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Synergism between Season, pH, conductivity and total dissolved solids (TDS) of Imo River quality for agricultural irrigation

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Abstract

Quality of fresh water sources as influenced by season and physicochemical characteristics is a major consideration for use in agricultural irrigation programs. Seasonal values and variations of pH, Conductivity, and Total Dissolved Solids (TDS) and their interactions in Imo River quality were determined under standard analytical methods. Water samples were collected for two seasons - dry and rainy, at seven major locations of human activities - Ekenobizi, Udo, Owerrinta, Alulu, Owaza, Akwette and Obigbo along the River. There were significant variations in seasons ($P < 0.05$) for all parameters at all the locations. Conductivity and TDS values increased during the rainy season than during the dry season. The pH (5.18 - 6.35) at some locations was acidic. Conductivity (0.01 - 64.00 µS/cm) and TDS (1.9 - 1600mg/L) did not exceed acceptable standards for irrigation water. Correlation at $R = 0.85$ showed that as the pH increased, TDS and Conductivity increased and as TDS increased, the Conductivity increased. This implied that increased rainfall and subsequent soil erosion and anthropogenic activities might have increased the concentration of ions in the River. Ions in the River might be absorbed by plants and might also accumulate to concentrations high enough to cause crop damage or reduced crop yields on irrigated soils. An acidic pH value is an implication that the River might need further evaluation. The values are satisfactory for the use of Imo River for agricultural purposes (irrigation).

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Introduction

There is strong link between the state of the environment and food production. For crops, the state of the environment directly influences soil nutrient availability, water (ground and surface water for irrigation), climate, and weather (rainfall and growth season) (FAO, 2003; FAO, 2006). Irrigated agriculture is dependent on an adequate water supply of usable quality for improved crop yield. Water is probably one of the most limiting factors in increasing food production. Yields on irrigated croplands are, on average, 2-3 times higher than those on rain-fed lands. Irrigated land currently produces 40% of the world's food on 17% of its land (FAO, 1999).

Water quality concerns have often been neglected because good quality water supplies have not been plentiful and readily available (CSD, 1997). To avoid problems when using these poor quality water supplies, there must be sound planning to ensure that the suitable quality of water is used (FAO, 2000). Irrigation water contains a mixture of naturally occurring salts. Water salinity is usually measured as TDS (Total Dissolved Solid) or EC (Electrical Conductivity). Soils irrigated with this water will contain a similar mix but usually at a higher concentration than in the applied water. The extent to which the salts accumulate in the soil will depend upon the irrigation water quality, irrigation management and the adequacy of drainage (Loch *et al.,* 2006). If salts become excessive, losses in yield will result due to high porosity, low soil aggregation, and high infiltration rates. To prevent yield loss, salts in the soil must be controlled at a concentration below that which might affect yield (Ayers and Westcot, 1976). The primary objective of irrigation is to provide a crop with quality, adequate and timely amounts of water, thus avoiding yield loss caused by extended periods of water stress during stages of crop growth that are sensitive to water shortages. However, during repeated irrigations, the salts in the irrigation water can accumulate in the soil, reducing water available to the crop and hastening the onset of a water shortage (Shahinasi and Kashuta, 2008). Understanding how this occurs will help suggest ways to counter the effect and reduce the probability of a loss in yield.

Imo River is a major source of water for domestic, industrial, and small scale agricultural irrigation activities in Abia, Anambra, Imo and Rivers states of South-eastern and South-southern Nigeria. Assessing the River quality to ascertain its potential for use in large scale irrigation and general crop development and improvement by the government and non-governmental organizations (NGOs), especially government owned Anambra-Imo River Basin Development Authority that is involved in large scale development of improved varieties of crops and oil palm, cocoa, plantain, banana, pineapple, and fruit crop cultivation, will go a long way in achieving world's Millennium Development Goals (MDGs) by providing food for all by the year 2020. This study was therefore aimed at determining the seasonal influence and human impact at major points on the pH, conductivity and Total Dissolved Solids (TDS) of Imo River quality to ascertain its suitability for use in agricultural irrigation practices.

Materials and methods

Study area

The study area is Imo River and is as shown in Fig. 1. Imo River is one of the major rivers in the south-eastern Nigeria. It probably originates from Isiochi in Abia State and cuts across three states including Abia, Imo, and Rivers states. Imo River flows from the eastern-north to the eastern-south, emptying in the Atlantic Ocean. The river serves as source of water for domestic uses, fishery, recreational activities, and agricultural irrigation programs for more than 5 million people settling close to the water body. Apart from the afore mentioned uses, the river serves as source of sand for sand excavators, recipient of industrial effluent discharges, dumping site for domestic wastes including sewage and industrial solid waste, and other rivers like Aba River emptying in Imo River. Some major human impacted points of the river include Ekenobizi, Udo, Owerrinta, Alulu, Owaza, Akwette and Obigbo.

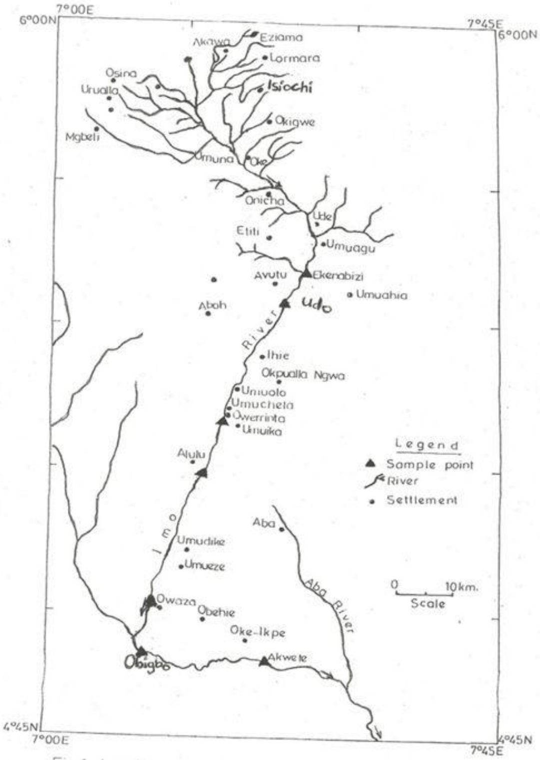

Fig. 1. Location map of Imo river showing the sampling points.

Sample collection

Surface water samples were collected from 7 major human impacted points of Imo River. Samples were collected in triplicates with the aid of 1 liter water sampling cans. Collected samples were transported to the laboratory within 4 hours. The samples were collected in two seasons – dry and rainy seasons for two years. The dry season was between November and March while the rainy season was between May and September.

Chemical analysis

The pH, Conductivity, and Total Dissolved Solids (TDS) were determined as described by the *Standard Methods for the Examination of Water and Wastewater* (APHA/AWWA/WPCF, 1985).

Statistical analysis

The result was subjected to different statistical analyses and presentations by using tools ranging from T-test, Analysis of Variance (ANOVA), and Tukey Grouping, by the method of Statistical Package for Social Sciences (SPSS 16.0).

Results

Table 1 shows the result of analysis of pH variations at the different locations and seasons. There were significant variations in seasons ($P<0.05$) at Ekenobizi (6.35±0.00 - 6.16±0.00), Udo (6.36±1.01 - 6.02±0.01), Owerrinta (5.94±0.02-5.66±0.01), Alulu (5.80±0.10 - 5.18±0.01), Owaza (6.16±0.01 - 5.80±0.10) and Akwette (5.92±0.01-5.83±0.01), while, there were no significant variations in seasons ($P>0.05$) at Obigbo (5.65±0.07-5.49±0.28). Majority of the locations recorded acidic pH values especially during the rainy season.

Table 2 shows the result of analysis of Conductivity variations at the different locations and seasons. There were significant variations in seasons ($P<0.05$) at all the locations; Ekenobizi (54.00±1.000-0.02±1.010), Udo (64.00±1.000-0.01±0.006), Owerrinta (43.00±1.000-0.02±0.001), Alulu (33.00±1.000-0.03±0.010), Owaza (37.00±1.000-0.01±0.006), Obigbo (33.00±1.000-0.01±0.006), and Akwette (43.00±1.000-0.02±0.010). There were higher values of electrical conductivity during the rainy season than in the dry season. While Udo and Ekenobizi recorded higher values than others.

Table 1. pH variations at different locations and seasons.

Location	Season	Mean Deviation
Ekenobizi	Dry	6.35±0.00A
	Rainy	6.16±0.01A
Udo	Dry	6.02±0.01A
	Rainy	6.36±1.01A
Owerrinta	Dry	5.66±0.01A
	Rainy	5.94±0.02A
Alulu	Dry	5.18±0.01A
	Rainy	5.80±0.10A
Owaza	Dry	6.16±0.01A
	Rainy	5.80±0.10A
Obigbo	Dry	5.49±0.28B
	Rainy	5.65±0.07B
Akwette	Dry	5.83±0.01A
	Rainy	5.92±0.01A

Table 2. Conductivity variations at different locations and seasons.

Location	Season	Mean Deviation
Ekenobizi	Dry	0.02±1.01A
	Rainy	54.00±1.00A
Udo	Dry	0.01±0.01A
	Rainy	64.00±1.00A
Owerrinta	Dry	0.02±0.00A
	Rainy	43.00±1.00A
Alulu	Dry	0.03±0.01A
	Rainy	33.00±1.00A
Owaza	Dry	0.01±0.01A
	Rainy	37.00±1.00A
Obigbo	Dry	0.01±0.01A
	Rainy	33.00±1.00A
Akwette	Dry	0.02±0.01A
	Rainy	43.00±1.00A

Table 3 shows the result of analysis of TDS variations at the different locations and seasons. There were significant variations in seasons ($P<0.05$) at all the locations; Ekenobizi (27.00±1.00 - 11.70±0.01), Udo (22.00±1.00-10.23±1.06), Owerrinta (21.50±0.10-2.50±0.10), Alulu (16.00±1.00-4.10±0.10), Owaza (18.50±0.10-2.70±0.10), Obigbo (21.50±0.10-1.90±0.10), and Akwette (21.50±0.50-21.50±0.50). Higher TDS values were recorded during the rainy season than the dry season at all locations.

Fig. 2 shows the interaction between conductivity and TDS. At R-square (0.85) as the TDS increased at all locations, the conductivity increased.

Table 3. TDS variations at different locations and seasons.

Location	Season	Mean Deviation
Ekenobizi	Dry	11.70±0.01A
	Rainy	27.00±1.00A
Udo	Dry	10.23±1.06A
	Rainy	22.00±1.00A
Owerrinta	Dry	2.50±0.10A
	Rainy	21.50±0.10A
Alulu	Dry	4.10±0.10A
	Rainy	16.00±1.00A
Owaza	Dry	2.70±0.10A
	Rainy	18.50±0.10A
Obigbo	Dry	1.90±0.10A
	Rainy	21.50±0.10A
Akwette	Dry	3.90±0.10A
	Rainy	21.50±0.50A

At $P<0.05$, values with *A - letter are significantly different from each other

At $P>0.05$, values with *B – letter are not significantly different from each other

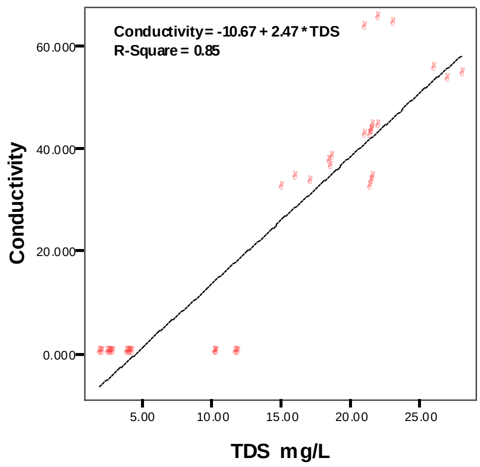

Fig. 2. Correlation of Conductivity and Total Dissolved Solids of Imo River samples.

Discussion

The pH at some locations was acidic. This might have been influenced by the influx of carbonate-bicarbonate and carbon (IV) oxide equilibrium (Gundersen and Steinnes, 2003). Apart from pollution, climate change or meteorological event (seasonal change) can affect pH of aquatic systems. This was supported by the report of Bezuidenhout *et al.* (2002); similar observations have been made by Odokuma and Okpokwasili (1993). Water pH affects metal toxicity in two ways, firstly the speciation and bioavailability of metals may change, and secondly, the uptake and toxicity of metals can be affected by changes in the sensitivity of the cell surfaces as well as heavy metals. This corroborates the works of Campbell and Stokes (1985). The pH is an indicator of the acidity or basicity of irrigation water, but is seldom a problem by itself. The main use of pH in a water analysis is for detecting abnormal water. The normal pH range for irrigation water is from 6.5 to 8.4 (FAO, 2000). An abnormal value is a warning that the water needs further evaluation. The greatest direct hazard of an abnormal pH in water is the impact on irrigation equipment. Equipment will need to be chosen carefully for unusual water. Irrigation water with a pH outside the normal range may cause a nutritional imbalance or may contain a toxic ion. The study revealed that the pH range favoured increased heavy metals speciation, bioavailability, and toxicity in Imo River. This is supported by the works of Gundersen and Steinnes (2003).

Table 4. Correlation of pH, conductivity, and TDS values of Imo River samples.

		pH	TDS	Conductivity
pH	Correlation coefficient	1	0.352*	0.478**
	P- value		0.022	0.001
TDS	Correlation coefficient	0.352*	1	0.920**
	P- value	0.022		0.001
Conductivity	Correlation coefficient	0.478**	0.920**	1
	P- value	0.001	0.001	

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

There was significant variation in conductivity across the locations and for different seasons (Table 2). This is in accordance with the report of Gundersen and Steinnes (2003). The dry and rainy seasons were in the ranges of 0.01-0.02 µS/cm and 33.0-64.00 µS/cm which are in accordance with the report of Akoma (2008). The low values in dry and high values in the rainy season show that conductivity was higher during the rainy season than the dry season. This was supported by the report of Odokuma and Okpokwasili (1996). This showed that increased rainfall and subsequent soil erosion increased the concentration of ions in the river. This was supported by the works of Ojo *et al.* (2000). Low salinity water (ECw < 20 µS/cm) sometimes has a pH outside the normal range since it has a very low buffering capacity. This should not cause undue alarm other than to alert the user to a possible imbalance of ions and the need to establish the reason for the adverse pH through full laboratory analysis (Shahinasi and Kashuta, 2008). Such water normally causes few problems for soils or crops but is very corrosive and may rapidly corrode pipelines, sprinklers and control equipment. The Electrical Conductivity (EC) of irrigation water can affect which plants can be grown in an otherwise suitable site. Plant tolerance to high salinity is species specific. According to Odokuma and Okpokwasili (1996), conductivity values less than 2250 µS/cm are satisfactory for agricultural purposes (irrigation). The conductivity did not exceed acceptable standards and Imo River can be used for irrigation purposes. The TDS was 1.9-11.70mg/L during dry season and 1600-27.00mg/L during the rainy season. The result is below FEPA standard (FEPA, 1991). The seasonal variation was similarly reported by Odokuma and Okpokwasili (1996). The TDS was high during the rainy than in the dry season. The same factors responsible for increased conductivity during rainy season might be responsible for the result. As the TDS increased the Electrical Conductivity (EC) increased. As more chemicals are introduced into the River especially due to human activities, they dissolve and ionize increasing the presence of dissolved ions and conductivity values.

Conclusion

This research confirmed the interaction between season, pH, Conductivity and Total Dissolved Solids on the quality of Imo River for use in agricultural irrigation practices. Discharge of chemical pollutants at different locations of the River influenced the suitability of the River for irrigation. Though the values were not high, continuous discharge will affect the water chemistry and subsequently the soil chemistry and reduce crop yield on irrigated soils. Good quality River water will assist stake holders in agriculture achieve the Millennium Development Goals (MDGs) by the year 2020.

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