An Examination of Akor River Pollution Status Using Nutrient Pollution Index, Aquaculture and Irrigation Parameter Bench Marks

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Abstract
Total of 90 water samples from surface water drinking communities were collected from February to August 2019. Nitrate (NO_3) values of water samples varied between 0.24 – 1.88mg/l), Phosphate (PO_4) values ranged from 0.36 -2.85 mg/l which are within the permissible limit prescribed by World Health Organization and Nutrient pollution index ranged from 0.08 - 0.67; thus indicating that Akor River is not polluted by nutrients. More than 77.9% of water samples showed low Dissolved Oxygen (DO) values indicating heavy contamination by organic matter and as such considered to be class IV (≥ 3.0) for aquaculture.

Majority of water samples (97.6%) and (64.3%) disclosed that pH and NH4-N within the category of disqualified (IV) water for aquaculture, 100% of water samples indicated temperature range within excellent-good grade for aquaculture activities. With respect to irrigation quality, SAR values in the water samples ranged from 0.251 - 0.92 mg/L by showing no danger of sodium as per SAR. Majority (91.67%) of SSP values were within the good irrigation category (20 - 40%) while 8.33% of SSP values was within the excellent irrigation All (100%) of water samples are suitable for irrigation according to magnesium hazard ratio (MHR). However, all (100%) of the water samples from the three stations have exhibited high value of potential salinity; thus making not good for irrigation purpose.

Key-words: Nutrient, pollution, benchmark, indices, quality

Introduction

Water is one of the most important natural resources necessary for human, animal survival and economic development (Hui et al. 2020). Quality and quantity of water in surface systems is of great concern, as potable water needs to have appropriate mineral content (Khatri and Tyagi, 2015). Anthropogenic activities and natural processes in rural and urban environment do affect surface water quality and quantity. These activities not only cause decay in water quality but threaten human and ecological health, drinking water availability and economic development (Ji et al. 2016; Imneisi and Aydin, 2020).

Some of the chemicals responsible for water pollution include but not only heavy metals silt, petroleum hydrocarbons, pesticides, pharmaceutical drugs and other contaminants like nitrate and phosphate (De Girolamo et al., 2019; Isiuku and Enyoh, 2020) arising from the use of disinfectants, agro-chemicals, indiscriminate waste disposal, and industry related activities. The water pollution has become a global threat for developing countries due to climate change vulnerability, unsustainable farming system and other development activities (Rana *et al*. 2017; Matta *et al*. 2018).

It is astute to regulate and monitor the surface water from pollution and to have solid data on surface water quality for viable management

Material and Methods

2.1.1. Description of Study Area

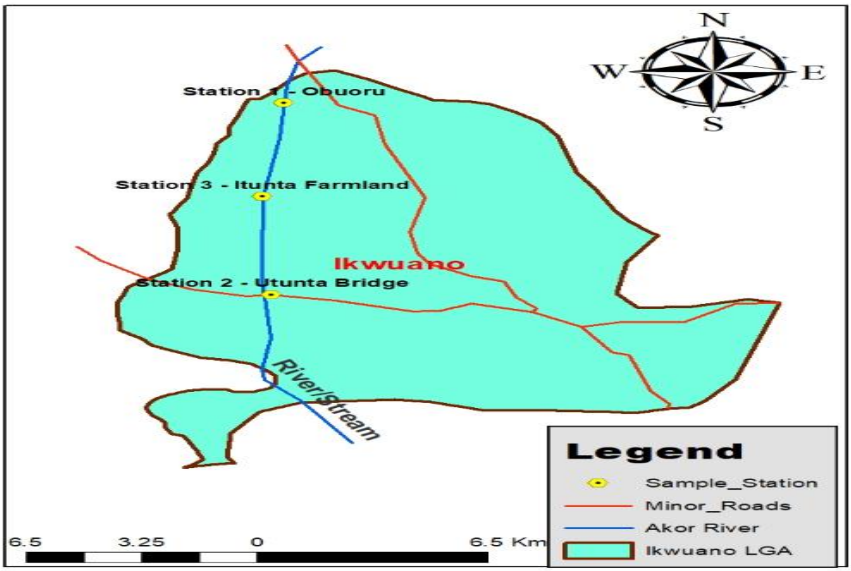

Figure 1: Map of study area with sampled points

Akor River

Station I: located in Obuoruupstream with GPS coordinates (N $O5^{O}$ 28''.029 and E 007^{O}37''.860). Anthropogenic activities in this station are washing and processing of foods, laundry, swimming, extraction of drinking water, sand mining and lumbering. It station is covered with bamboo and other vegetative tree canopies with a lot ofaquatic macrophytes as well as sandysubstrate with moderate flowingvelocity.

Station II is in GPS coordinates (N 05^{o} 26''.921 and E 007^{o} 38''.639). This station is associated with numerous activities such asmining farming activities (nursing of coo and rice, farming of coco). Other activities are laundry, fishing, swimming, extraction of drinking water. It is open vegetated and wadeable with relatively high velocity.

Station 111: Is located at GPS coordinate (N 5 °29.792' and E 007°38.838')and within farmlands. Anthropogenic activities within this station are vegetable and coco farming, an open surface with relatively high velocity. The sandy substrates and a lot of aquatic macrophytes were also observed in the station.

Water sample collection and Analysis

Two 2-litre sample bottles that were previously cleaned and dried were used to collect spot surface water samples from three established stations in Akor River. Digital pH meter/ thermometer (Hach EC 20) was employed to measure water temperature and pH, dissolved oxygen (DO) content was determined with winkler method with azide modification. NO_3^- N and SO_3^{2-} were analyzed usingHach DR 1900 spectrophotometer. PO_4^{3-} was determined by the stannous chloride method. The major cations (Na^+, K^+, Ca^{2+}, and Mg^{2+}) were analyzed using an atomic absorption spectrometer whereas ammonia (NH_4-N) was analysed using Auto discrete analyzer.

Nutrient pollution Index(NPI)

The NPI gives useful information for management and control of the pollution of nutrients

$$\text{NPI} = \frac{C_{nw}}{Max_N} + \frac{C_{pw}}{Max_p} \quad (1)$$

C_{nw} and C_{pw} are concentration of nitrate and phosphate in samples whereasMax_N and $Max_p$are maximum permissible values (50 mg/l) of nitrate and phosphate(5 mg/l). The classification for NPI is categorized as NPI of < 1 (non-polluted), NPI of 3 ≤ 6 (considerable polluted) and NPI of > 6 (very high polluted) (Isiuku and Enyoh, 2020)

Irrigation Indices

The quality of irrigation water points out its mineral content and as well as its effects on plants and the soil (Adimalla et al. 2020),

therefore making the assessment of surface water for irrigation purpose necessary. A number of indices have been employed for evaluation of irrigation water quality - sodium adsorption ratio (SAR), soluble sodium percentage (SSP), magnesium hazard (MHR) and potential salinity (PS). These indices are important in examination of any water quality for agricultural activities.

Sodium adsorption ratio (SAR): Sodium adsorption ratio (SAR) is a useful index for examination of the suitability of water for irrigation purposes and it demonstrates the sodium hazard (Kundu and Ara 2019). It is estimated using the following formula as described by Dissanayake *et al*. (2020)

$$\text{SAR} = \frac{Na^{+}}{\sqrt{\frac{Mg^{2+} + Ca^{2+}}{2}}} \qquad (2)$$

The concentrations of ions are measured in mg/L. (< 10 (Excellent/low sodium hazard), 10-18 (Good/Medium Sodium hazard),18-26 (Permissible/High Sodium Hazard) and >26(Doubtful/high Sodium Hazard) (Tomaz *et al*. 2020),

Soluble Percentage Sodium (SSP): Soluble Sodium percentage is also a useful index for examination of sodium hazard and water quality for agricultural activities (Udom et al. 2019). It is estimated using the following formula as described by Anyanwu et al. (2022)

$$\%\text{Na} = \frac{Na^{+} + K^{+}}{Ca^{2+} + Mg^{2+} + Na^{+} + K^{+}}\ x\ 100 \qquad (3)$$

The concentrations of ions are measured in mg/L. <20 (Excellent), 20-40% (Good), 40-60% (Permissible), 60-80% (Doubtfu) and >80%(Unsuitable) (Anyanwu *et al.*2022)

Magnesium hazard Ratio (MHR): The effect of Magnesium in irrigated water is measured as the magnesium ratio (Anyanwu. 2022) and estimated as magnesium hazard using the following formula (Shil et al. 2019).

$$\text{MHR} = \frac{Mg^{2+}}{Ca^{2+} + Mg^{2+}} \; x\, 100 \qquad (4)$$

< 50% (suitable) and > 50% (unsuitable)

Potential Salinity

Potential Salinity is one of useful index recognised globally for examination of irrigation water quality. It quantifies the suitability of water on the basis of concentration of insoluble salts (chloride and sulphate) and estimated using the following formula in (Meena and Bisht, 2020)

$$\text{Potential Salinity (PS)} = Chloride + \frac{Sulphate}{2} \qquad (5)$$

The concentrations of ions are measured in mg/L.

Results

The results of nutrients with some important water quality parameters for drinking, fish culture and irrigation farming were presented in table 1.

Benchmark for drinking water quality

Nutrients

During the period of examination, the maximum values of all the analysed nutrients (NH_4-N, PO_4 and NO_3-N) were recorded in May, 2019 in the three stations. The lowest values were recorded in January, 2019 in station I and III whereas in station II, lowest values of all the analysed nutrients were registered in February, 2019. The highest concentrations (3.12 mg/l) of PO_4 was registered in station I (May, 2019) whereas the lowest value (0.36mg/l) wasregistered in station II (February, 2019) (Table 1).

The highest concentrations (1.85 mg/l) of NO_3-N was registered in station I (May, 2019) whereas the lowest value (0.24mg/l) wasregistered in station II (February, 2019). The highest

concentrations (1.13 mg/l) of NH_4– N was registered in station I whereas the lowest value (0.19 mg/l) wasregistered in station II (February). Akor water was within the class 11 (≤ 0. 5) – class IV (≤ 1.5) according to You *et al*. (2021)

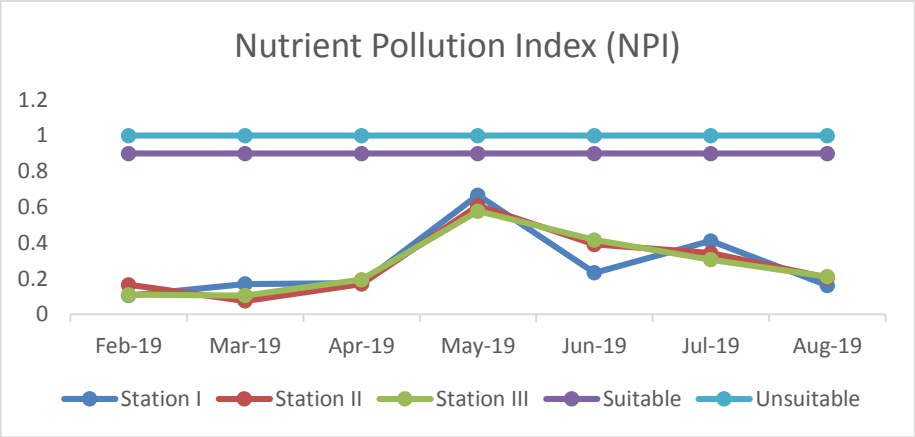

Figure 2: Spatio-temporal variations of NPI of samples water from Akor River, Ibere Ikwuano, Abia State Nigeria

Nutrient pollution index (NPI)

NPI ranged from 0.076 (February, 2019) in station II - 0.667 (May, 2019) in station I, indicating non-polluted water. NPI values indicated that Akor River is not enriched with NO_3-N and PO_4; not at risk of eutrophication.

Aquaculture Parameters Benchmarks

Dissolved oxygen (DO)

Dissolved oxygen (DO) is globally recognised as one of the determining factors controlling the biota in the aquatic habit (Alprol *et al*., 2021). The dissolved oxygen (DO) varies from 1.1mg/L (March, 2019) in station II - 6.80 mg/L (May, 2019) in station I; almost all the mean values were within the

category ≥ 5 (III). China, (2002) classified water with DO values as ≥ 2.0 (class V), ≥ 3.0 (class IV), ≥ 5.0(class III), ≥ 6.0 (class II) whereas ≥ 7.5 (class I). Based on China, (2002) classification, 58.9% of water from Akor River is considered to be class I11 (≥ 5.0), 29.2% is within the class IV(≥ 3.0), 9.4% is within the class V (2.0) and 2.5% is within the class 11 (≥ 6.0).

Water pH

You *et al*. (2012) classified pH of water for aquaculture as: 7.5 as excellent water (grade I), 6.75-8.25 as good water (grade II), 6.25 - 8.75 as qualified (grade III) whereas < 6 or > 9 is classifies as disqualified (grade IV). The pH values in Akor Rivers varies between 4.6 (May) and 6.6 (February,2019), both were in station I. Majority of water samples (97.6%) were within the category of disqualified (IV) aquaculture water whereas 2.4% of the samples fell under qualified (grade III). The results of this research revealed that water from Akor river may not be suitable for fish culture

Surface Water Temperature

Water temperature varies from 24.72ºC in station III (July, 2019) - 29.43ºC (February, 2019) in station II. The temperature values were within the range of 24-28 ºC (excellent) to 28-30 ºC Good aquaculture water. You *et al*. (2012) classified water temperature for aquaculture as: 24 -28 (26) as excellent water (grade I), 22-24 (23 ºC) or 28-30 (29 ºC) as good water (grade II), 20-24(21 ºC) or 30-32 (31 ºC) as qualified (grade III) whereas < 20 or > 32 ºC is classifies as disqualified (grade IV). 97.5% of samples water are within excellent class while 2.5% is within good grade.

Ammonia-Nitrogen (NH_4-N)

Ammonia-Nitrogen level ranged from 0.185 mg/l (February, 2019) in station II -1.11 mg/l (May, 2019) in station I. The level of NH_4-N indicated that Akor River is in category of disqualified (> 0.20) with exception of the level recorded in station II (February, 2019).

Fish species inhabiting Akor River are under NH_4-N stress. You *et al*. (2021) also classified water with NH_4-N contents for aquaculture as 0.05 mg/l as excellent (grade I), 0.125 as good (grade II), < 0.20 as qualified (grade III), whereas > 0.20 is considered as disqualified (grade IV). Majority (96.7 %) of the samples were within the category of disqualified while only 3.3% were considered to under grade III.

Irrigation farming Benchmark

The SAR varies from 0.25 (February, 2019) in station I – 0.92 (May, 2019) in station II. All values registered were below 1, indicating excellent irrigation water quality (table 1).

Table 1: Summary of mean of physic-chemicals parameters (ranges in parenthesis) and pollution indices of Akor River, Ibere, Abia State Nigeria

Parameter	Station I	Station II	Station III
PO_4(mg/L)	1.29(0.50-3.12)	1.32 (0.36-2.85)	1.23(0.50 -2.71)
NO_3(mg/L)	0.82(0.30-1.11)	0.85 (0.24-1.88)	0.84(0.27-1.75)
NPI	0.28(0.11-0.67)	0.28(0.08-0.61)	0.28(0.11-0.58)
DO(mg/L)	4.91(3.10 -6.80)	4.38 (1.10 -6.40)	4.38(3.50 - 6.30)
pH(mg/L)	5.96(4.60 -6.60)	5.94(5.30-6.50)	5.69 (5.00 - 6.30)
Water Temperature	26.71(26.37-28.20)	27.00(25.31- 29.43)	26.43 (24.72 - 28.09)
NH_4-N(mg/L)	0.63(0.26 -1.13)	0.56(0.19-1.11)	0.60 (0.26-0.99)
SAR	0.54(0.25-0.91)	0.57(0.38-0.92)	0.62(0.29-0.91)
SSP (%)	22.08(16.30- 25.28)	22.81(19.0-28.49)	22.74(18.36-25.60)
MHR (%)	36.71(31.96-42.86)	40.79(31.96-45.16)	40.36(32.10-44.38)
PS	90.59(53.24 - 124.53)	77.07(53.27-95.71)	83.79(70.95-99.52

Soluble sodium percentage (SSP)

The soluble sodium percentage (SSP) varies from 16.30 (January, 2019) in station I - 28.49% (May, 2019) in station II. Majority (91.67%) of SSP values were within the good irrigation category (20 - 40%) while 8.33% of SSP values was within the excellent irrigation category (< 20). Udom *et al*. (2019) reported

100% samples values (28.16 – 34.69%) within the good irrigation category (20-40%) in Abak River in the same region.

Magnesium Hazard Ratio (MHR)

Magnesium Hazard Ratio varies from 31.956% (August) – 45.161% (January) both in station II. All (100%) of the sampled waters had Magnesium Hazard Ratio (MHR) less than 50% (< 50%), indicating that water from Akor River is in suitable for crop farming (Table 1).

Potential Salinity (PS)

Potential Salinity is one of tools globally recognised and used for examination of irrigation water quality. It quantifies the suitability of water on the basis of concentration of insoluble salt. Potential salinity (PS) in water from Akor River varies from 53.44 mg/l (February and March) in station I and station II respectively - 124.527 mg/l in station I (May).

Discussion

Drinking water

The results of some analysed nutrients (NO_3-N and NH_4-N) were within the range obtained by Kanownik et al. (2019) whereas PO_4 values were quite higher that values obtained by Kanownik et al. (2019) in Drinking Water Resource Quality for a Regional City in Central Europe. All the values of nitrate and phosphate recorded were within the acceptable limits (50 mg/l) and (5 mg/l) for drinking water respectively (WHO, 2004). Similarly, the results of this current study were within or slightly higher than the results obtained in surface water bodies in the same region, Ezeabasili *et al*. (2014) in water supply quality in Awka, Anambra State, Verla *et al*. (2018) in River Uramiriukwa, Imo state)

However, Okeke and Adinna, (2013). Aganigbo *et al.* (2016), Okoye and Orakwe (2018) and Isiuku and Enyoh (2020) registered quite higher nitrate and phosphate concentrations

compared to this current study in Otamiri river in Imo state, Mbanabor Area, Anambra Basin, Agulu lakeand in water bodies in South Eastern, Nigeria. The high level of NH_4-N, PO_4, and NO_3 in the wet season may be ascribed to run off from farmlands due to the application of both natural and synthetic fertilizers for agricultural purposes. The examination of the water suitability for drinking water revealed that, among the analysed nutrients according to Kanownik et al. (2019), Majority (98.3%) ammonium nitrogen (NH_4 -N) and nitrates (NO_3) values quantified Akor River water as class I whereas ammonium nitrogen (NH_4 -N) and phosphates (PO_4) levels in May, 2019 in the three stations throughout the sampling period revealed that water from the river is class II.

Nutrient pollution index (NPI) for the surface water possibly account for total effect of NO_3-N and PO_4 on environmental health. It is useful tool for computing the overall quality of surface waters. The classification for NPI is categorized as NPI of < 1 (non-polluted), NPI of $3 \leq 6$ (considerable polluted) and NPI of > 6 (very high polluted) (Isiuku and Enyoh, 2020).

Aquaculture Benchmark

Nitrates have immense significance as major nutrients for the succession and productivity of phytoplanktons and aquatic macrophyte (Mishra and Patro, 2015. Water body with dissolved oxygen concentrations below 5mg/l may negatively affect the functioning and survival of aquatic organisms and below 2mg/l may cause mass mortality of most fish Chapman (1996). Mean dissolved oxygen recorded in this study fall below5mg/l and may affect survival of aquatic organisms. According to WHO the target guidelines is 25-30ºC, within which maximal growth rate of plant, efficient food conversion, best condition for aquatic lives, resistance to disease and tolerance of toxins are enhance (Sulchdev, 2012). The water temperature recorded in this study were with optimum (25 -30ºc) for aquatic lives and range where resistance to disease and tolerance of toxins are enhance.

Irrigation Water Quality

Sodium Absorption Ratio (SAR)

Excess sodium level in irrigation water influences the soil permeability, water infiltration and total salinity negatively; thus resulting in poor crop growth and yield (Megahed, 2020; Anyanwu *et al*. 2022). SAR is vital tool used to estimate the relative proportion of sodium ion in relative with magnesium and calcium ions in water made for irrigation (Davoudi *et al*. 2021, Anyanwu et al. 2021). The SAR values registered in this current study were within or slightly higher than Anyanwu *et al*. (2022) and Udom *et al*. (2021) who also registered a range within excellent irrigation water quality in Ikwu and Abak Rivers in South-eastern, Nigeria.

However, SAR values reported in surface water from South-western Nigeria were slightly higher than the present values, Eruola *et al*. (2020) registered higher values (2.34 – 4.28) in Owiwi River, Abeokuta, Ogun State, and Ogunfowokan *et al*. (2013) reported relatively higher SAR values (1.04–8.46),(1.41–9.07) and (1.32–8.28 in Abagbooro, Agbogbo and Amuta streams respectively in Ile-Ife, all in south-Western Nigeria.

Soluble sodium percentage (SSP)

The results of soluble sodium percentage were in consonants with Udom *et al*. (2019) that reported 100% water samples within the good irrigation category (20-40%) in Abak River in the same region. However, Anyanwu *et al*. (2021) and Omofunmi *et al*. (2019) registered 100% samples within the excellent irrigation category in Ikwu River in the same region, Umuahia, Abia state and in Ero dam, Ikun –Ekiti, Ekiti State, South-west region, Nigeria.

Magnesium Hazard Ratio (MHR)

The presence of magnesium in irrigation water is very important for proper crop growth and development. Excess levels of magnesium will adversely affect crop yields due to the salinity of the soils will

increase (Anyanwu *et al* 2021). Presence of magnesium in water is a useful parameter for the examination of irrigation water quality; calcium and magnesium are usually in an equilibrium state in most water (RamyaPriya and Elango 2018; Anyanwu *et al*. 2021). These results were in consonant with results obtained by Anyanwu *et al.* (2021) in Ikwu River Umuahia, Abia State, Nigeria. However, some studies registered MHR within unsuitable irrigation water category from surface water bodies (above 50%). Eruola *et al*. (2020) registered (55.2 – 55.9%) in Owiwi River, Abeokuta, Ogun state, Udom *et al*. (2019) reported (77.78 - 87.59%) in Abak River, Abak andOmofunmi *et al*. (2019) obtained high values (88.7 - 95.1%) in Ero dam, Ikun –Ekiti, Ekiti State, all in Nigeria.

Potential Salinity is a vital parameter for assessing the suitability of water for irrigation uses All (100%) of the water samples from the three stations have exhibited high value of potential salinity. The results indicated that water from Akor River contains high level chloride impurity and it is not good for irrigation purpose. Meena and Bisht, (2020) reported a similar result in water sample from Chaksu tehsil, Jaipur District, Rajasthan, India. Potential Salinity is one of tools globally recognised and used for examination of irrigation water quality. However, Udom *et al*. (2019) reported a lower level between 1.09 meq/L to 1.358 meq/L in Abak River, Abak

Conclusion

Majority of the investigated parameters were within benchmark for drinking water, irrigation and aquaculture benchmarks with an exemption of few oxygen, pH and ammonia which fell below aquaculture benchmark. All irrigation indices were within the irrigation water quality benchmark except potential salinity. Generally, Akor River has not been impacted adversely by both season and anthropogenic activities.

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Declaration of Conflict of Interest
The Authors declare that there is no conflict of interest

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