	0.409	0.155	0.064
Temperature °C	0.005	0.189	0.536	Temperature °C	-0.092	0.393	0.131

At station II during dry the season, the first three components recorded some degree of positive loadings on TA, TH, Ca, pH, K, SO₄, and BOD and that of negative loadings on A (Table 5).

In wet season, some degree of positive loadings was on Na and TDS, Temperature BOD pH, Po₄-P, TA, Cl, Do, A and TSS exhibited some levels of negative loadings and Ca (Table 5).

Table 5: Seasonal Variation on Component Matrix on Station II

Dry Season				Wet Season			
Parameters	1	2	3	Parameters	1	2	3
Temperature °C	0.196	-0.315	-0.143	Temperature °C	-0.087	0.396	0.131
pH	-0.009	0.400	0.249	pH	-0.059	-0.107	-0.489
EC (μs/cm)	-0.329	0.137	0.024	EC (μs/cm)	-0.102	0.190	0.016
Na ⁺ (mg/l)	0.268	-0.252	0.061	Na ⁺ (mg/l)	0.400	0.093	-0.107
K ⁺ (mg/l)	-0.000	-0.317	0.400	K ⁺ (mg/l)	0.235	0.235	-0.189
SO ₄ (mg/l)	-0.000	-0.317	0.400	SO ₄ (mg/l)	0.209	-0.339	0.214
PO ₄ -P (mg/l)	-0.222	-0.228	0.326	PO ₄ -P (mg/l)	0.092	-0.347	0.329
TA (mg/l)	0.521	0.140	0.119	TA (mg/l)	-0.369	0.155	-0.055
Cl ⁻¹ (mg/l)	0.270	0.222	0.194	Cl ⁻¹ (mg/l)	-0.366	0.104	0.265
TH (mg/l)	0.507	0.043	-0.299	TH (mg/l)	0.149	0.189	0.120
Mg (mg/l)	0.331	-0.033	-0.203	Mg (mg/l)	-0.286	-0.206	0.139
DO (mg/l)	-0.166	0.321	-0.218	DO (mg/l)	0.003	-0.374	0.074
A (mg/l)	0.073	0.219	-0.358	A (mg/l)	-0.382	0.193	-0.032

TDS (mg/l)	-0.272	0.165	0.014	TDS (mg/l)	0.362	0.173	0.065
BOD (mg/l)	0.179	0.400	0.473	BOD (mg/l)	0.013	0.323	0.396
TSS (mg/l)	0.011	0.075	0.201	TSS (mg/l)	0.266	0.255	-0.776
Ca (mg/l)	0.344	0.075	0.041	Ca (mg/l)	0.140	0.074	0.505

At station III during the dry season, positive loadings of various degree were noted for Na, Mg, Do, A, TDS, while Ca recorded a negative loading. In the wet season, positive loadings were noted for pH, K, Po₄, Do, BOD and negative loadings were noted for Ec, Na, TH (Table 6).

The PCS of the water variables were structured on seasonal basis and has revealed various groupings on the assessment of the water resources.

On both seasons on Station 1 loadings were mostly TSS, PO₄-P, BOD, Na, TD, TA, TH, CA and temperature (Table 4). TA, CA, TH, K, TS, SO₄, PO₄-P, BOD, Temperature, TSS, NA, TDS were the most loadings noted for Site II (Table 5). Station III recorded most loadings on A, BOD, temperature, K, PO₄-P, DO, TA, TH, TDS, Na and Ec for both seasons (Table 6).

Table 6: Seasonal Variation on Component Matrix on Station III

Dry Season				Wet Season			
Parameters	1	2	3		1	2	3
Temperature °C	0.293	-0.186	-0.220	Temperature °C	-0.265	-0.006	0.318
pH	-0.197	-0.264	0.281	pH	0.500	0.239	0.031
EC (µs/cm)	-0.376	0.008	0.004	EC (µs/cm)	0.175	0.265	-0.400
Na ⁺ (mg/l)	0.152	-0.072	0.500	Na ⁺ (mg/l)	0.215	-0.124	-0.985
K ⁺ (mg/l)	0.262	0.229	0.222	K ⁺ (mg/l)	0.032	0.500	0.064
SO ₄ (mg/l)	0.291	0.241	0.062	SO ₄ (mg/l)	0.031	0.004	0.108
PO ₄ -P (mg/l)	0.204	-0.131	-0.422	PO ₄ -P (mg/l)	0.400	0.026	0.003
TA (mg/l)	-0.178	0.329	-0.125	TA (mg/l)	0.224	-0.304	0.261
Cl ⁻ (mg/l)	-0.217	0.291	-0.177	Cl ⁻ (mg/l)	0.202	0.182	0.299
TH (mg/l)	-0.146	0.344	-0.135	TH (mg/l)	0.040	-0.400	0.316
Mg (mg/l)	0.115	0.263	0.400	Mg (mg/l)	0.291	-0.207	-0.175
DO (mg/l)	0.500	-0.026	0.193	DO (mg/l)	0.400	-0.191	-0.032
A (mg/l)	-0.07	0.373	0.114	A (mg/l)	0.051	0.254	0.183
TDS (mg/l)	0.047	0.380	-0.087	TDS (mg/l)	-0.067	0.254	0.183
BOD (mg/l)	-0.231	-0.306	0.001	BOD (mg/l)	0.176	0.165	0.500
TSS (mg/l)	-0.374	0.025	0.053	TSS (mg/l)	-0.321	-0.194	0.217
Ca (mg/l)	0.275	0.041	-0.370	Ca (mg/l)	0.219	-0.205	0.135

The loading positivity of TSS, Ec and TDS pointed to the fact that the aquatic resources has an increased level of dissolved contaminants (Akpan, 2021) and (Garcia, *et al.*, 2017), and these include; PO₄-P, Na⁺, K⁺ and SO₄, several pertinent factors could be responsible for these loading menace which may include conditions of climatic variable and factors of pH/Do due to water variables variability, which is a pointer of Agricultural and Domestic waste contamination of the water source (Akpan, 2021, Garcia *et al.*, 2017; Akpan, 2015, Abiaobo *et al.*, 2017, Akpan, 2013).

This study showed that there are various influences on the aquatic environment, as depicted by the loading factors of the variables. These include: Domestic Wastes Factors influence (TSS, BOD), Organic Materials Factors influence (K), Physico-Chemical Factor influence (DO, pH); Nutrient factor influence (SO₄, PO₄-4, Ca, Mg) and Mineral factor influence (Mg, Ec). The mineral factor influence is likely to be attributed to inputs from natural sources (Gastro *et al.*, 2007, Akpan, 2021). Most inputs of natural sources aid in the breaking down of organic materials (Shine *et al.*, 1995, Akpan, 2021), these were mostly observed in the study sites. The human (anthropogenic) inputs could be due to agricultural backups, transportation system and fishery procedures. These could likely introduce to the aquatic environment various concentration of pollutants, which will invariably kick up its pollution level (Akpan, 2021).

CONCLUSION

The principal component statistics (PCS) as used in this research showed a minimized principal component number, which vividly narrate the most variable variances of the experimental data set. It exposed that temperature, TA, TDS, TH, Ca, Na, Do, Ec, BoD and K were the most pertinent factors influencing the water variables of the aquatic environment in all seasons. Other factors which contributed various degrees of loading were Mg, A, SO₄, PO₄-P, TSS and P^H. All these influencing factors were classified into: Organic factor influence, domestic waste factor influence and physico-chemical factor influence. However, these could be attributed to human (anthropogenic) and natural sources. These are pointers to negative impact of the water variables of the study stations, therefore an all-inclusive measure, through collaboration of government and private developers in the routine checkups of the study site; and the need on educational awareness on the menace of poor practices within and without the aquatic environment should be taken as priority.

References

- A. Ilin and Raiko, T. (2010). Practical approaches to PCA in the presence of Missing values. *J. Mach. Learn Res. II*.
- Abbas, F. M. Alkarkhi, Wasin, A. A., Alqaraghuili, in Easy Statistics for food science with R, 2019.
- Abiaobo, N. O., Akpan, I. I. and Umana S. I. (2017). Assessment of heavy metals concentration in shell and fin fish from Iko River estuary, Southern Nigeria. *J. Agric., Eco. Res. Int.* 12(4), 1-8.
- Akpan, A. W. (2004). Longitudinal Profiles of Total Hydrocarbons, Oil and Trace Metal Concentration in Surface Waters of Qua Iboe River (South-Eastern, Nigeria) East of the Niger Delta (Nigeria). *J. Aq. Sc.* Vol.190, pp.41-47.
- Akpan, I. I. (2013). Assessment of Water Quality in Imo River Estuary using Multivariate Statistical Method. *J. App. Chem.* (108R-JAC) Vol.4, Issue 5, pp.35-40.
- Akpan, I. I. (2021). Assessment of water chemistry in a segment of Qua Iboe River Estuary by Principal Component analysis. *J. Aq. Sc.* 36(1), 1-11.
- Akpan, I. I. and Etim, U. (2015). Observations on the Variations (Seasonal and Spatial) in water quality and ecological adversity of Uta Ewa, Niger Delta Region, Nigeria. *Int. J. of Oceanography and Marine Ecological System* 4(1):311.
- American Public Health Association (1998). Standard Methods for the Examination of Water and Waste Water Analysis.
- Carlos Alexandre Borges Garcia. Helenic Leite Garcia maria Caroline Silva Mendonca. Anamalla Ferreira da Silva. Jose do Patrocinio Hora Alves. Silvanio Silverio Lopes da Costa. Geovanny Oliveira Araujo and Igor Santos Silva

(2017): Assessment of Water Quality using Principal Component Analysis: A Case Study of the Acude da Macela-Sergipe – Brazil. World Water Congress. International Water Resources Association IWRA). Cancun. Quintana Roo. Mexico.

Chatfield, C. and Collins, A. J. (1980). *Introduction to Multivariate Analysis*. London: Chapman and Hall.

Cochran, R. N. and Horne, f. H. (1977). Statistically weighted principal component analysis of rapid scanning wavelength kinetics experiments. *Anal. Chem.*, 49, 846-853.

Garcia, R. Y., Martinez, M. P., Mayor, P., Crespo, C. G. and Mele, A. R. (2017). Water contamination from oil extraction activities in Northern Peruvian Amazonian Rivers. *Elsevier*

Idodo-Umeh, G. (2002). Pollution assessment of Olomoro water bodies using Physical-chemical and biological indices: Ph.D. Thesis University of Benin, Benin city, Nigeria, 455pp.

Jonah, U. E. and Akpan, I. I. (2021). Application of multimetric index on water quality assessment of Qua Iboe River Estuary, Akwa Ibom State, Nigeria.

M. M. Taboada-Castro, M. L. Rodriguez-Blanco & M. T. Taboada-Castro. (2007). Assessment of Seasonal variations in Stream Water by Principal Component Analysis. *WIT Transaction on Ecology and the Environment*, Vol.106.

Robu, I. B., Istrate C. The analysis of the PC of financial reporting in the case of Romanian listed companies. *Procedia Economics and Finance* 2015; 20: 553-561.

Shine, J. P., Ika, R. V. and Ford, I. E. (1995). Multivariate Statistical Examination of spatial and Temporal Patterns of Heavy Metal Contamination in New Bedford Harbor Marine Sediment, *Environmental Science Technology*, 29, pp.1781-1788.