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WATER AND SEDIMENT QUALITY ASSESSMENT, AND EFFECT ON ARTHROPOD SPECIES DIVERSITY OF JAJA CREEK AND ADJOINING DOWNSTREAM SECTION OF THE IMO RIVER, SOUTH-SOUTH, NIGERIA

Akpan A. U.[1*], Ukpai O. M.[2], Ehisianya C. N.[2], Esenowo I. K.[1], Effiong M. U.[1], Okore O. O.[2], Oboho D. E.[1], Eduok I. E.[1], and Essien U. B.[1]

[1]Department of Animal and Environmental Biology, Faculty of Biological Sciences, University of Uyo, Akwa Ibom State, Nigeria.

[2]Department of Zoology and Environmental Biology, College of Natural Sciences, Michael Okpara University of Agriculture, Umudike, Abia State, Nigeria.

[*]Corresponding Author's Email: akpanudoh@uniuyo.edu.com, akpanau13001f@gmail.com; Tel.: +2348038981129

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ABSTRACT: *This study assessed the water and sediment quality and effect on the diversity of arthropod species of Jaja creek and adjoining downstream section of Imo river. Three (3) sampling sites each were marked out along the stretch of the Jaja creek and adjoining Imo river, plus control sampling site. Collections of samples, water, sediment and arthropods were carried out in the seven (7) sampling sites, observing standard procedures. The collected water and sediment samples were fixed with 1:1 nitric acid for the measurement of inorganic loads and heavy metals in the laboratory. Collections of arthropod fauna were done across the seven sampling sites and they were stored in 70% ethyl alcohol until identification and counting. Single factor pollution index (SF_{pi}) and Nemerow's pollution index (P_N) were calculated to assess the water and sediment quality. The Nemerow's pollution index of sulphate, nitrate, phosphate, iron, manganese, zinc, and copper revealed that the water and sediment was polluted. Fifty (50) different arthropod species were identified and grouped into three classes of Crustaceans, Insecta, and Arachnida, with nine orders and 23 families. The diversity indices and Pearson correlation results revealed that the water and sediment quality affected the arthropod species diversity. A strong conservation plan should be established for the preservation of the water bodies' and the aquatic arthropod species.*

KEYWORDS: Physico-chemical parameters, inorganic load, heavy metals, single-factor pollution index (SF_{pi}), and Nemerow's pollution index (P_N).

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INTRODUCTION

Water is an essential element of any aquatic ecosystem. Its availability is an essential prerequisite for the growth and development of aquatic organisms (Dey*et al*., 2021). Water quality monitoring actions have focused on the level of pollutants. The excessive contamination and pollution of surface water by various materials is a global public health concern, as these materials are potentially responsible for causing deleterious effects on human health through the food chain (Dey*et al*., 2021). Inorganic materials and heavy metals have been part of the most frequent observed water pollutants resulting from anthropogenic and industrial activities. The major inorganic loads that have been seen as major pollutants to aquatic environments include nitrate, phosphate, nitriteand sulphate, and they have found their way into aquatic environments through the application of fertilizers on farmlandsand industrial activities (Akpan*et al.,* 2024), and they have been reported in the Imo river of the South-East region (Okorie&Nwosu, 2014).

Heavy metals are pollutants creating a serious threat to the biosphere due to their property of bioaccumulation in different tropics levels of an ecosystem (Muchuweti*et al*., 2006;Khlifi&Hamzachaffai, 2010; Abiaobo&Asuquo, 2020). The unrestricted disposal of industrial waste, agrochemicals, and transportation waste leads to the severe pollution of soil, waterand air by heavy metals (Jàrup, 2003).

Heavy metals—Arsenic (As), Cadmium (Cd), Chromium (Cr), Cobalt (Co), Lead (Pb), Manganese (Mn), Mercury (Hg), Nickel (Ni), Thallium (Ti) and Zinc (Zn)—enter aquatic environments from a variety of sources directly exposed to surface water, in addition to the discharge of various treated and untreated liquid wastes into the water bodies (Farombi *et al.*, 2007). According to Farombi *et al.* (2007), an aquatic ecosystem is the ultimate recipient of almost everything, including inorganic content loads and heavy metals. As inorganic contents and heavy metals find their way into water bodies, they are deposited in water and sediment (Linnik&Zubenko, 2000).

The presence of inorganic materials, and heavy metals in values above normal in an aquatic environment could affect arthropods' distribution and diversity (Arimoro&Osakwe, 2006), and they have been reported by Hart and Zabbey (2005), Bellingham (2012), Lawson and Oloko (2013), Davies and Ugwumba (2013), Okorie and Nwosu (2014), Amusan *et al.* (2018), Uwadiae (2018), Akpan *et al*. (2019) andPopoola *et al.* (2019) to have exerted a major influence on biological activities and growth of aquatic arthropod species. The presence of the load of contaminants and pollutants in aquatic environments could create a serious threat to aquatic fauna (Abiaobo&Asuquo, 2020). For the evaluation of the pollution levels of the water and sediment of the Jaja creek and adjoining Imo river, thoughmany indices have been developed to test for contamination and pollution levels in aquatic environments, in this study, Single Factor Pollution Indexes (SF_{pi}) and Nemerow's Pollution Index (NPI) would be adopted for the evaluation of the status of the water and sediment quality of the creek and the river.

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METHODOLOGY

Study Area

The study area was IkotAbasi Local Government Area, and it lies between Longitudes 7^o 30'E and 7^o 45'E Latitudes 4^o 30'W and 4^o 45'N (Figure 1) (Ekpo&Ukpong, 2014). The study area has a climatic condition and it is divided into rainy and dry seasons (Onyekuru *et al*., 2017). The two water bodies that were selected for the research study were Jaja creek and Imo river.

Jaja creek (UtaEwa estuary) (Latitude 4^{o}32' 44.082'N and Longitude 7^{o}33'15.108'E) stretches its length into Opukalama village (Akpan*et al.,* 2024). The creek forests provide a habitat to a variety of aquatic arthropods and other animal species (Hutchison *et al.,* 2014; Akpan*et al*., 2024). The creek is bounded by a thick mangrove forest dominated by Nipa palm (*Nypafruticans*) and interspersed by *Rhizophora* species (Esenowo *et al.,* 2016; Akpan *et al.,* 2019; Akpan*et al.,* 2024).

The Imoriver drains four states, namely Imo, Abia, AkwaIbom and Rivers States, and empties into the Atlantic ocean (Figure 1) (Amangabara, 2015). The downstream section of the Imo river that drains through AkwaIbom (UtaEwa), adjoining the Jajacreek was marked for this research work. This section is characterised by associated forest structure with Nipa plants and dispersing mangrove plants, and the ALSCON plant is stationed on this section of the river (Ekpo&Ukpong, 2014; Abiaobo *et al*., 2020).

Seven (7) sampling sites with distinguishing ecological characteristics were marked for this study: three sites from the Jaja creek, three sites from the adjoining Imo river, and control point (Figure 1).

Site 1 was marked out of Jajacreek and it lies between Latitude 4^o 32' 41.2692'N and Longitude 7^o 32' 44.5164'E. Vegetation is sparse with mainly mangrove *Rhizophora* sp. and Nipa palm (*Nypafruticans*). Site 2 of the Jaja creek lies within Latitude 4^{o}32' 45.6684'N and Longitude 7^o 33' 12.276'E, and Site 3 lies within Latitude 4^o 32' 44.1636'N and Longitude 7^o 33' 48.474'E close to Opukalama village.

Site 4 was marked as the Control. It lies between Latitude 4^o 32' 26.0808'N and Longitude 7^o 32' 32.2188'E, and it makes the point of conflux between the Jaja creek and the adjoining downstream section of the Imo river. The vegetation is thick with mainly mangrove *Rhizophora* sp. and Nipa palm (*Nypafruticans*).

Sites 5, 6and 7 were marked out from the adjoining downstream section of the Imo river with coordinates: Latitude 4^o 31' 36.5592'N and Longitude 7^o 32' 53.1888'E, Latitude 4^o 32' 31.8444'N and Longitude 7^o 22' 49.908'E , and Latitude 4^o 32' 44.1636'N and Longitude 7^o 31' 55.3332'E respectively.

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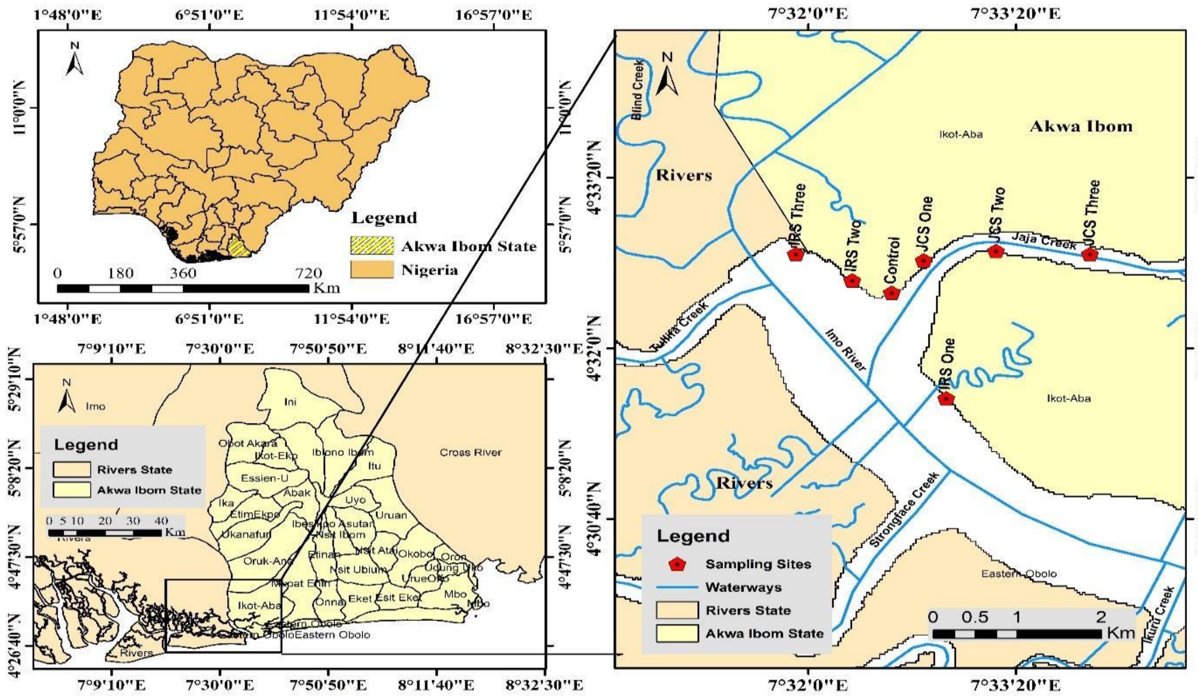

Figure 1: Map showing the study area (Cartography Studio, Department of Geography and Natural Resources Management, University of Uyo) (Akpan*et al.*, 2024).

Water and Sediment Sample Collection and Measurement of Variables

Water and sediment samples were collected for a period of two years between January 2020 and December 2021 in accordance with standard procedures using clean 330 ml amber bottles(Onyekuru *et al*., 2017; Akpan*et al*., 2024).

Testing for Inorganic Load Analysis of the Water and Sediment Sample

Sulphate, phosphate, nitrate, and nitrite from the water and sediment samples were carried out in the laboratory, according to the APHA (2002) standards.

Testing for Heavy Metal Analysis of the Water and Sediment Sample

The water and sediment samples from the field were stored in the refrigerator until analyses for the following heavy metals: zinc, iron, manganese, copper, lead, chromium, cadmium, and aluminum. After 24 hours, digest solutions of the water and sediment samples were prepared by measuring 50 ml and 1 g of water and sediment samples respectively into 250 ml crucible, digested with aqua regia (HCl and HNO_3, ratio of 3:1) at 130ºC using an electric hotplate for 30 minutes per portion of spectrophotometer (model: Varian spectra 100, Australia)and was set with power on for ten minutes. The standard metal solutions were injected to calibrate the atomic absorption spectroscopy (AAS) using acetylene gas. An aliquot of the digest solutions was injected and the concentrations were obtained from the AAS (Parker, 1972; AOAC, 1990).

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Arthropod Sample Collection

Arthropods were collected from the seven sampling sites. A variety of collection techniques were adopted. Arthropod sampling at the littoral zone was carried out using a scoop net, when the tide was low. At low tide, the holes of the onshore dwelling arthropods were exposed, and they were dug and the scoop net was used to harvest the emerging arthropods. At the mid-channel of the estuary vanVeen grab of size 0.1 m^2 and square lift net at low tide from an anchored paddling boat (Esenowo *et al.*, 2016; Uwadiae, 2018; Akpan *et al*., 2019;Akpan*et al*., 2024) was used to collect the arthropods. Locally made crab traps (Addo*et al*., 2018) commonly used by the local fishermen in the community were also set at the sampling sites during low tide and later harvested at ebbing tide. According to Carmona-Suâres and Conde (2002), though with modifications, a seine net with a mesh diameter of 1.0 cm of six (6) metres long and 1 m tall was used to set traps for the collection of prawns and shrimps at the sampling sites (Akapan*et al*., 2024). The sediment-dwelling arthropods were collected from the sediment using elutriation technique (Alonso-Zarazaga& Domingo-Quero, 2010). The arthropods sampled in the field were stored in a clean container and packed properly (Lawal-Are, 2009), and transported to the laboratory of the Department of Animal and Environmental Biology of University of Uyo, for proper storageand subsequent identification and counting.

Identification

The arthropod samples collected were identified using the identification guides documented by Abby-Kalio (1982), Carpenter and Niem (1998), Bezerra (2012), and Carpenter and De Angelis (2014).

Statistical Analysis

Data that were obtained from the physico-chemical parameters, nutrient loads, heavy metal, and arthropods were entered into the Microsoft Excel version 2013 and analysed using SPSS 20 and PAST 4.2.

Single Factor Pollution Index (Sfpi)

The single factor pollution index analysis method was applied to assess the pollution level of one pollutant of each of the water and sediment of the two water bodies using the equation below:

$P_i = C_i / S_i$ ……………………. (Liu *et al*., 2017)

where Pi is the single factor pollution index, Ci (µg/l) is the measured concentration of inorganic load parameters and heavy metals, and Si (µg/L) is the standard value of the contaminants and pollutants. The value of the single factor index $P_i \leq 1$ indicates no pollution level (Category I). Category II: $1 < P_i \leq 2$ is regarded as a low pollution level. Category III: $2 < P_i \leq 3$ is moderately polluted. Category IV: $P_i > 3$ indicates high levels of pollution.

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Nemerow Pollution Index Analysis (Npia)

Thus, Nemerow pollution index analysis was calculated with the equation below:

Nemerow pollution index (P_N): $Pn = \sqrt{(Pi)^2 + Pmax^2 / 2}$ ………. (Shen*et al.*, 2021).

Interpretation

Pn = Comprehensive pollution index of the sampling point

P_{max} = the maximum value of the single-item pollution index of the pollutants at the sampling point;

$P_i = \frac{1}{n}\sum_i^n = i$ $P_i$is the average value of the single-factor index.

RESULTS

Inorganic Load of the Water Sample from the Jaja Creek and Adjoining the Downstream Section of the Imo River

The results of the inorganic load measured from the water samples from the Jaja creek and adjoining downstream section of the Imo river revealed that the inorganic load parameters were significantly different between all the sampling sites (Table 1). The mean results of the heavy metals present in the Jaja creek and Imo river sampling sites revealed that the heavy metal were significantly different between the sampling sites at p<0.05 (Table 2).

Table 1: Mean inorganic load for water for Jaja creek and adjoining Imo river by sampling sites for the study period.

Sites	Nitrate (mg/l)	Sulphate (mg/l)	Phosphate (mg/l)	Nitrite (mg/l)	THC (mg/l)
Site 1 (Jaja Creek)	2.23±0.04cd	5.13±0.05b	0.33±0.01bc	0.19±0.01c	36.35±0.15a
Site 2 (Jaja Creek)	2.30±0.03bc	5.17±0.05ab	0.34±0.01abc	0.21±0.01c	35.69±0.38bc
Site 3 (Jaja Creek)	2.44±0.02a	4.86±0.08c	0.34±0.00abc	0.41±0.04a	36.09±0.13abc
Total Mean (JajaCreek)	**2.32±0.02a**	**5.05±0.04b**	**0.34±0.00ab**	**0.27±0.02a**	**36.05±0.14b**
Site 4 (Control)	2.28±0.01c	5.09±0.04b	0.32±0.01c	0.17±0.00c	36.64±0.10a
Site 5 (Imo River)	2.17±0.04d	5.33±0.06a	0.36±0.02ab	0.22±0.01c	35.61±0.12c
Site 6 (Imo River)	2.16±0.04d	5.33±0.07a	0.37±0.01a	0.22±0.01c	36.25±0.19ab
Site 7 (Imo River)	2.38±0.04ab	5.32±0.07a	0.35±0.01abc	0.31±0.02b	36.46±0.21a
Total Mean (Imo River)	**2.24±0.02b**	**5.32±0.04a**	**0.36±0.01a**	**0.25±0.01a**	**36.11±0.11b**
Overall Total Mean	**2.28±0.01**	**5.17±0.02**	**0.34±0.00**	**0.25±0.01**	**36.16±0.08**
Mean Range Value	**1.60–3.02**	**4.05–6.12**	**0.05–0.55**	**0.10–0.82**	**34.39 –37.99**
p Value	<0.001*	<0.001*	0.026*	<0.001*	0.002*

Means along the same column with different alphabet(s) are significantly different at p<0.05.

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Table 2: The results of mean±se of the heavy metals of the water of all the sampling sites of Jaja creek and adjoining Imo river during the study period.

Means along the same column with different alphabet(s) are significantly different at p<0.05.

Sites	Cadmium (mg/l)	Chromium (mg/l)	Iron (mg/l)	Lead (mg/l)	Manganese (mg/l)	Zinc (mg/l)	Copper (mg/l)	Aluminium (mg/l)
Site 1 (Jaja Creek)	0.08±0.02c	0.04±0.00b	0.68±0.01d	0.03±0.00b	0.32±0.00b	5.37±0.06b	1.36±0.02c	0.02±0.00bc
Site 2 (Jaja Creek)	0.08±0.02c	0.05±0.00b	0.68±0.01d	0.02±0.00b	0.31±0.01b	5.37±0.06b	1.38±0.02c	0.06±0.01a
Site 3 (Jaja Creek)	0.10±0.03c	0.06±0.01b	0.73±0.01abc	0.03±0.01b	0.35±0.01b	5.74±0.11a	1.74±0.03a	0.04±0.01b
Total Mean (JajaCreek)	**0.09±0.01b**	**0.05±0.00b**	**0.69±0.01c**	**0.03±0.00a**	**0.33±0.01b**	**5.49±0.05a**	**1.49±0.02a**	**0.04±0.00a**
Site 4 (Control)	0.05±0.00c	0.05±0.00b	0.76±0.01a	0.02±0.00b	0.33±0.01b	5.48±0.05b	1.43±0.04c	0.02±0.00c
Site 5 (Imo River)	0.30±0.04b	0.05±0.00b	0.71±0.01bc	0.02±0.00b	0.30±0.01b	4.86±0.08c	1.41±0.01c	0.03±0.00bc
Site 6 (Imo River)	0.39±0.03a	0.06±0.00b	0.71±0.01c	0.02±0.00b	0.85±0.18a	4.62±0.08d	1.41±0.00c	0.03±0.00bc
Site 7 (Imo River)	0.44±0.04a	0.18±0.03a	0.74±0.01ab	0.05±0.01a	0.85±0.16a	5.05±0.11c	1.66±0.03b	0.06±0.01a
Total Mean (Imo River)	**0.38±0.02a**	**0.10±0.01a**	**0.72±0.00b**	**0.03±0.00a**	**0.67±0.08a**	**4.85±0.05b**	**1.49±0.01a**	**0.04±0.00a**
Overall Total Mean	**0.21±0.01**	**0.07±0.00**	**0.71±0.00**	**0.03±0.00**	**0.47±0.04**	**5.21±0.04**	**1.48±0.01**	**0.04±0.00**
Mean Range Value	**0.03–0.67**	**0.02–0.40**	**0.05–0.85**	**0.01–0.18**	**0.24–1.82**	**4.16–6.59**	**1.16–1.95**	**0.01–0.18**
p Value	<0.001*	<0.001*	<0.001*	<0.001*	<0.001*	<0.001*	<0.001*	<0.001*

Inorganic Loads of the Sediment of the Jaja Creek and Adjoining Downstream Section of the Imo River

The results of the inorganic loads measured from the sediment of the Jaja creek and downstream section of the Imo river revealed that the inorganic loads between the sampling sites of the two water bodies were significantly different at $p<0.05$ (Table 3).

Table 3: Mean±SD of the inorganic loads of the sediment per site of Jaja creek and adjoining Imo river.

Sites	Sulphate (mg/l)	Ammonium (mg/l)	Nitrate (mg/l)	Nitrite (mg/l)	Phosphate (mg/l)
Site 1 (Jaja Creek)	33.67±0.29a	8.34±0.26a	5.33±0.07b	1.67±0.18c	9.09±0.06c
Site 2 (Jaja Creek)	31.70±0.26bc	7.39±0.14b	4.97±0.04c	1.54±0.14c	9.47±0.08bc
Site 3 (Jaja Creek)	29.78±0.43d	7.39±0.10b	5.88±0.18a	2.26±0.17ab	9.96±0.25ab
Mean Total (Jaja creek)	**31.72±0.24b**	**7.71±0.11a**	**5.40±0.07a**	**1.82±0.10b**	**9.51±0.09a**
Site 4 (Control)	34.70±0.29a	6.75±0.06c	4.37±0.11d	1.75±0.06bc	8.96±0.08c
Site 5 (Imo River)	33.84±0.25a	5.30±0.30d	5.13±0.02bc	2.29±0.27ab	8.95±0.05c
Site 6 (Imo River)	32.19±0.46b	7.20±0.09bc	4.40±0.04d	2.52±0.19a	9.17±0.03c
Site 7 (Imo River)	30.89±0.48c	7.43±0.20b	5.31±0.09b	2.24±0.21ab	10.43±0.37a
Mean Total (Imo River)	**32.31±0.26b**	**6.64±0.15b**	**4.95±0.05b**	**2.35±0.13a**	**9.52±0.14a**
Overall Mean Total	**32.40±0.16**	**7.12±0.08**	**5.06±0.05**	**2.04±0.07**	**9.43±0.07**
p Value	<0.001*	<0.001*	<0.001*	0.001*	<0.001*

Means along the same column with different alphabet(s) are significantly different at p<0.05.

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Heavy Metal Contents of the Sediment of the Jaja Creek and Adjoining Downstream Section of the Imo River

The mean±sd results of the metals measured from the sediment of the two water bodies revealed that cadmium varied among the sites along the stretch of Jaja creek and the Imo river. Site 7 of the adjoining Imo river recorded 3.87±0.11 mg/kg of cadmium. Site 3 (3.65±0.08 mg/kg) of Jaja creek recorded the highest, whereas Site 1 (Jaja creek) recorded 3.02±0.02 mg/kg as the least (Table 4).

Table 4: Mean±SD of the metals of the sediment of the sampling stations of Jaja creek and adjoining Imo river.

Sites	Cadmium (mg/kg)	Chromium (mg/kg)	Iron (mg/kg)	Lead (mg/kg)	Manganese (mg/kg)	Zinc (mg/kg)	Copper (mg/kg)	Aluminium (mg/kg)
Site 1 (Jaja Creek)	3.02±0.02c	2.24±0.04d	11.12±0.06a	0.04±0.00b	4.91±0.06bc	7.92±0.18bc	7.25±0.05d	1.42±0.04de
Site 2 (Jaja Creek)	3.07±0.02c	2.57±0.03c	11.20±0.07a	0.05±0.00b	5.08±0.12ab	7.76±0.11c	7.08±0.05d	1.44±0.04cde
Site 3 (Jaja Creek)	3.65±0.08b	3.19±0.09b	11.52±0.24a	0.04±0.00b	5.22±0.13a	7.32±0.10d	7.49±0.06c	1.66±0.05b
Mean Total (Jaja Creek)	**3.25±0.04ab**	**2.67±0.05b**	**11.28±0.09a**	**0.05±0.00ab**	**5.07±0.06a**	**7.67±0.08c**	**7.28±0.03b**	**1.51±0.03b**
Site 4 (Control)	3.21±0.02c	2.58±0.02c	11.36±0.05a	0.04±0.00b	4.79±0.04cd	8.12±0.04b	7.30±0.07cd	1.39±0.06e
Site 5 (Imo River)	3.20±0.08c	2.67±0.06c	11.00±0.06a	0.04±0.00b	4.46±0.07e	8.60±0.06a	7.75±0.06b	1.54±0.03bc
Site 6 (Imo River)	3.16±0.07c	3.12±0.08b	11.09±0.27a	0.04±0.00b	4.62±0.10de	8.57±0.08a	8.10±0.11a	1.53±0.02cd
Site 7 (Imo River)	3.87±0.11a	3.65±0.11a	11.11±0.19a	0.09±0.02a	4.93±0.09bc	8.68±0.09a	8.11±0.11a	1.79±0.04a
Mean Total (Imo river)	**3.41±0.06a**	**3.15±0.06a**	**11.07±0.11a**	**0.06±0.01a**	**4.67±0.05b**	**8.62±0.05a**	**7.99±0.06a**	**1.62±0.02a**
Total	**3.31±0.03**	**2.86±0.04**	**11.20±0.06**	**0.05±0.00**	**4.86±0.04**	**8.14±0.05**	**7.58±0.04**	**1.54±0.02**
Mean Range Value	**2.7–4.79**	**2.15–4.67**	**7.34–13.23**	**0.01–0.45**	**4.08–6.10**	**5.91–9.23**	**6.54–9.42**	**0.62–2.01**
p Value	<0.001*	<0.001*	0.296	<0.001*	<0.001*	<0.001*	<0.001*	<0.001*

Means along the same column with different alphabet(s) are significantly different at p<0.05.

Single Factor Pollution Index (SF*pi*)

The results of the single pollution index for the water quality of the Jaja creek and the adjoining downstream sector of the Imo river revealed that all the sampling sites show clean lines of pollution (Category I) with nitrate, sulphur and phosphate, as their single factor pollution index was less than 1 (Table 5). The single factor pollution index (SFpi) of Ca for all the sampling sites was greater than 3 with sites of the Imo river recording the highest; Site 7 recorded 44, followed by Site 6 (39) (Table 5). The results of the single pollution index for the test of the sediment quality of the Jaja creek and Imo River are expressed in Table 6.

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Table 5: Single factor pollution index (SF*pi*) for the water quality of the Jaja creek and Imo river.

Sampling Area	Sites	SF*pi*Na	SF*pi*Su	SF*piPh*	SF*piNi*	SF*pi*Ca	SF*piCh*	SF*piFe*	SF*piPb*	SF*piMn*	SF*piZn*	SF*piCu*	SF*piAl*
Jaja Creek	1	0.045	0.051	0.094	0.095	8	0.08	0.68	0.3	2.67	1.074	0.91	0.1
	2	0.046	0.052	0.092	1.05	8	0.1	0.48	0.2	2.58	1.074	0.92	0.3
	3	0.049	0.049	0.092	2.05	10	0.12	0.73	0.3	2.72	1.15	1.16	0.2
Control point	4	0.046	0.051	0.091	0.85	5	0.12	0.76	0.2	2.75	1.096	0.953	0.1
Imo River	5	0.043	0.053	0.103	1.1	30	0.1	0.71	0.2	1.5	0.972	0.94	0.15
	6	0.043	0.053	0.106	1.1	39	0.12	0.71	0.57	0.57	0.984	0.94	0.15
	7	0.048	0.053	0.100	1.55	44	0.36	0.74	0.5	0.57	1.01	1.11	0.3

The value of the single factor index Pi ≤ 1 indicates clean lines of pollution degree (Category I), 1 < Pi ≤ 2 is regarded as low pollution degree (Category II), 2 < Pi ≤ 3 is moderately polluted (Category III), and Pi > 3 indicates high levels of pollution degree (Category IV).

Table 6: Single factor pollution index (SF*pi*) for the sediment quality of the Jaja creek and Imo river.

Sampling Area	Sites	SF*pi*Na	SF*pi*Su	SF*piPh*	SF*piNi*	SF*pi*Ca	SF*piCh*	SF*piFe*	SF*piPb*	SF*piMn*	SF*piZn*	SF*piCu*	SF*piAl*
Jaja Creek	1	0.11	0.34	2.60	8.35	0.07	0.04	Nil	Negli.	Nil	0.09	1.51	Nil
	2	0.10	0.32	2.71	7.7	0.07	0.05	Nil	Negli	Nil	0.09	1.48	Nil
	3	0.12	0.03	2.85	11.3	0.09	0.06	Nil	Negli	Nil	0.08	1.56	Nil
Control Point	4	0.09	0.35	2.56	8.75	0.08	0.05	Nil	Negli	Nil	0.09	1.62	Nil
Imo River	5	0.10	0.34	2.56	0.10	0.08	0.05	Nil	Negli	Nil	0.10	1.61	Nil
	6	0.09	0.32	2.62	12.6	0.08	0.06	Nil	Negli	Nil	0.10	1.69	Nil
	7	0.11	0.31	2.98	11.2	0.09	0.07	Nil	Negli	Nil	0.10	1.69	nil

The value of the single factor index Pi ≤ 1 indicates clean lines of pollution degree (Category I), 1< Pi ≤ 2 is regarded as low pollution degree (Category II), 2 < Pi ≤ 3 is moderately polluted (Category III), and Pi > 3 indicates high levels of pollution degree (Category IV).

Nemerow's Pollution Index Results for the Water and Sediment Quality of theJaja Creek and the Imo River

The Nemerow's pollution index results testing for the water quality of the Jaja creek and Imo river revealed that nitrate (2.68 and 2.66 for Jaja creek and Imo river respectively) was categorised in the Category III of the category of the pollution of the index (Table 7). Cadmium, chromium, iron, lead, and manganese were in Category I for the two water bodies (Table 7). The results of the Nemerow's pollution index for the sediment quality of the Jaja creek and adjoining downstream section of the Imo river revealed that the sediment of the two water bodies was seriously polluted (Category V) with sulphate, ammonium, nitrate, phosphate, total organic carbon (TOC), total organic matter, total hydrocarbon (THC), iron, manganese, zinc, and copper (Table 8).

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Table 7: Nemerow's pollution index for the water quality of the Jaja creek and Imo river.

Variables	Nemerow's Pollution Index (PN)				Category of Pollution (IR)
	Jaja Creek (JC)	Category of Pollution (JC)	Control	Imo River (IR)	
Nitrate (mg/l)	2.68	III	2.33	2.66	III
Sulphate (mg/l)	5.67	V	5.67	5.74	V
Phosphate (mg/l)	0.44	I	0.36	0.45	I
Nitrite (mg/l)	0.61	I	0.18	0.60	I
THC (mg/l)	37.05	V	36.88	37.06	V
Cadmium (mg/g)	0.49	I	0.05	0.57	I
Chromium (mg/g)	0.12	I	0.06	0.41	I
Iron (mg/g)	0.79	I	0.82	0.77	I
Lead (mg/g)	0.14	I	0.03	0.15	I
Manganese (mg/g)	0.40	I	0.37	2.39	II
Zinc (mg/g)	6.08	V	5.96	5.78	V
Copper (mg/g)	2.01	II	1.99	1.74	II
Aluminium (mg/g)	0.17	I	0.05	0.10	I

P_N: Category I (≤1 – No pollution), Category II (1 to 2 – slightly polluted), Category III (2 to 3 – lightly polluted), Category IV (3 to 5 – moderately polluted), and Category V (>5 – seriously polluted).

Table 8: Nemerow's pollution index for the sediment quality of the Jaja creek and Imo river.

Variables	Nemerow's Pollution Index (PN)				Category of Pollution
	Jaja Creek	Category of Pollution	Control	Imo River	
Sulphate (mg/l)	36.53	V	35.88	34.73	V
Ammonium (mg/l)	8.63	V	7.04	8.16	V
Nitrate (mg/l)	6.72	V	5.43	5.97	V
Nitrite (mg/l)	3.92	IV	1.91	4.05	IV
Phosphate (mg/l)	12.08	V	9.13	12.09	V
TOC (%)	14.48	V	13.24	14.37	V
Total organic matter (%)	26.12	V	23.84	25.32	V
THC (mg/Kg)	301.98	V	294.63	293.37	V
Cadmium (mg/g)	3.87	IV	3.58	4.15	IV
Chromium (mg/g)	3.81	IV	2.65	3.98	IV
Iron (mg/g)	12.78	V	11.49	12.02	V
Lead (mg/g)	0.11	I	0.05	0.32	I
Manganese (mg/g)	5.67	V	4.85	5.38	V
Zinc (mg/g)	8.49	V	8.17	8.94	V

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Copper (mg/g)	7.71	V	7.72	8.90	V
Aluminium (mg/g)	1.78	II	1.63	1.83	II

P$_N$: Category I (≤1 – no pollution), Category II (1 to 2 – slightly polluted), Category III (2 to 3 – lightly polluted), Category IV (3 to 5 – moderately polluted), and Category V (>5 – seriously polluted).

Arthropod Species Identified at the Jaja Creek and Adjoining Downstream Section of the Imo River

Fifty (50) arthropod species were collected and identified, and grouped into three (3) classes (crustacean, insecta, and arachnida), nine (9) orders (decapoda, diptera, hymenoptera, hemiptera, coleoptera, odonata, megaloptera, trichoptera, and araneae) and 26 families (Table 9).

Table 9: Arthropod species collected and identified along the stretch of Jaja creek and adjoining Imo river.

CLASS	ORDER	FAMILY	SCIENTIFIC NAME
Crustacean	Decapoda	Palaemonidae	*Nematopalaemon*sp(Aurivillius, 1898) *Macrobrachiumcaledonicum*
		Pandalidae	*Pandalus*sp (Plate 12)
		Penaeidae	*Penaeus*sp
		Ocypodidae	*Ocypode*sp *Ucatangeri* *Ucapugilator*
		Portunidae	*Callinectesmarginatus* (A. Milne-Edwards, 1861) *Callinectesamnicola*(Rochebrune, 1883) *Callinectespallidus* (Rochebrune, 1883) *Carcinus*sp
		Gecarcinidae	*Cardisomacarnifex* *Cardisomaarmatum*
		Grapsidae	*Goniopsispelii* *Chiromantes*sp *Holometopus*sp (Milne Edwards).
		Panopeidae/ Xanthidae	*Panopeusafricanus*A. Milne-Edwards, 1867.
		Sesarmidae	*Sesarmaalberti* (Rathbun, 1921) *Aratuspisonii* *Sesarmaelegans* (Herklots, 1851) *Armases*sp *Neosarmatiummeinerti*

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			(de Man, 1887)
		Pilumnidae	*Pilumnussp*
			Potamonautessp
Insecta	Diptera	Dixidae	*Dixasp (adults)*
		Chironomidae	*Chironomussp*, Meigen, 1803 (adults)
			Tanypussp, Meigen, 1803
	Hymenoptera		*Polynemanatans*, Lubbock, 1864
			Polynemasp
		Mymaridae	
		Hydrometridae	*Hydrometra*sp
		Mesoveliidae	*Mesoveliasp*, Mulsant& Rey, 1852
	Hemiptera	Notonectidae	*Notonectasp*, Linnaeus, 1758
		Naucoridae	*Pelocoris*sp (Stål, 1876)
		Nepidae	*Nepa*sp (Adults)
		Gerridae	*Gerris*sp (Adults)
	Coleoptera	Dytiscidae	*Cybistersp* (Adults)
			(Curtis, 1827)
			Libellulasp (Adults) (Linnaeus, 1758)
		Libellulidae	*Aethriamanta*sp
	Odonata		*Brachythemis*sp
			*Aciagrion*sp
		Coenagrionidae	*Pseudagrion*sp
		Protoneuridae	*Elattoneura*sp
	Megaloptera	Sialidae	*Sialislutaria*(Adult)
			(Linnaeus, 1758)
	Trichoptera	Polycentropodidae	*Polycentropus*sp (larva)
Arachnida	Araneae	Dictynidae	*Dictyna*sp
			(Sundevall, 1833)
			Myrmarachnesp

Arthropod Species Diversity Indices

The diversity indices results showed the dominance, Shannon (H) diversity, and evenness for the sampling sites along the stretch of Jaja creek and the adjoining Imo river, and for control (Table 10). The Shannon H diversity results revealed that Site 2 of Jaja creek recorded a relatively high diversity of 2.50, seconded by Site 3 (2.12) and, thirdly, Site 1 (2.02) (Table 10).

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Table 10: Diversity indices for the arthropod species collected across the sampling sites during the sampling period.

	Jaja Creek Sites				
Imo River Sites					
	1	2	3	Control (4)	5
	6	7			
Taxa_S	14	24	21	29	36
	20	26			
Individuals	3777	21179	19763	28049	
	29608	19616	21362		
Dominance_D	0.2343	0.1149	0.2053	0.1813	
	0.2215	0.1644	0.236		
Simpson_1-D	0.7657	0.8851	0.7947	0.8187	
	0.7785	0.8356	0.764		
Shannon_H	2.02	2.499	2.118	2.128	
	2.008	2.372	1.979		
Evenness_e^H/S	0.2095	0.3381	0.2311	0.2333	
	0.2068	0.2976	0.201		

Principal Component Analysis (PCA)

The results of the test for the principal parameters of the water and sediment of the water bodies as it affected the arthropod species identified in this study are presented in Figure 2. The results indicate that temperature, pH, silt, and Cr showed a positive effect on the arthropod species (Figure 2).

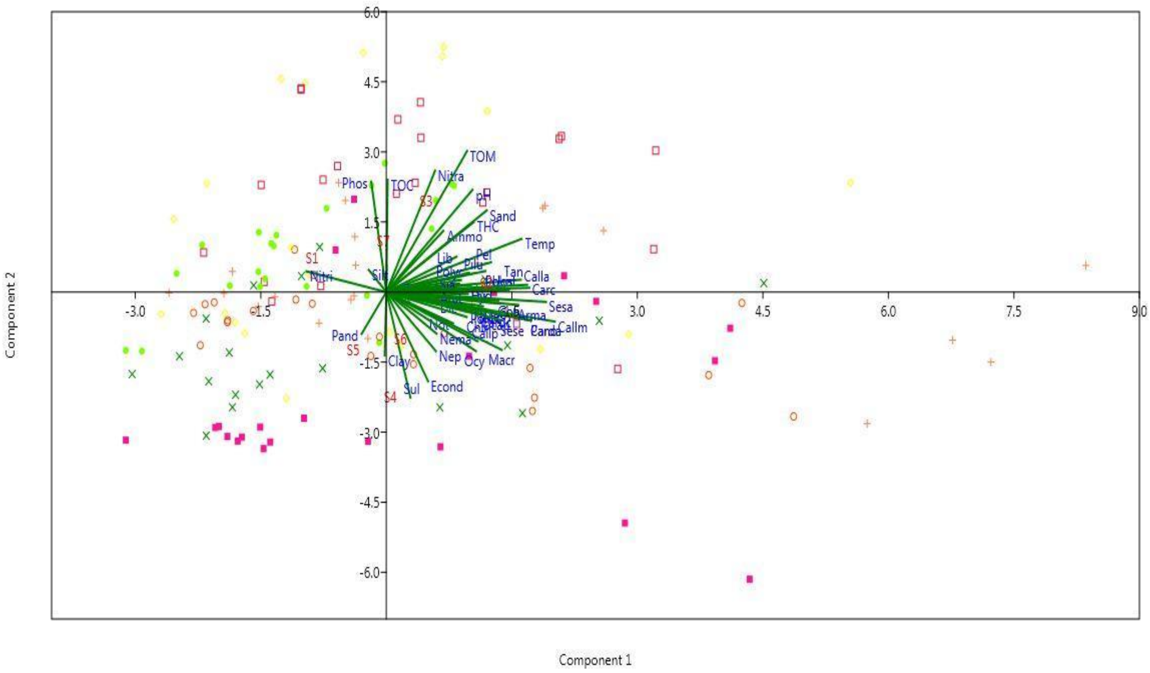

Figure 2: PCA expressing the effect of the water and sediment quality on the arthropod species.

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DISCUSSION

Water and Sediment Quality of the Jaja Creek and Adjoining Downstream Section of the Imo River

Single Factor Pollution Index and Nemerow's Pollution Index

From the single factor pollution index results to test the water quality, it could be deduced that all the sites showed clean lines of pollution of nitrate, sulphate, and phosphate. Single factor pollution indexes (SF_{Pi}) of nitrite were categorised into Category II, which indicated that all the sampling sites of the two water bodies were moderately polluted with nitrite (Popoola*et al*., 2019). All of the sampling sites were seriously polluted with cadmium, while for chromium, iron, and lead, from the single factor pollution indexfor all the sites, it fell in Category I, showing clean lines of pollution (Zabbey& Hart, 2005). Sites 1, 2, 3 and 4 categorised into Category III were moderately polluted with Mn, while Site 5 was lowly polluted. For Zn, Sites 1, 2, 3, 4 and 7 were lowly polluted, while Sites 5 and 6 were not polluted with Zn. The single factor pollution index for Cu indicates that Sites 3 and 7 were lowly polluted (Category II).

From the single factor pollution index results to measure the sediment quality of the two water bodies, all the sampling sites of the Jaja creek and Imo river were moderately polluted (Category III) with phosphate. For nitrite, only Site 1 was of Category I, which shows clean line of pollution (Category I), while Sites 1, 2, 3, 4, 6 and 7 were highly contaminated (category IV). The single factor pollution index for the sediment quality indicated that for cadmium, chromium, and zinc, from all the sampling sites, the pollution level was categorised as Category I.

The assessment of Nemerow's pollution index (P_N) of the water quality of the Jajacreek and Imo river reveals that all the water samples were seriously contaminated and polluted with sulphate, zinc, and THC (Category V), except phosphate, nitrate, Pb, Ca, Crand Fe, but moderately contaminated with nitrite (Category III), and lowly polluted with Cu (Category II). For the sediment quality of the two water bodies, the Nemerow's pollution index (P_N) assessment indicated that the sediment samples were highly contaminated with sulphate, nitrate, phosphate, ammonium, TOC, TOM and THC, and polluted with Fe, Mn, Znand Cu, but moderately polluted with nitrite, Ca and Cr.

As assessed with Nemerow's pollution index (P_N), the sediment of the two water bodies was highly contaminated with sulphate, phosphate, nitrate, nitrite, ammonium, TOC, TOM and THC, and polluted with Fe, Mn, Zn, Cu, Ca and Cr than the water, confirming that sediment is an ultimate sink for inorganic loads and heavy metals in water bodies (Olaniyi&Popoola, 2021).

The high level of inorganic loads, TOC and THC may be connected to the increased accumulation of human anthropogenic activities involving pollutants which are components of grease and fuel of engine boats wash, discharged and emptied into the water bodies which later have their settlement in the sediment (Deekae *et al*., 2010).

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Diversity Indices and Principal Component Analysis

By the diversity indices and principal component analysis results, it could be deduced that the water and sediment quality influenced the abundance and diversity of the arthropod species in the Jaja creek and Imo river. Principal component analysisresults further buttress the fact that the levels of contaminants and pollutants in the Jaja creek and Imo river affect the arthropod species diversity, as some of the inorganic loads and heavy metals negatively correlated with the arthropod species, which indicate that as the variables are increasing, the arthropod species are decreasing in population. These explain why there are variations in the taxa richness and individual abundance of the arthropod species for each of the sampling sites (Uwadiae, 2018).

CONCLUSION

The Jaja creek and the adjoining downstream section of Imo river in the South-South region of Nigeriaare considered as important water bodies because they have natural breeding sites for crabs, prawns, shrimps, and insects. This study thoroughly assessed the water and sediment quality of the Jaja creek and the Imo river using single factor pollution index, Nemerow's pollution index, diversity indices, and Pearson correlation matrix. The water and sediment quality at the seven (7) points were found satisfactory in terms of temperature, pH, electrical conductivity, total dissolved solids, and salinity. However, the water and sediment of the two water bodies were found to be contaminated with inorganic compounds (nitrate, sulphate, nitrite, phosphate) and polluted with heavy metals (Ca, Cr, Fe, Cu). Anthropogenic activities and direct discharge effluents from homes are considered as the major source of pollutants in the two water bodies.

The levels of the contaminants and pollutants in the two water bodies were found to have an influence on the arthropod species' abundance and diversity. The arthropod species of the two water bodies evidenced by the arthropod species collected, abundance and diversity are present in good numbers across the sites.

The conservation of these species would depend primarily on the preservation of the muddy patches, which serve as a micro-habitat for the decapods in the aquatic environment.

Competing Interests

The authors declare that they have no competing interests.

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