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Assessing the potential of a surface water body for multiple uses. Case study: the Anambra River Basin, south-eastern Nigeria

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ABSTRACT. Anthropogenic activities causing deterioration in water quality and a decrease in meeting the ecosystem service potentials of surface water are considered one of the major basic environmental challenges. Water samples were collected from three sampling stations (Ogurugu, Otuocha, and Otu-Nsugbe) in the Anambra River Basin and analyzed following standard protocols and procedures for nine months. The cosystem services potentials of the Anambra River Basin were evaluated using physico-chemical parameters and some indices: Comprehensive pollution index (CPI), nutrient pollution index (NPI), salinity potential, and soluble sodium percentage (SSP). All the water quality parameters were within the standard level for drinking water, aquaculture practice, recreation (swimming/bathing) and agricultural purposes, with the exception of pH and phosphate, whereas dissolved oxygen met aquaculture criteria only in station II. Comprehensive pollution index (0.150 – 0.449), nutrient pollution index (0.07 – 0.46), and soluble sodium percentage (6.0% -26.92%) were within the category of non-polluted or excellent to sub-clean. Potential salinity (39.39 - 97.19) was high, indicating water from the Anambra River Basin contained crystallized solutes. Conclusion: the Anambra River Basin is not at risk of eutrophication but may not support irrigation program due to the high potential salinity. However, the river needs to be monitored, and anthropogenic activities need to be regulated.

Keywords: Pollution, surface-water, physico-chemical, irrigation, indices

1. Introduction

The deterioration of water quality of surface water bodies as a result of human activities such urbanization and agriculture to meet basic needs of man has become a global problem (Mateo-Sagasta et al., 2017; Wang et al., 2020). Rivers are facing multi-dimensional stressors such as flow disturbance, water pollution, climate influences, habitat fragmentation leading to degradation and biodiversity erosion (Matta et al., 2020).

Saving and controlling surface water from pollution and having solid data on surface water quality for proper management have become very necessary. Considering the dynamic nature of the surface water ecosystem and the influence of various watershed activities, rapid interpretation of water quality is required (Effendi, 2016). However, the interpretation of data from a large number of physicochemical parameters and drawing proper conclusions can be very challenging (Popović et al., 2016). Therefore, it is necessary to apply appropriate water quality indices (Anyanwu and Umeham, 2020; Isiuku and Enyoh, 2020; Anyanwu et al., 2022). Regular evaluation of the surface water quality using useful and reproducible indices is required to maintain and control the surface water from degradation (Barakat et al., 2016; Shukla et al., 2017; Matta et al., 2020).

Water quality indices (WQIs) are accepted and useful tools for evaluating water quality, and different indices use different sets of variables (Bharti and Katyal, 2011). They are useful communication tools for presenting the health status of waterbodies to the public in a reliable way by policymakers, environmentalists, conservationists and different governmental agencies (Sadiq et al., 2010). The use of water quality indices has become a prevalent and reliable approach to water quality assessment and monitoring and has been extensively used by researchers (Adimalla et al., 2020;

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Anyanwu and Umeham, 2020; de Andrade Costa et al., 2020; Sharma et al., 2021; Anyanwu et al., 2022). This study was carried out to evaluate the potential of the Anambra River Basin water in south-eastern Nigeria for multiple uses with some selected water quality indices.

2. Material and methods

2.1. The studied area

The Anambra River Basin is situated in south-east of Nigeria, it is approximately 207.4 km to 210 km long (Odo, 2004) and rises from the Ankpa hills (ca. 305-610m above sea level) and flows into the River Niger at Onitsha (Odo, 2004). It is spatially located between latitudes 6°00'N and 6°30'N and longitudes 6°45'E and 7°15'E. A total of 14014 km^2 are drained by the river basin (Odo, 2004) (Fig.1).

2.2. Description

The Ogurugu fishing site (station I)

The Ogurugu fishing site is upstream with GPS coordinates (N 6°47'28" and E 6°56'48"). It is located in the Uzo-uwani local Government Area, Enugu State. A number of anthropogenic activities were observed, such as laundry, swimming, fishing, extraction of drinking water, manual sand mining, and farming (rice, cassava), at flood plain, transportation of different goods and human beings, and lumbering. The surface was partially canopied with aquatic plants, and the flow velocity was moderate.

The Otuocha Fishing site (station II)

The Otuocha Fishing site is about 210 km downstream of Ogurugu (N 6°20'30", E 6°50'33"), with a daily market along its bank. Notable human activities within the site are water transportation by canoe, washing, fishing, farming along banks, and extraction of water for irrigation.

The Otu-Nsugbe Fishing site (station III)

The Otu-Nsugbe is about 17 km downstream of the Otuocha fishing site (N 6°16'71", E 6°48'73"). It is located in Nsugbe at the Anambra River floodplain with notable anthropogenic activities, such as farming activities, mechanical dredging, fishing, and water transportation

Samples collection and analyses

Water samples were collected monthly for nine months (February - October 2022). Samples were collected with a clean 1 litre water sampler, after collection transferred and stored in 1litre plastic bottles and then transported to the laboratory in an ice chest for analysis. The physicochemical parameters were analyzed using standard methods. Three parameters - electrical conductivity, pH, and dissolved oxygen (DO) – were determined in situ with a multi-parameter meter (HQ40d). In the laboratory, nitrate nitrogen (NO_3-N) and phosphate (PO_4-P) were determined using the HACH-DR 6000 UV-Vis spectrophotometer, total dissolved solids (TDS)-gravimetric; Cl^- - titrimetric; K^+, Na^+-flame photometric (APHA, 1992); Ca^{2+}, Mg^{2+}- spectrophotometric (ISO 11885, 2007); SO_4^{2-} - turbidimetric method (APHA, 2005), while biochemical oxygen demand was determined after five days using the multi-parameter (HQ40d).

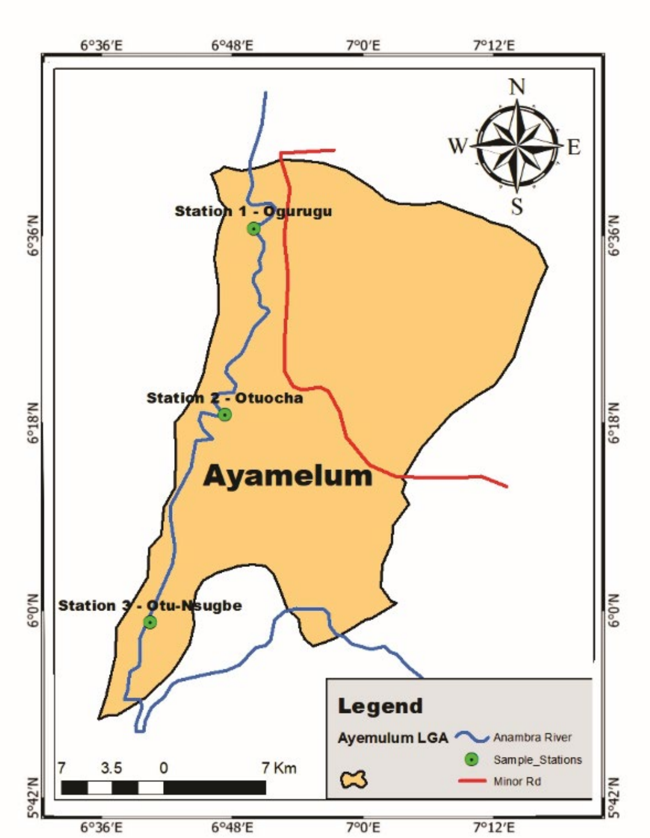

Fig.1. Map of studied area

Comprehensive pollution index (CPI)

The comprehensive pollution index method offers useful information for the management and control of the pollution in a watershed (Son et al., 2020; Anyanwu et al., 2022). The equation for computing *CPI* is as follows:

$$PI_i = \frac{C_i}{S_i} \quad (1)$$

where C_i - measured concentration of parameter in water; S_i - permitted standard of parameter according to environmental standard (FMEnv., 2011).

$$CPI = \frac{1}{n}\sum_{i=0}^{n} PI_i \quad (2)$$

where *CPI* = Comprehensive Pollution Index; *n* = number of parameters investigated; PI_i = single factor pollution index number *i*. The *CPI* was computed using 13 water parameters: dissolved oxygen, biochemical oxygen demand, electrical conductivity, pH, turbidity, total dissolved solid, total suspended solid, chemical demand oxygen, chloride, phosphate, nitrate, sulphate, sodium, potassium, calcium, and magnesium.

Nutrient pollution index (NPI)

NPI was computed using the expression in Eq.

$$NPI = \frac{c_n}{\max_c} + \frac{c_p}{\max_p} \quad (3)$$

where $NPI = C_n$ an C_p are the monthly mean concentration of nitrate and phosphate in water samples, and are maximum allowable concentration of 50 mg/l and

5 mg/l for nitrate and phosphate in surface water respectively (FMEnv., 2011). 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).

Potential salinity (PS)

This index indicates the suitability of water on the basis of concentration of insoluble salt (Meena and Bisht, 2020). It was computed using equation below

$$\text{Potential salinity } (PS) = Chloride + \frac{Sulphate}{2} \quad (4).$$

Soluble Sodium Percentage (SSP)

Soluble Sodium percentage is another important parameter used in evaluating sodium hazard and water quality for agricultural purposes (Udom et al., 2019). It is calculated using the following formula:

$$\text{Soluble Sodium Percentage } (SSP) = \frac{Na^{+} + K^{+}}{Ca^{2+} + Mg^{2+} + Na^{+} + K^{+}} \cdot 100 \quad (5)$$

3. Results and discussion

3.1. Physicochemical parameters

The summary of physico-chemical parameters determined in the Anambra River is shown in Table 1.

Water Temperature

Temperature is a principal water indicator that changes with the variation of climatic conditions of an area. Higher water temperature increases the rate of biochemical activity of aquatic organisms (Bhatnagar and Devi, 2013), thus increasing oxygen demand. The solubility of oxygen and the level of ammonia in aquatic ecosystems depend on water temperature. The spatio-temporal variations of water temperature ranged between 26.87°C and 30.12°C, with mean values of 29.24 ±2.04°C (station I), 28.76±3.12°C (station II), and 28.10±2.11°C (station III). The lowest value (26.87°C) was recorded at station 1 (September 2022), and the highest (30.12°C) was recorded also at station 1 (February, 2022). All the water temperature values were within the permissible range (40°C) and 20 – 32°C for drinking water (WHO, 2010) and for aquaculture (Kasmir and Rosmiati, 2014; Mutea et al., 2021). However, the temporal-spatial values registered during the sampling period were lower than the recommended level (22–26°C) for swimming and recreational aquatic environments (WHO, 2007).

Water pH and Dissolved Oxygen

The pH is measured as the negative logarithm of hydrogen ions concentration. The pH of natural aquatic ecosystems is greatly influenced by the concentration of carbon dioxide, which is an acidic gas (Boyd, 1979). It is very important to maintain the aquatic resource within a pH range of 6.5–8.5, as any alteration may lead to the destruction of aquatic organisms (Mutea, et al., 2021). Water with a low pH promotes corrosion of metal pipes and fittings, which can cause a sour taste (WHO, 2011). Swimming in surface water with a low pH can indeed result in the corrosive nature of water, skin and eye irritation, loss of chlorine, and skin stains in swimmers (Hoseinzadeh et al., 2013).

The spatio-temporal variations of water pH ranged between 5.0 and 6.9, with mean values of 5.53±0.30 (station I), 5.42±1.01 (station II), and 5.5±0.19 (station III). The lowest value (5.0) was recorded at station 1 (April and May, 2022) and the highest was also recorded at station 1 (February, 2022). The pH values were within the acidic range with mean values below permissible pH limits (6.5 to 9) for aquaculture (Ekubo and Abowei2011; Bhatnagar and Devi, 2019). The mean values exceeded also the range for water drinking, swimming/bathing and agriculture

Table 1. Summary of the mean values of the water quality parameters at each sampling station and the standard recommended for multi-uses

Param.	Min	Max	Station I	Station II	Station III	Aquaculture benchmark (VEPA, 2015)	Drinking water (WHO, 2010)	Recreation (WHO,2007)	Agriculture (FAO,1994)
Tem. (°C)	26.87	30.12	29.24 ± 2.04^{a}	28.76 ± 3.12^{a}	28.10 ± 2.11^{a}	20-32	40	22-26	-
pH	5.0	6.9	5.53 ± 0.30^{a}	5.42 ± 1.01^{a}	5.50 ± 0.19^{a}	6.5-8.85	6.5-8.5	7.0-8.4	6.5-8.5
DO (mg/l)	1.9	10	3.85 ± 0.24^{a}	6.11 ± 1.00^{b}	4.60 ± 0.13^{c}	5-15	> 5	9 -10	-
BOD (mg/l)	1.10	4.4	1.50 ± 0.10^{a}	2.16 ± 0.08^{a}	1.67 ± 0.11^{a}	01-02	-	1-2	-
TDS (mg/l)	0.40	15.50	2.75 ± 0.10^{a}	4.25 ± 1.10^{b}	4.10 ± 0.84^{b}	-	500	500	3000
TSS (mg/l)	0.90	3.10	1.92 ± 0.18^{a}	1.86 ± 0.09^{a}	1.47 ± 0.20^{b}	25-150	50	50	0.25
Cl (mg/l)	34.90	97.10	45.90 ± 7.11^{a}	64.76 ± 12.03^{a}	55.69 ± 10.14^{c}	50	250	100	1065
PO_4^{3-} (mg/l)	0.21	1.43	0.46 ± 0.11^{a}	0.56 ± 0.03^{b}	0.49 ± 0.13^{c}	0.05-0.5	11	0.2	-
SO_4^{2-}	0.04	0.35	0.10 ± 0.00^{a}	0.14 ± 0.04^{b}	0.15 ± 0.07^{c}	-	200	1000	-
NO_3^{-}	0.11	0.51	0.20 ± 0.05^{a}	0.37 ± 0.14^{a}	0.27 ± 0.10^{c}	0.1-4.50	50	20	10
CPI	0.15	0.31	0.22±0.05	0.27±0.11	0.22±0.05				
NPI	0.07	0.46	0.15±0.11	0.20±0.06	0.17±0.14				
PS	34.93	97.19	45.95±9.49	65.94±15.22	56.54±9.05				
SSP	11.58	22.92	17.10±3.91	17.35±3.4	18.87±4.63				

purpose (Klamt et al., 2021).

The results of this study agreed with those noted by Odo et al. (2022) that recorded a range of 4.6 to 6.6 mg/l in the Akor River in Ikwuano. The pH value has a direct relationship to the quality of water suitable for human consumption. Water with a high carbon dioxide content, low total alkalinity and low pH is considered aggressive (Klamt et al., 2021).

Dissolved oxygen affects the growth, survival, distribution, behaviour and physiology of aquatic organisms (Solis, 1988). Spatio-temporal variations of dissolved oxygen (DO) ranged from 1.9 to 10 mg/l, with a mean value of 3.85 ± 0.24 mg/l (station I), 6.11 ± 1.00 (station II), and 4.6 ± 0.13 (station III). The lowest value was recorded at station I (February, 2022), while the highest was recorded at station II (June, 2022). Spatio-temporal values of dissolved oxygen met standards for aquaculture, swimming, and agriculture between April and June 2022 at all the stations, while the mean values for stations I and III were lower than the recommended value (5–15 mg/l) for aquaculture and other aquatic biota (Boyd, 2014). Concentrations below 5 mg/l may adversely affect the functioning and survival of biological communities, and concentrations below 2 mg/l may lead to the death of most fish (Chapman, 1996). Dissolved oxygen is the quantity of oxygen dissolved in water, and it is essential to determine whether the water under study can support aquatic life (Nalder and Islam, 2015). A higher concentration of dissolved oxygen is associated with better water quality and taste (Omer, 2019). The survival and physiological activities of aquatic organisms at station I and station III, may be adversely affected. Dissolved oxygen depletion in water causes poor feeding of fish, starvation, reduced growth, and more fish mortality, either directly or indirectly (Bhatnagar and Garg, 2000). Aquatic ecosystem with a dissolved oxygen level of 3.0-5.0 mg/l is unproductive, and for average or good production, it should be above 5.0 mg/l (Bhatnagar and Devi, 2013). Very high concentration (> 14) of dissolved oxygen sometimes becomes lethal to fish fry in nursery ponds (Bhatnagar et al., 2004).

BOD

Bhatnagar and Dev (2013) pointed out that the desired ranges of BOD level for aquaculture should be between 1 mg/l and 2 mg/l. Spatio-temporal variations of biochemical oxygen demand (BOD) ranged between 1.10 and 4.40 mg/l, with a mean value of 1.50 ± 0.10 mg/l (station I), 2.16 ± 0.08 mg/l (station II), and 1.67 ± 0.11 mg/l (station III) (Table 1). The lowest value was recorded in station I (March, 2022), while the highest was in station II (May, 2022). The high BOD concentrations in this study may be ascribed to high levels of organic contamination from the agricultural farms and other anthropogenic activities that support micro-bacteria growth (Crim, 2007). All the values of BOD recorded were within the values (1 – 2 mg/l) recommended for aquaculture (VEPA, 2015) and water body for swimming/ recreation purposes (WHO, 2007). A high mean value at station II and wet season may cause sufficient oxygen for respiring aquatic organisms in the river. Individuals involved in water-based activities (swimming, sporting, and other recreational) are likely to be most sensitive to eutrophic conditions linked to high BOD, and the demand for all recreational activities is likely to be impacted due to impediment of activities, discomfort, and visual unpleasantness (Breen et al., 2018). Aquatic ecosystem with BOD levels between 1.0 and 2.0 mg/l is considered clean, 3.0 mg/l is fairly clean, 5.0 mg/l is considered doubtful and 10.0 mg/l is definitely bad and polluted (Ekubo and Abowei, 2011).

Total dissolved solid (TDS) and Total suspended solid (TSS)

Total dissolved solids influence the aesthetic value of the water through altering the turbidity and limit water body from performing its ecosystem functions as a drinking water source and irrigation supply (Titilawo et al., 2022). Total dissolved solid (TDS) ranged from 0.4 mg/l at station I (April, 2022) to 15.5 mg/l at station II (August, 2022), with mean values of 2.75 ± 0.10 (station I), 4.25 ± 1.10 (station II), and 4.10 ± 0.84 (station III).

Total suspended solid (TSS) ranged between 0.9 mg/l at station III (February, 2022) and 3.10 mg/l at station II (August, 2022), with mean values of 1.92 ± 0.18 (station I),1.86 ± 0.09 (station II), and 1.47 ± 0.20 (station III). All the values of TSS were within the range (25-150 mg/l) recommended for aquaculture, and 500 mg/l for drinking water and swimming/ recreation and (WHO, 2007), 0.25 mg/l for agricultural purposes (Table 1). A large accumulation of suspended solids will reduce light penetration; thereby suppress photosynthetic activity of phytoplankton, algae and macrophytes. TSS > 80 mg/l may cause injure fish gills (Teodorowicz et al., 2006). The results of this study are quite below 450 mg/l set by FAO (2004), as cited by Misstear et al., (2017) for irrigation agriculture, and 600 mg/l set by WHO (2012) for drinking water. The results were in line with those of Odo et al., (2022) that recorded a range between 0.6 mg/l and 4.2 mg/l in the Akor River. A total suspended solids concentration below 20 mg/l appears clear, while levels over 40 mg/l may begin to appear cloudy (Fondriest Environmental, 2014).

Chloride (Cl^-)

Chloride is a common component of most aquatic ecosystem and is useful in maintaining their osmotic balance of aquatic organisms. When the level of chloride in the aquatic environment exceeds 100 mg/l, it causes burns on the gills and other parts. Chloride ranged from 34.9 mg/l at station I – 97.1 mg/l at station II (August, 2022), with mean values; 45.90 ± 7.11(station I), 64.76 ± 12.03(station II) and 55.69 ± 10.14 (station III).

All Cl values fall within the level desirable of 250 mg/l for drinking water, 100 mg/l for recreational activities, and 1065 mg/l for agricultural purposes (Table 1). However, few (45%) of the water samples had a concentration of chlorine (Cl) above the permissible value (50 mg/l) for aquaculture production (Table 1). High concentrations of chloride can make waters unpalatable and, therefore, unfit for drinking or livestock watering (Chapman, 1996), as well as inhibit plant growth, impair reproduction, and reduce the diversity of organisms in streams (United States Geological Survey, 2009). The free residual chlorine < 3 mg/l in the water pool was indicative of unsatisfactory management of the water disinfection and filtration process, because free residual chlorine may be unable to oxidize the organic compounds and kill the microorganisms that had enhanced the water while passing through the filters (Fadaei and Sadeghi, 2014).

Phosphate (PO_4^{3-})

It is an essential plant nutrient and stimulates plant (algae) growth in aquatic ecosystems. Phosphate is often in limited supply and its role for increasing the aquatic productivity is well recognized (Bhatnagar and Devi, 2013). Phosphate ranged from 0.21mg/l at station II (April, 2022) – 1.43 mg/l at station 1 (July), with mean values of 0.46 ± 0.11(station I), 0.56 ± 0.03(station II), and 0.49 ± 0.13 (station III). More than half (65.24%) of sampled water had values above 0.05 - 0.5 mg/l recommended for aquaculture and 0.2 mg/l for swimming/recreation water (Table 1). However, all the values recorded were quite below the level (11 mg/l) for drinking water. The values recorded in this recent study were within/slightly higher than the recommended level (0.05 to 0.5 mg) for aquaculture (Bhatnagar et al., 2004; Stone and Thomforde, 2004; Bhatnagar and Devi, 2013).

Sulphate (SO_4^{2-})

The presence of sulphate in aquatic ecosystem can alter taste of drinking water from the system, and very high levels can cause a laxative effect in unaccustomed consumers (Klamt et al., 2021). Sulphate ranged from 0.04 mg/l at station I (April, 2022) to 0.35 mg/l at station III (July, 2022), with mean values of 0.10 ± 0.002 (station I), 0.14 ± 0.04 (station II) and 0.15 ± 0.07 (station III). All the values recorded were within the adverse level (200 mg/l) good for drinking water (WHO, 2010), the desirable level (1000 mg/l) for swimming/recreational activities, and the level (0-96 mg/l) for agricultural purpose (FAO, 1994). High concentrations of sulphate above 400 mg/l may make water unpleasant to drink (Chapman, 1996). Gastrointestinal related diseases have been linked to drinking water with a high level of SO42- (Klamt et al., 2021). It is recommended that health authorities should be notified of drinking water sources with SO42- concentrations above 500 mg/l (WHO, 2017).

Nitrate (NO_3^-)

Nitrate ranged from 0.11 mg/l at station I (April) to 0.51 mg/l at station III (July), with mean values of 0.20 ± 0.05 (station I), 0.37 ± 0.14 mg/l (station II), and 0.27 ± 0.10 mg/l (station III). All the values recorded in the sampled water during the sampling period were within the level (0.1 to 4.5 mg/l) good for aquaculture (Bhatnagar and Devi, 2013). Nitrate is relatively nontoxic to fish and causes no health hazard except at exceedingly high levels (above 90 mg/l) (Stone and Thomforde, 2004; Santhosh and Singh, 2007). Nitrates have immense significance as major nutrients for the succession and productivity of phytoplankton and aquatic macrophytes (Mishra and Patro, 2015).

Generally, the nitrate concentration was within the maximum permissible limit of 50 mg/l for drinking water, as recommended by the Standard Organization of Nigeria (2015). Excess nitrate ion in drinking water is worrying as it causes blue baby syndrome in newborns and may cause stomach cancer in adults as well as increasing the likelihood of breast cancer in women (Baird and Cann, 2011) and other health disorders (USEPA, 2017). Contamination of fresh water with nitrates leads to significant environmental problems and health risks when water is used for drinking (WHO, 2007).

3.2. Drinking water quality indices

Comprehensive Pollution Index (CPI)

Spatio-temporal variations of CPI ranged from 0.150 at station I (March, 2022) to 0.449 at station II (May, 2022). All the CP1 values were within the status of non-polluted (< 0.4). However, station II in May 2022 exceeded the non-polluted level (<0.4). The results were within the level of CPI recorded by Anyanwu et al. (2022) in the Ikwu River, Umuahia. However, Matta et al. (2018) and Imneisi and Aydin (2018) reported high level (0.54 -2.47) in the Ganga River at Rishikesh, India, and (0.60-0.88) in the Elmali and Karacomak streams, Turkey respectively.

Nutrient Pollution Index (NPI)

Spatio-temporal variations of the nutrient pollution index (NPI) ranged from 0.07 at station I (April, 2022) to 0.46 at station I (July, 2022). All the NPI values were within the category of non-polluted (< 1) throughout the sampling period. Season has a great effect on the nutrient pollution index, although the seasonal activities have not had negative impact on water quality.

Pollution of food and water sources with nitrate is of concern due to its mental retardation as a result of methemoglonaemia (Isiuku and Enyoh, 2020). This indicated that throughout the sampling duration, the Anambra River Basin was not enriched with phosphate and nitrate; thus, both human and aquatic animals that depend on the river for socio-economic activities and survival, respectively, are not at risk of eutrophication. According to Isiuku and Enyoh (2020), surface water bodies are moderately polluted in the dry season and highly polluted in therainy season in south-eastern Nigeria.

3.3. Irrigation water quality indices

Potential Salinity (PS)

Potential Salinity indicates the suitability of water on the basis of the concentration of insoluble salt. Potential salinity (PS) in water from th Anambra River Basin ranged from 34.93 mg/l at station I (February, 2022) to 97.19 mg/l at station II (August, 2022). All the water from the three stations exhibited high potential salinity. The results indicated that water from the Anambra River Basin is not good for irrigation purposes. The results were within the high potential salinity recorded in Chaksu tehsil, Jaipur District, Rajasthan, India (Meena and Bisht, 2020). However, the result was quite higher than < 3.0 recorded by Pivic et al. (2022). Majority (91.63%) of their water samples had a potential salinity (PS) of more than 70%; thus falling out of good water for irrigation.

Soluble Sodium Percentage (SSP)

High sodium level in water for irrigation adversely affect the soil permeability, water infiltration, and total salinity leading to insoluble salt crystals and alkaline soil, which negatively affect some vulnerable crops (Megahed, 2020). Soluble sodium percentage (SSP) ranged between 11.58 % (September, 2022) at station I and 22.92 % (April, 2022) at station I. Wilcox (1950) classified SSP as <20% (excellent), 20 – 40% (good), 40 – 80% (fair), and >80% (poor/unsuitable).

SSP is one of the vital parameters widely used for assessing sodium hazard and water quality for irrigation purposes (Anyanwu et al., 2022). The SSP values were within the excellent irrigation category (<20%) at station I, with exception of 26.92% and 25.27% recorded in April and May 2022, respectively; which are within the good water category. At station II, all the values were within the excellent category (< 20%), except 21.95% recorded in August 2022. All the values recorded at station III were within the good irrigation water category, except for those recorded in July-September 2022. The SSP values were within the excellent irrigation. The SSP values were lower than those previously recorded in some Nigerian rivers; (28.16-34.69%) recorded by Udom et al. (2019) in the Abak River were within the good irrigation water category, and Eruola et al. (2020) recorded values (51.8 – 54.0%) that was within the fair/permissible category in the Owiwi River, Abeokuta, Ogun State. However, Anyanwu et al. (2022) and Omofunmi et al. (2019) recorded values within the excellent category in the Ikwu River, Umuahia, Abia State, and Ero dam, Ikun –Ekiti, Ekiti State, all in Nigeria.

4. Conclusion

This assessment revealed that all the parameters evaluated were within acceptable limits for drinking, fish production, recreation, and agriculture purposes, except pH (May - October 2022) and dissolved oxygen (February - March, July - October 2022). All the indices were also favourable and within their respective acceptable limits. The indices applied effectively examined the water quality of Anambra for multiple purposes and revealed that the water quality of the Anambra River Basin was suitable for the designated purposes.

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Conflict of interests

The authors hereby state that this research work and manuscript production complied with ethical standards, and none of the authors have any potential conflict of interests. We further declare that this research was not funded by any agency.

References

Adesuyi A.A., Nnodu V.C., Njoku K.L. et al. 2015. Nitrate and phosphate pollution in surface water of nwaja creek, Port Harcourt, Niger Delta, Nigeria. International Journal of Geology, Agriculture and Environmental Sciences. 3(5); 14-20.

Adimalla N., Dhakate R., Kasarla A. et al. 2020. Appraisal of groundwater quality for drinking and irrigation purposes in Central Telangana, India. Groundwater for Sustainable Development. 10;100334.

Amah-Jerry E.B., Anyanwu E.D., Avoaja D.A. 2017. Anthropogenic impacts on the water quality of Aba River, Southeast Nigeria. Ethiopian Journal of Environmental Studies and Management. 10(3):299 - 314.

Anyanwu E.D., Umeham S.N. 2020. Identification of water body status in Nigeria using predictive index assessment tools: a case study of Eme River, Umuahia, Nigeria. International Journal of Energy and Water Resources. 4(30) 271-279. DOI: 10.1007/s42108-020-00066-5

Anyanwu E.D., Ukaegbu A.B. 2019. Index approach to water quality assessment of a south eastern Nigerian river. International Journal of Fisheries and Aquatic Studies 7(1); 153-159.

APHA. 1992. Standard Methods for the Examination of Water and Wastewater. In: 18th (Ed.). Greenberg, A.E., Clesceri, L.S., Eaton, A.D., Eds.; American Public Health Association: Washington, DC, USA.

APHA. 2005. Standard Methods for the Examination of Water and Wastewater. In: 21st (Ed.). American Public Health Association/American Water Works Association/ Water Environment Federation: Washington, DC, USA.

Awofolu O., Mbolekwa Z., Mtshemla V. et al. 2005. Levels of trace metals in water and sediments of Tyume River and its effect on the irrigated farmland. Journal of Water Sanitation 31: 87-94.

Baird C., Cann M. 2011. Química Ambiental. In: 4 (Ed.) Porto Alegre: Bookman.

Barakat A., Baghdadi M.E., Rais J. et al. 2016. Assessment of spatial and seasonal water quality variation of OumErRbia river (Morocco) using multivariate statistical techniques. International Soil and Water Conservation Research. DOI: 10.1016/j.iswcr.2016.11.002

Bauder T.A., Waskom R.M., Davis J.G. 2014. Irrigation water quality criteria. Colorado State University Extension, Fort Collins, 55.

Bharti N., Katyal D. 2011. Water quality indices used for surface water vulnerability assessment. International Journal of Ecology and Environmental Science 2(1):154–173

Bhatti M. T., Latif M. 2011. Assessment of Water Quality of a River using an Indexing Approach during the Low-Flow Season. Irrigation and Drainage 60: 103-114.

Boaventura R., Pedro A.M., Coimbra J., Lencastre E. 1997. Trout farm effluents: characterization and impacts on the receiving streams. Environmental Pollution 95(3): 379-387

Breen B., Curtis J., Hynes S. 2018. Water quality and recreational use of public waterways. Journal of Environmental Economics and Policy 7(1): 1–15 DOI: 10.1080/21606544.2017.1335241

Chapman D. 1996. Water Quality Assessment. A Guide to the use of Biota, Sediments and Water in Environmental monitoring (2nd Edition). Taylor and Francis, London and New York. 626

Crim J.F. 2007. Water Quality Changes Across an Urban-Rural Land Use Gradient in Streams of the West Georgia Piedmont; American Society of Agronomy (ASA): Madison, WI, USA, 130

de Andrade Costa D., Soares de Azevedo J.P., Aurélio dos Santos M. et al. 2020. Water quality assessment based on multivariate statistics and water quality index of a strategic river in the Brazilian Atlantic Forest. Scientific Reports 10:22038. DOI: 10.1038/s41598-020-78563-0

Effendi H. 2016. River water quality preliminary rapid assessment using pollution Index. Procedia Environmental Sciences 33, 562 – 567.

Ekubo A.A., Abowei J.F.N. 2011. Review of some water quality management principles in culture fisheries. Research Journal of Applied Sciences, Engineering and Technology 3(2): 1342-1357

Eruola A.O., Makinde A.A., Eruola A.O. et al. 2020. Water Quality Assessment of Owiwi River for Potential Irrigation of Vegetables.Nigerian Journal of Technology 39(1): 293 – 300, DOI: 10.4314/njt.v39i1.32

Fadaei A.,Sadeghi M. 2014. Evaluation and assessment of drinking water quality in Shahrekord. Iran. Resour &Environt 4(3): 172 168. DOI: 10.5923/j.re.20140403.05

FAO. 1994. Water quality for agriculture. Water quality guidelines. Food and Agricultural Organization, Rome.

Federal Ministry of Environment. 2011. National Environmental (Surface and Groundwater Quality Control) Regulations. S.I. No. 22(49):98 Federal Ministry of Environment. Abuja, Nigeria.

Fondriest Environmental. 2014. Turbidity, Total Suspended Solids and Water Clarity. Fundamentals of Environmental Measurements. Web. URL: https://www.fondriest.com/environmental-measurements/parameters/water-quality/turbidity-total-suspended-solids-water-clarity

Hoseinzadeh E., Mohammady F., Shokouhi R. et al. 2013. Evaluation of biological and physico-chemical quality of public swimming pools. Hamadan (Iran). International Journal of Environmental Health Engeering2(1):21. DOI: 10.4103/2277-9183.113207

Imneisi I., Aydin M. 2018. Water Quality Assessment for Elmali Stream and Karacomak Stream using the Comprehensive Pollution Index (CPI) in Karacomak Watershed. Kastamonu, Turkey. Fresenius Environmental Bulletin 27(10): 7031-7038.

International Financial Corporation. 2007. Environmental, Health, and Safety Guidelines for Aquaculture: 6.

Isiuku B.O., Enyoh C.E. 2020. Pollution and health risks assessment of nitrate and phosphate concentrations in water bodies in South Eastern, Nigeria. Environmental Advances 2 (100018): 1 – 9.

ISO 11885. 2007. Water Quality—Determination of Selected Elements by Inductively Coupled Plasma Optical Emission Spectrometry (ICP-OES). ISO: Geneva, Switzerland.

Ji X., Dahlgren R.A., Zhang M. 2016. Comparison of seven water quality assessment methods for the characterization and management of highly impaired river systems. Environmental monitoring and assessment 188:1-16.

Kasmir M., Rosmiati H. 2014. Water Quality Parameter Analysis for the Feasibility of Shrimp Culture in Takalar Regency. Indonesia. Modern Applie Science 8: 321.

Khatri N., Tyagi S. 2015. Influences of natural and anthropogenic factors on surface and groundwater quality in rural and urban areas. Frontiers in Life Science 8:1, 23-39, DOI: 10.1080/21553769.2014.933716

Klamt R.A., Costa A. B., Gaedke M. A. et al. 2021. Drinking water quality indices: a systematic review. Ambient. Água 16(2), 1-14.

Mateo-Sagasta J., Zadeh S.M., Turral H. et al. 2017. Water pollution from agriculture: a global review. Executive summary. FAO, Rome, Italy and International Water Management Institute (IWMI). Colombo, Sri Lanka: 35.

Matta G., Nayak A., Kumar A. et al. 2020. Water quality assessment using NSFWQI, OIP and multivariate techniques of Ganga River system, Uttarakhand, India. Applied Water Science 110:206.

Matta G., Naik P.K., Machell J. et al. 2018. Comparative study on seasonal variation in hydro-chemical parameters of Ganga River water using comprehensive pollution index (CPI) at Rishikesh (Uttarakhand) India. Desalination and Water Treatment 118: 87–95. DOI: 10.5004/dwt.2018.22487

MDEQ. n.d. Total Suspended Solids. In Michigan Department of Environmental Quality. URL: http://www.michigan.gov/documents/deq/wb-npdes-TotalSuspendedSolids 247238 7.pdf

Meena A.L., Bisht P. 2020. Assessment of water quality for irrigation purpose: a case study of Bassi and Chaksu Tehsils, Jaipur District, Rajasthan, India. Sustainability, Agri, Food and Environmental Research 323180.

Megahed H. 2020. GISbased assessment of groundwater quality and suitability for drinking and irrigation purposes in the outlet and central parts of Wadi ElAssiuti, Assiut Governorate, Egypt. Bulletin of the National Research Centre 44(187). DOI: 10.1186/s42269-020-00428-3

Mishra S., Patro L. 2015. Evaluation of nitrate and nitrite contents in water of Chilika Lagoon, Odisha, India. International Journal of Advance Research and Innovative Ideas in Education (IJARIIE) ISSN: 2395-4396

Misstear B., Banks D., Clark L. et al. 2017. Water Wells and Boreholes. Appendix 5 FAO irrigation water quality guidelines 473-474

Mutea F.G., Nelson H.K., Au H.V. et al. 2021. Assessment of Water Quality for Aquaculture in Hau River, Mekong Delta, Vietnam Using Multivariate Statistical Analysis. Water 13: 3307. DOI: 10.3390/ w13223307

Pivic R., Maksimovic J., Dinic Z. et al. 2022. Hydrochemical Assessment of Water Used for Agricultural Soil Irrigation in the Water Area of the Three Morava Rivers in the Republic of Serbia. Agronomy 12: 1177. DOI: 10.3390/agronomy12051177

Popović N.Z., Đuknić J.A., Čanak Atlagić J.Ž. et al. 2016. Application of the Water Pollution Index in the Assessment of the Ecological Status of Rivers: A Case Study of the Sava River, Serbia. Acta Zoologica Bulgarica 68(1), 97-102.

Reda A.H. 2015. Assessment of physicochemical quality of spring water in Arbaminch Ethiopia. Journal of Environmental Analytical Chemistry2:5. DOI: 10.4172/2380-2391.1000157

Sadiq R., Haji S.A., Cool G. et al. 2010. Using penalty functions to evaluate aggregation models for environmental indices. Journal of Environmental Management 91(3): 706–716

Sharma S.K., Ravi V.K., Kumar S. et al. 2021. Use of Overall Index of Pollution and Water Quality Index to Assess Rani Pond at Aurangabad, Bihar, India. Plant Archives 21(1): 2377-2382

Shukla A.K., Ojha C.S.P., Garg R.D. 2017. Surface water quality assessment of Ganga River Basin, India using index mapping. In: IEEE International Geoscience and Remote Sensing Symposium (IGARSS). Fort Worth, TX: 5609–5612

Son C.T., Giang N.T.H., Thao T.PV. et al. 2020. Assessment of Cau River water quality assessment using a combination of water quality and pollution indices, Journal of Water Supply: Research and Technology-Aqua (692), 160–172. DOI: 10.2166/aqua.2020.122

Teodorowicz M., Gawrońska H., Lossow K. et al. 2006. Impact of Trout farms on water quality in the MARÓZKA stream (Mazurian Lakeland, Poland). Archives of Polish Fisheries 14(2):243-255.

Udom E.A., Ekpo A.E., Oluka S.I. 2019. Assessment of irrigation water qualities of Abak River, Abak, Akwa Ibom State, Nigeria. Global Journal of Pure and Applied Sciences 25(2), 135-144.

United States Geological Survey. 2009. Chloride Found at Levels That Can Harm Aquatic Life In Urban Streams Of Northern US. Science Daily. URL: https://www.sciencedaily.com/releases/2009/09/090916123513

USEPA (US Environmental Protection Agency). 2017. Risk assessment guidance for superfund (RAGS). 1993. Volume I: human health evaluation manual (part E) interim. United States Environmental Protection Agency. Washington, D.C

Wang L., Li H., Dang J. et al. 2020. Effects of Urbanization on Water Quality and the Macrobenthos Community Structure in the Fenhe River, Shanxi Province, China. Hindawi Journal of Chemistry 8653486. DOI: 10.1155/2020/8653486

WHO. 2006. Guidelines for Safe Recreational Water Environments: Swimming Pools and Similar Environments. Vol. 2, World Health Organization, USA. ISBN: 9789241546805: 118

WHO. 2007. The world health report a safer future Global Public Health Security in the 21st Century ISSN 1020–3311

Wilcox L. U. 1950. Classification and Use of Irrigation Waters, Department of Agriculture, United States. Washington D. C. 696: 16.