JCHR (2023) 13(4), 789-802

Journal of Chemical Health Risks

jchr.damghan.iau.ir

ORIGINAL ARTICLE

Metal Pollution and Ecological Risk in Water from Chanomi Creek, Warri, Niger Delta, Nigeria

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(Received: 27 May 2023 Accepted: 21 August 2023)

KEYWORDS

Heavy metal;
Pollution;
Risk;
Chanomi;
Creek;
Marine

ABSTRACT: The utilisation of surface water has increased in the Niger Delta area of Nigeria due to high ground water abstraction rates. This study aims to assess the pollution status of heavy metals in water from Chanomi Creek, Nigeria, and conduct an ecological risk assessment to evaluate potential environmental impacts and implications for marine life and local communities. Ten stations adjoining the creek were sampled and analysed for Cr, Cd, Cu, Pb, Ni, Fe, Zn, As, and Mn, using atomic absorption spectrophotometry. Indices such as the heavy metal pollution index (HPIs), Nemerow pollution index (PN), and potential ecological risk indices (PERI) were used to assess the degree of water contamination and its suitability for marine life and agricultural purposes. Monthly data were aggregated and analysed as dry and wet seasons to evaluate seasonal influences on these parameters. During the dry season, Cd, Cu, Pb, Ni, and Zn increased significantly ($p < 0.05$). The HPIs for both seasons clearly exceeded the threshold of 100, making the water grossly inadequate for drinking. Across seasons, PN for agricultural purposes ranged from 0.4 to 2.3 indicating slightly to moderate pollution status but was heavily polluted for aquatic life (PN: 98 – 240). High ecological risks (PERI > 400) were observed for human consumption and aquatic life. Chanomi Creek is moderately contaminated for animal watering and irrigation but extensively polluted for marine life.The study posits possible impacts on ecosystem health, biodiversity, and communities relying on the creek. Urgent action is required with effective pollution control and sustainable water management practices for environmental and health safety.

INTRODUCTION

Water is essential to the sustainability of life and for the health and productivity of living organisms [1]. Consequently, water quality has become a crucial determinant in specific utilisation purposes [2]. Water sources are easily contaminated with pathogens, chemicals, heavy metals and excessive salinity, posing health risks to crops, livestock, farmworkers, and consumers [1]. Contamination of water sources by heavy metals has become a global environmental concern, given the non-degradable properties of these species [3]. The Niger Delta area in Nigeria expectedly typifies an oil-rich aquatic ecosystem rife with surface water

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DOI: 10.22034/jchr.2023.1986623.1751

resources but, unfortunately, polluted by oil spillage and activities of explorative and extractive industries [4].Heavy metals are among the persistent organic pollutants that are ubiquitous and bioaccumulate in aquatic systems [5, 6]. Heavy metals are toxic to living organisms at low concentrations; thus,their environmental ubiquity has far-reaching health implications[7]. The toxicity of heavy metals in organisms varies, ranging fromlung inflammation, nervous system disorders, renal failures, fibrosis, emphysema, and tumours in humans [8] to liver damage, gills and digestive gland destruction in marine organisms[9, 10].

ChanomiCreekis a lotic tropical brackish water system in Niger Delta, Nigeria. This creek has been degraded through the substantial loss of its mangrove forests and conversion of the forest for various purposes to meet human needs (e.g. subsistence and commercial farming, land reclamation, gas pipelines, and residential buildings) [11]. Chanomi Creek, well-known for its shipping, transporting, oil and gas exploration and extraction activities, provides water for irrigation, laundry,and other domestic necessities. Unfortunately, increased industrial and social activities in this area have led to a rise in groundwater abstraction rates, making surface wateran alternative source in this region [12]. Therefore, assessing the heavy metal pollution status of surface water in this creek for different utilizations was the general objective we set out to achieve in this research. The study is anticipated to yield significant insights into the environmental condition of the creek and the necessity for sustainable management practices.The study's contribution lies in securing the conservation of aquatic life and fostering the well-being of the local community, which relies on the creek's resources for multiple purposes.We made use of models such as the heavy metal pollution index (HPI) used for drinking water [13]; Nemerow pollution index (PN) [14, 15] and the potential ecological risk index (PERI) [16, 17] to determine the pollution status and the ecological risk posed by heavy metal exposure in Chanomi creek for marine life protection and agricultural purposes (e.g., irrigation and livestock watering). We also used principal component analysis (PCA) for source apportionment.

MATERIALS AND METHODS

Study area

This study was undertaken at ChanomiCreek (Figure 1) Warri, Niger Delta, Nigeria. ChanomiCreek lies along the Escravos River, noted for shipping as well as oil and gas industrial activities [11]. The study area is characterised by two seasons: the dry season (low flow/discharge), which lasts from November to March, and the wet season (high flow/discharge) from May to October. Wet and dry conditions usually characterise April and August. The average temperature of the wet season is 26°C, while the dry season was found to be 33°C[11]. The creek experiences tidal influences. The creek water level rises and becomes turbid during the rainy season due to a high volume of water from the Escravos River and other adjoining creeks. The primary lowland rainforest of the area is Rhizophora species. Noticeable anthropogenic stressors on the creek’s shores are sawmill industries, block-making industries, petroleum and gas pipelines, open defecation, open market, wastewater, hostels, and residential buildings, as well as the use of agrochemicals.

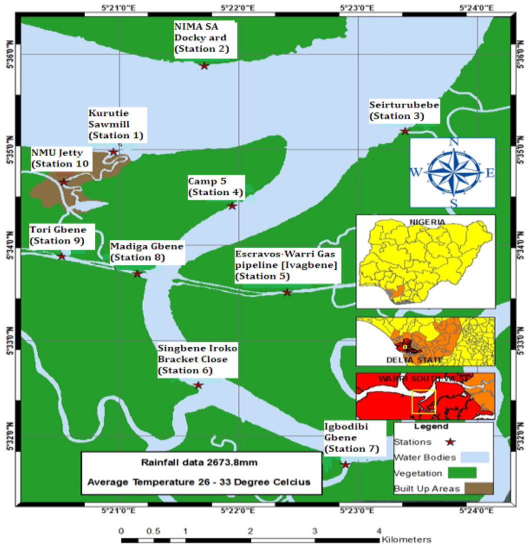

Figure 1. Map showing sampling stations along theChanomi Creek.

Sample collection

Ten adjoining sampling stations (S1to S10) were selected for the study, and coordinates were marked using the Global Positioning System (GPS) (Magellan SporTrak GPS Receiver) along with the longitudinal flow of the stream in the study area (Figure 1). Samples were collected monthly from May 2019 to March 2020 between 07:00 am and 11:00 am on each sampling month. Water samples were collected midstream of each station in new and sterilised 1.5 Litre (L) plastic containers pre-rinsed with water from the respective stations. The water samples were kept in a cold environment and stored in a refrigerator at 4℃, pending their laboratory analyses.

Sample analysis

Metals in water samples were analysed as previously describedbyWelz [18]. Briefly, water samples were digested with aqua regia (a mixture of HNO_3 and HCl at a ratio of 1:3). Thereafter, using atomic absorption spectrophotometry, water samples were analysed for Cr, Cd, Cu, Pb, Fe, Ni, Zn, As, and Mn. As a quality control measure, reference standards for the metals were compared in each case with water samples, and a calibration curve was plotted.

Pollution and Ecological Risk Assessment

The under-listed indices were used to determine the pollution status for the suitability of uses for drinking, irrigation, livestock watering, and marine habitat quality using metal permissible limits [19,20,21] for these disparate uses,asindicatedin Table 1.

Table 1. Water heavy metal standards for different utilizations.

Metals	NSDQW (S_i)	Weightage (W_i)	CCME[a]	FAO (IR)[b]	FAO (LS)
Cr	0.05	20.00	0.001	0.10	1.00
Cd	0.003	333.33	0.000091	0.01	0.05
Cu	1.0	1.00	0.004*	0.20	0.50
Pb	0.01	100.00	0.007*	5.00	0.1
Fe	0.3	3.33	0.30	5.00	NN
Ni	0.02	50.00	0.15	0.20	-
Zn	3.0	0.33	0.03	2.00	24.00
As	0.01	100.00	0.005	0.10	0.20
Mn	0.2	5.00	-	0.20	0.05

[a]Values for long term exposure in freshwater habitat; [b]maximum limits are based on a water application rate of 10,000m^3/hectare per year, which is consistence with irrigation practices; *upper limit of the range of values. Note: NSDWQ =Nigerian Standard of Drinking Water Quality (2015); CCME = Canadian Council of Ministers of the Environment (2007); FAO = Food and Agriculture Organization (1985); IR = Irrigation; LS = Livestock watering, NN = not needed.

Heavy metal pollution (HPI) assessment

The HPI is a model that estimates the composite influence of heavy metals on the overall quality of drinking water. The HPI model was used to calculate the heavy metal pollution index of the water samples[13].

$$HPI = \frac{\sum_{i=1}^{n} W_i Q_i}{\sum_{i=1}^{n} W_i}$$

In this model, the unit weightage (W_i) was taken as a value inversely proportional to the recommended standard (S_i) of metal concentration (Table 1) set by the Nigerian Standard of Drinking Water Quality [19]. The Q_i is the sub-index of the ith parameter while n is the number of parameters considered. The sub-index (Qi) of the ith parameter is calculated from the equation below:

$$Q_i = \frac{M_i}{S_i} \text{x}\, 100$$

Where M_i is the monitored value of the heavy metal in the water sample and S_i the standard value of the ith parameter in milligram per litre (mg/L). The HPI value of 100 is considered the critical pollution index value for drinking water [13, 22].

Nemerow Pollution Index (PN)

The Nemerow Pollution Index is commonly used to assess the overall degree of pollution and includes the contents of all analyzed heavy metals in the water samples [14]. It is calculated from the following formula:

$$PN = \sqrt{\frac{\left(\frac{1}{n}\sum_{i=1}^{n} PI\right)^2 + PI_{max}^2}{n}}$$

where PI = ratio of the concentration of the monitored metal in the water sample to the permissible value of a given purpose, PI max = maximum value for the PI within the set and n = the number of heavy metals considered.

Potential Ecological Risk Index (PERI)

Potential ecological risk (RI) is an index applicable for assessing the degree of ecological risk caused by heavy metal concentrations in the water, air, and soil. This index was introduced by [18], and it is calculated using the following formula:

$$PERI = \sum_{i=1}^{n} E_r^i$$

where n = the number of heavy metals and E_r = single index of the ecological risk factor calculated as:

$$E_r = PI \text{ x } T_r$$

where PI = ratio of the concentration of the monitored metal to the permissible value of a given purpose and the Tr is “toxic- response” factor for a given metals; Ni = 5, Cd = 30,Cr = 2, Cu = 5, Zn =1 and Pb = 5 [16]. Fe was not used in the calculation of PERI because it does not have value for the toxic response factor.

Statistical analysis

Data obtained from the study were analyzed with SPSS version 20. The monthly data were pooled and analyzed as dry and wet seasons to estimate the effects of season on the parameters.Differences between variables for the two seasons were determined with the paired t-test at a $p < 0.05$ significant level. Pearson’s correlation ($p < 0.05$ and $p < 0.01$) significance levels were used to determine the relationships between variables, while principal component analysis (PCA) at Eigene value > 1 was used for the determination of source apportionment of metals.

RESULTS AND DISCUSSION

Metal Concentrations

The distribution of heavy metal during the dry season was in the order of Fe > Zn >Pb> Ni > Cd > Cu > Cr, while the order was Fe > Zn >Cu >Pb> Cd> Ni > Cr during the wet season. This indicates that Fe and Zn are the most dominant metals in the region. This may be a result of natural enrichment process. Iron and zinc naturally occur in geological formations and mineral deposits, releasing these metals into the environment through weathering and erosion [47]. In subtropical regions with abundant rainfall, accelerated weathering processes break down rocks and minerals, releasing Fe and Zn into the water. Leaching also transports these metals from upper soil layers to lower depths, accumulating them in the water column [48, 49]. Furthermore, the presence of vegetation and high organic matter content in tropical and subtropical regions enhances the availability of Fe by facilitating their release from minerals through chelation and complexation processes [50, 51]. The mangrove-dominated areas like the Chanomi Creek further contribute to the trapping of Fe in mangrove roots.Consequently, these regions exhibited higher concentrations of Fe and Zn in thecreek.

The results of the paired t-test indicated that there were significant ($p < 0.05$) seasonal variations in the levels of Cd, Cu, Pb, Ni, and Zn (Table 2). Except for Cu, the levels of these metals were significantly higher ($p < 0.05$) in the dry season. The significant increase in Cd, Cu, Pb, Ni, and Zn observed during the dry season agrees with a recent study [23].Across the stations, we observed that the mean metal concentrations were also generally higher during the dry season (Table 3). During the dry season, the Cd levels exceeded the standard set limitsfor all purposes of water utilizations in 50% of the stations (S1, S3, S4, S9, and S10), while during the wet season, the same observation was made in only 20% of the stations (S5 and S10). Elevated levels of heavy metals during the dry season can be attributed to anthropogenic activities, such as waste dumping, agriculture, industrial processes, and natural factors. These natural factors include decreased dilution, increased evaporation, reduced flushing, and geochemical processes.During the dry season, precipitation is generally reduced, resulting in lower water volumes in creeks and other water bodies. This limited water availability contributes to higher concentrations of heavy metals since less water dilutes the metals [25].Additionally, the reduced flow of water during the dry season hinders the flushing of metals from the creek. With insufficient water movement, metals can accumulate in the creek, leading to higher concentrations during the dry season.Furthermore, increased evaporation during the dry season can concentrate heavy metals in the remaining water. As water evaporates, the metals become more concentrated, increasing their levels.

The levels of Pb and Fe from the stations during both seasons (except for station 10 during the dry season) were higher than drinking water and marine life standard values. Expectedly, seasonal variation has been found to affect the metal concentration of surface water in creeks previously [24 - 26]. This effect was also attributed to evaporation from the surface waters and the low influx of freshwater during the dry season. Heavy metal pollution of surface water sources is indeed a global environmental issue [27]. Previous studies in different creeks have reported contrasting observations on heavy metal contamination of surface water sources [28 - 30]. In the present study, except for As and Mn, whose values were less than the detection limits of the instrument, all heavy metal levels across stations or seasons exceeded the permissible limits set for at least one of the purposes of water utilizations determined.These metals have been found to be persistent with bioaccumulative tendencies in aquatic habitat [5, 31]. As a consequence, they can pervade the food chains with a great deal of health implications [7, 31].

Table 2. Seasonal variations in mean metal levels of water samples (mg L^{-1}).

Metal	**Seasons**		**p-value**
	Dry	**Wet**	
Cr	0.024	0.026	0.608
Cd	0.046	0.036	0.009I
Cu	0.031	0.054	<0.001
Pb	0.065	0.041	< 0.001
Fe	1.745	1.586	0.277
Ni	0.059	0.026	<0.001
Zn	0.226	0.120	< 0.001
As	<0.050	<0.050	1.000
Mn	<0.001	<0.001	1.000

Table 3. Mean metal distribution at different stations during the dry and wet Season (mg L^{-1}).

Dry Season							
Station	**Cr**	**Cd**	**Cu**	**Pb**	**Fe**	**Ni**	**Zn**
1	0.03^{b}	$0.06^{a,b,c,d}$	0.04^{b}	$0.05^{a,b}$	$1.52^{a,b}$	0.06^{a}	0.29^{b}
2	0.02^{b}	$0.04^{a,b,c}$	0.04^{b}	$0.08^{a,b}$	$1.74^{a,b}$	0.02^{a}	0.25^{b}
3	0.02^{b}	$0.05^{a,b,c,d}$	0.03^{b}	$0.08^{a,b}$	$1.40^{a,b}$	0.07^{a}	0.32^{b}
4	0.02^{b}	$0.05^{a,b,c,d}$	0.03^{b}	$0.04^{a,b}$	$1.17^{a,b}$	0.05^{a}	0.21^{b}
5	0.03^{b}	$0.04^{a,b,c}$	0.02^{b}	$0.04^{a,b}$	$3.02^{a,b}$	0.06^{a}	0.17^{b}
6	0.03^{b}	$0.04^{a,b,c}$	0.03^{b}	$0.07^{a,b}$	$2.18^{a,b}$	0.05^{a}	0.17^{b}
7	$0.05^{a,b}$	$0.04^{a,b,c}$	0.03^{b}	$0.06^{a,b}$	$1.69^{a,b}$	0.07^{a}	0.19^{b}
8	0.01^{b}	$0.04^{a,b,c}$	0.03^{b}	$0.05^{a,b}$	$1.61^{a,b}$	0.08^{a}	0.17^{b}
9	0.01^{b}	$0.05^{a,b,c,d}$	0.04^{b}	$0.08^{a,b}$	$1.58^{a,b}$	0.06^{a}	0.21^{b}
10	0.02^{b}	$0.05^{a,b,c,d}$	0.02^{b}	$0.10^{a,b,d}$	$1.54^{a,b}$	0.09^{a}	0.28^{b}
Wet season							
1	0.03^{b}	$0.03^{a,b,c}$	0.08^{b}	$0.04^{a,b}$	$1.75^{a,b}$	0.03^{a}	0.10^{b}
2	0.02^{b}	$0.03^{a,b,c}$	0.06^{b}	$0.04^{a,b}$	$1.77^{a,b}$	0.02^{a}	0.11^{b}
3	0.02^{b}	$0.04^{a,b,c}$	0.07^{b}	$0.05^{a,b}$	$1.82^{a,b}$	0.02^{a}	0.14^{b}
4	0.04^{b}	$0.02^{a,b,c}$	0.04^{b}	$0.04^{a,b}$	$1.42^{a,b}$	0.02^{a}	0.10^{b}
5	0.03^{b}	$0.06^{a,b,c,d}$	0.04^{b}	$0.04^{a,b}$	$1.82^{a,b}$	0.03^{a}	0.10^{b}
6	0.04^{b}	$0.03^{a,b,c}$	0.03^{b}	$0.05^{a,b}$	$1.12^{a,b}$	0.02^{a}	0.12^{b}
7	0.04^{b}	$0.02^{a,b,c}$	0.02^{b}	$0.03^{a,b}$	$1.30^{a,b}$	0.03^{a}	0.12^{b}
8	0.01^{b}	$0.04^{a,b,c}$	0.08^{b}	$0.01^{a,b}$	$1.20^{a,b}$	0.03^{a}	0.09^{b}
9	0.01^{b}	$0.03^{a,b,c}$	0.07^{b}	$0.06^{a,b}$	$1.61^{a,b}$	0.03^{a}	0.21^{b}
10	0.01^{b}	$0.05^{a,b,c,d}$	0.06^{b}	$0.05^{a,b}$	$2.06^{a,b}$	0.03^{a}	0.11^{b}

a ≥ drinking water quality; b ≥ brackishwater habitat; c ≥ irrigation water quality; d ≥ livestock water quality

Pollution and Ecological Risk Assessment

Heavy metal constituents are essential to water suitability for specific usage, species requirements, or ecosystem protection [2]. Chanomi Creek is seriously facing groundwater scarcity, prompting concerns that the local population may use surface water alternatives. Thus pollution indices, as previously developed and used by different authors [14, 16, 32], provide a classification scale for this purpose.

The HPI classifies drinking water into ‘good for drinking’ or ‘not good for drinking’ based on a threshold value of 100. A value of 100 for the HPI would imply that the concentration of all metals considered have the exact values of their permissible limits for the purpose of drinking. However, we observedaverageHPI values of more than multiples of 8 and 11 of this critical value during wet and dry seasons respectively. (Table 4).These astronomic values of HPI during both seasons suggest that the water from this creek's stream is dangerous for consumption. This is worrisome since the probability of drinking water from this source was very high given that township water supply around and within adjoiningcommunities was hardly provided.However, the high HPI values observed in this research contrasted with a recent observation in Edagberi Creek in Rivers State, Nigeria [33], which reported very low HPIs. This disparity could be attributed to variances in anthropogenic activity in the areas and the likely effect of modelling methods. The consistent positive deviations from the average valuesinS3 and S10 during bothseasons suggest that besides dilution or evarporation as the case may be, other factors such as anthropogenic activities or natural process may have impacted the quality of water at these sites.

Table 4.Percent deviation of Site HPI values from mean HPI.

Station	Dry Season		Wet Season	
	HPI	% Dev Mean	HPI	% Dev Mean
1	1378.42	17.85	807.18	-8.25
2	1035.00	-11.51	677.63	-22.98
3	1218.99	4.22	1071.36	21.77
4	1120.48	-4.2	604.39	-31.3
5	1063.72	-9.06	1422.72	61.71
6	1127.89	-3.63	675.73	-23.19
7	1015.89	-13.14	633.72	-27.97
8	1075.35	-8.06	850.39	-3.34
9	1233.04	5.42	782.37	-11.07
10	1436.83	22.84	1269.42	44.29
Mean	1170.49		879.49	

Drinking Quality

Classification: < 100 = Good for drinking

>100 = Not good for drinking

HPI = Heavy metal pollution index

Besides drinking, we also investigated the pollution status and risk in utilization of these water sources for irrigation, livestock watering and marine life.The estimated average PN values for the dry and wet seasons were 1.77 and 1.37 for irrigation uses, 195.90 and 151.87 for marine life, and 0.47 and 0.36 for livestock watering (Table 5). Based on the Nemerow pollution indexclassification (Table 5), the water sources were generally insignificantly polluted for livestock watering, slightly polluted for irrigation purposes but heavily polluted for marine life, irrespective of the season. This indicates that water sources from this creek was not suitable for aquatic life. The implication is that these heavy metals can accumulate in the tissues of organisms and magnify through the food chain, reaching higher concentrations in top predators, thereby causing possible health hazards.Despite the observation of a slight pollution status of the water sources for irrigation purposes in this creek, care should be taken in using this water for this purpose. Heavy metal dispersion in agricultural goods is pervasive [34] and may impact irrigated crops substantially. Plant foods irrigated with water containing modest concentrations of heavy metals have been shown to incorporate some of these hazardous elements in high amounts[35-37], raising consumer health risks.

The result of the potential ecological risk index (PERI) and its classification is shown in Table 6. We observed that average ecological risk is low for livestock watering for dry (PERI = 31.25) and wet (PERI = 24.06) respectively and slightly low for irrigation purposes (PERI = 109.69) during the wet season. The PERI of 141.06 showed that the ecological risk of the water sources was moderate for irrigation purposes during the dry season; however, both dry and wet season ecological risks were very high (PERI > 400) for human exposure and aquatic life protection. Metal contamination levels of surface water sources in this creek poses a very high ecological risk for aquatic life in both seasons. This observation is in line with our previous observations in this region [11] which correlated well with low aquatic biodiversity of the area. Our observation in this regard is consistent with a previous study of similar setting in Bangladesh[38]. High ecological risk levels can result in habitat degradation and biodiversity loss [11, 17]. Certain species may be more sensitive to pollutants, leading to population declines and reduced genetic diversity [11]. The loss of key species can disrupt ecosystem functioning and resilience, making it harder for the ecosystem to recover from disturbances.Aquatic ecosystems are natural sinks for heavy metal pollution, which can have significant environmental consequences as evidenced by biomagnification up food chains [6, 40].

Increased heavy metals in aquatic ecosystems reduce marine organism survival, human health, and productive activities [41]. In the last several decades, demand for fish and shellfish for food, feed, and other items has expanded faster than for any other agricultural commodity [42].

Table 5. Nemerow Pollution Index for Different Water Utilizations.

Station	**Dry**			**Wet**		
	PN_{IR}	**PN_{AQ}**	**PN_{LS}**	**PN_{IR}**	**PN_{AQ}**	**PN_{LS}**
1	2.30	252.23	0.59	1.25	137.72	0.34
2	1.54	168.28	0.43	1.05	115.66	0.26
3	1.88	203.96	0.48	1.7	187.81	0.42
4	1.92	210.13	0.45	0.89	98.17	0.29
5	1.54	168.29	0.41	2.32	257.77	0.58
6	1.54	168.32	0.45	0.99	109.73	0.28
7	1.54	168.48	0.39	0.96	105.86	0.24
8	1.54	168.11	0.4	1.41	156.58	0.34
9	1.92	210.13	0.47	1.15	127.00	0.33
10	1.92	210.22	0.59	2.01	222.39	0.49
Mean	1.77	195.90	0.47	1.373	151.87	0.36

Pollution:

Classification:

Insignificant (PN < 1)
Slightly (1 ≤ PN < 2.5)
Moderate (2.5 ≤ PN < 7)
Heavy (PN ≥ 7)

Note: PN = Nemerow Pollution Index; IR = Irrigation; AQ = Aquatic Life; LS = livestock

Table 6. PERI distribution for different sites during the seasons.

Station	**Dry**				**Wet**			
	$PERI_{HU}$	**$PERI_{IR}$**	**$PERI_{AQ}$**	**$PERI_{LS}$**	**$PERI_{HU}$**	**$PERI_{IR}$**	**$PERI_{AQ}$**	**$PERI_{LS}$**
1	609.43	173.05	19023.51	37.04	352.93	100.47	10966.84	22.21
2	440.41	120.62	13343.33	28.14	294.81	83.83	9195.3	18.66
3	528.01	144.88	15889.16	32.47	470.6	135.15	14883.16	29.5
4	496.77	141.78	15590.11	30.19	258.04	71.32	7836.72	16.48
5	469.17	132.93	14592.51	28.33	633.86	184.13	20351.91	38.78
6	488.5	135.28	14879.4	30.16	288.96	79.43	8740.48	18.31
7	440.27	120.65	13191.26	26.89	275.88	76.83	8417.28	16.93
8	471.74	130.8	14303.02	28.42	382.92	113.45	12415.14	23.66
9	530.56	144.64	15879	32.94	335.43	92.63	10111.79	21.41
10	616.68	165.99	18213.43	37.95	558.44	159.76	17593.78	34.7
Mean	509.15	141.06	15490.47	31.25	385.19	109.70	12051.24	24.06

Ecological risk:

Classification:

Low (PERI < 110)
Moderate (110 ≤ PERI < 200)
Considerable (200 ≤ PERI < 400)
Very high (PERI ≥ 400)

Note: PERI = Potential ecological risk index; HU = Human exposure; IR = Irrigation; AQ = Aquatic Life; LS = Livestock

Principal component analysis

Three components emerged during the dry season with the Eigene value greater than 1 and explained approximately 60 % of cumulative variance. The PC-1 was loaded with Cd, Pb, Ni, and Zn with 27.62 % of the total variance, the PC-2 was loaded with Cu and Fe with 17.12 % of the variance, while PC-3 loaded only Cr with 15.69% of the variance. During the wet season, however, two components emerged from the PCA. The PC-1 was loaded with Pb, Fe, Ni and weakly with Zn with 26.00 % of the total variance, while the PC-2 loaded Cu and negatively Cr with 19.78 % of the variance (Table 7).

Significant and positive correlation between metal concentrations (Cd, Pb, Ni, and Zn) and PCA suggested a common source of pollution. Similar trends in co-contamination have previously been observations in the creeks of the Niger Delta [43, 44]. These metals may be specifically anthropogenic and could have predominantly come from crude oil spills [43]. Other tenable sources of pollution include agricultural practices, urban and industrial wastes, disposal of untreated and partially treated effluents containing toxic metals, and metal-containing compounds [21, 45, 46]. The typical loading of Cu-Fe can be attributed to natural sources. While PCA is a useful tool for identifying potential pollution sources, the limited explained variance from this study suggests the need for further exploration of other possible pollution sources in the creek. Utilizing additional data, employing advanced statistical techniques, and conducting field studies will contribute to a more comprehensive and accurate understanding of the pollutants' origins, enabling effective pollution control and management strategies.

Table 7. Principal Component Analysis (PCA)

Metal	Season				
	Dry			Wet	
	PC-1	PC-2	PC-3	PC-1	PC-2
Cr	0.045	0.019	0.857	0.291	-0.804
Cd	0.598	0.415	0.116	0.344	0.365
Cu	0.14	0.762	-0.297	0.155	0.796
Pb	0.651	0.298	-0.262	0.716	-0.02
Fe	-0.126	0.657	0.312	0.643	0.293
Ni	0.667	-0.057	0.307	0.589	-0.004
Zn	0.736	-0.203	-0.096	0.496	-0.04
Eigen value	**1.934**	**1.198**	**1.098**	**1.82**	**1.385**
% of variance	**27.62**	**17.12**	**15.69**	**26**	**19.78**
Cumulative %	**27.62**	**44.74**	**60.43**	**26**	**45.78**

Note: PC = principal component

Future perspectives of environmental monitoring in Chanomi Creek and across other Niger Delta ecosystems

One potential avenue for research would involve expanding the spatial scope of the study. Instead of focusing solely on Chanomi Creek, multiple sampling sites could be established across different surface water bodies in the Niger Delta region. These sites could be strategically selected to represent a range of environments, including creeks, rivers, estuaries, and other water bodies that are susceptible to pollution. Thus, researchers would better understand the pollution levels and sources present throughout the different regions and water sample locations.There is a need to expand the spatial scope and conduct longitudinal studies spanning multiple years. Such extended sampling duration would provide a more accurate depiction of temporal variations in pollution levels. This approach enables capturing seasonal patterns and assessing the consistency of pollution observed in Chanomi Creek across different times of the year. Moreover, longitudinal studies facilitate the identification of long-term trends in pollution levels, which could indicate persistent pollution sources or changes in environmental conditions.

Future research could employ a combination of techniques to identify specific pollution sources. Water samples from different sites could undergo comprehensive laboratory analysis to measure pollutant concentrations, including heavy metals, organic compounds, nutrients, and microbial indicators. Isotope analysis could distinguish between natural and anthropogenic origins of pollutants. Additionally, analysing other environmental media, such as sediment and seafood samples, could provide insights into historical pollution trends, the potential for pollutant accumulation over time and health risks effects.

Beyond physicochemical analysis, studies could investigate socio-economic and industrial activities in the region. This would involve engaging with local communities, industries, and governmental agencies to gather information through interviews on various activities occurring near the creek, such as agriculture, oil and gas extraction, industrial operations, waste disposal, and urban development. These engagements could establish linkages between specific activities and potential pollution sources, enabling a more comprehensive assessment of pollution contributors in the Niger Delta region. This study also advocates for the utilization of advanced monitoring techniques to supplement traditional sampling approaches. Remote sensing technologies, such as satellite imagery or aerial surveys, could provide valuable insights into large-scale pollution patterns and changes over time. These technologies can detect changes in water colour, turbidity, or algal blooms, serving as pollution indicators. Furthermore, installing real-time monitoring systems and sensor networks at critical locations would enable continuous tracking of water quality parameters, facilitating the identification of short-term pollution events and their sources.

In general, effectively addressing the complexity of studying pollution across the Niger Delta region requires collaborative research efforts involving multidisciplinary teams. Integrating expertise from environmental scientists, chemists, ecologists, geologists, social scientists, and local stakeholders would establish a comprehensive understanding of the degree and sources of pollution. Such collaborations could foster the development of effective mitigation strategies and policies to address identified pollution sources and protect the water bodies of the Niger Delta region.

CONCLUSIONS

The surface water of ChanomiCreekwas contaminated with heavy metals, which undoubtedly could pose a high ecological risk for humans and the survival of aquatic organisms. Throughout the seasons, Fe and Zn were the predominant metals in the region, while cadmium and lead exceeded permissible limits.The sources of contamination by metals such as lead and cadmium could be attributed to anthropogenic activities. At the same time, natural enrichment processes may have impacted the levels of iron and zinc in the water. The NP index showed that the creek has minimal pollution levels for livestock watering, and moderate pollution for irrigation purposes consistently throughout the year. However, the presence of significant ecological hazards (PERI > 400) and (HPI > 100) suggests potential risks for aquatic life protection and raises concerns about potential health risks.Control of water pollution in this region should be paramount to averting severe metal-related diseases. This creek could be entrenched by applying the precautionary principle and preventing pollution at source criteria. Finally, an adequate potable water supply is advocated in this region to discourage the possible use of surface water sources for consumption. This creek's water delivery infrastructure must be improved in light of this environmental risk indicator for human consumption and ecosystem integrity.Certain pollution sources, such as stormwater runoff after heavy rainfall or industrial spills, may occur between sampling dates and go unnoticed. Thus, monthly sampling intervals alone may not capture short-term fluctuations and episodic events that can significantly impact water quality. More frequent sampling intervals, such as weekly or even daily, could be considered during periods of higher pollution risk. Future studies are required to extend the sampling duration to cover all four seasons, which could provide a more comprehensive understanding of the temporal dynamics and help identify any seasonal trends.

ACKNOWLEDGEMENTS

The authors extend their gratitude to all those who reviewed this research and contributed to its enhancement.

Conflict of interests

The authors state that they have no competing interests, both financial and non-financial, to declare.

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