Assessment of Community Risk Perception, and Physicochemical Dynamics of Acid Rain Contamination in Bonny Island, Niger Delta, Nigeria

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ABSTRACT

Acid precipitation presents a profound threat to environmental sustainability and public health in gas-flaring industrial hubs across sub-Saharan Africa. This study investigates community awareness, health perception, and the physical-chemical dynamics of harvested rainwater in Bonny Island, Rivers State, Nigeria. Utilizing Yamane's formula based on a population projected at an annual growth rate of 3.2%, a structured sample size of 384 respondents was surveyed alongside seasonal physicochemical analyses across four stations (SS1–SS4). Socio-demographic findings indicated that 31.5% of respondents were aged 46–55, 36.5% held secondary education, and 41.7% were civil/public servants, with 38.0% residing in Bonny Island for over 20 years. Although rainwater harvesting is widely practiced (85.6%), respondents reported notable physical impairment, with 26.8% observing visible particulates and 24.5% identifying unusual smells or tastes. About 79.6% expressed awareness of potential rainwater contamination, local perception attributed contamination primarily to oil and gas production/ emissions (52.6%), revealing significant public knowledge regarding atmospheric pollution pathways. Seasonal empirical testing demonstrated severe atmospheric acidification, with mean rainwater pH dropping from 4.31 ± 0.39 in the dry season to 3.62 ± 0.99 in the wet season (reaching a critical minimum of 2.42 at SS4), consistently breaching WHO permissible drinking standards (6.5–8.5). Heavy metal correlation matrices highlighted strong associations between toxic species, particularly mercury and lead ($r = 0.86$ dry; $r = 0.87$ wet). The study underscores an urgent imperative for targeted environmental education, continuous atmospheric monitoring, and structured rainwater treatment intervention policies in industrial coastal communities.

Keywords: Acid rain, Bonny Island, Community awareness, Rainwater harvesting, Environmental perception, Yamane formula, Niger Delta, Heavy metals

INTRODUCTION

Rainwater harvesting (RWH) remains a critical primary water supply mechanism for domestic, agricultural, and drinking purposes across developing coastal communities, particularly where municipal piped water infrastructure is lacking or inefficient (Adeniyi et al., 2021). However, industrial expansion, rapid urbanization, and intensified fossil fuel extraction have progressively degraded atmospheric quality, converting pristine precipitation into a vehicle for toxic contaminant deposition (Nwankwoala & Ugwu, 2020). Acid rain is defined as precipitation exhibiting a pH below 5.6 which arises primarily from atmospheric transformations of sulphur iv oxide (SO_2) and nitrogen oxides (NO_x) into sulphuric and nitric acid aerosols (Olobaniyi & Efe, 2019).

Bonny Island, situated in the Niger Delta region of Nigeria, serves as a central economic hub hosting major petroleum exploration, gas liquefaction (Nigeria LNG), and maritime export operations. Despite the profound economic significance of these industrial activities, continuous industrial emissions and natural gas flaring release immense volumes of particulate matter, sulphur complexes, and heavy metal precursors into the troposphere (Ede & Edokpa, 2021). Consequently, local populations relying heavily on harvested rainwater face dual exposure: the direct physical risk of consuming acidic, heavy metal-laden water and the socio-environmental risk stemming from inadequate risk perception and public awareness.

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Understanding community consciousness regarding rainwater contamination is paramount for designing successful environmental health interventions. While technical monitoring provides quantitative insights into pollutant concentrations, local risk perceptions dictate household water usage, pre-use treatment behaviors, and public policy compliance (Hunter et al., 2022). Therefore, this research assesses community awareness, risk perception, and household water management practices in Bonny Island alongside empirical physicochemical and heavy metal correlation assessments across contrasting seasons, providing a comprehensive evaluation to inform regional policy and public health strategy. Figure 1 below shows the map and locations of the study area.

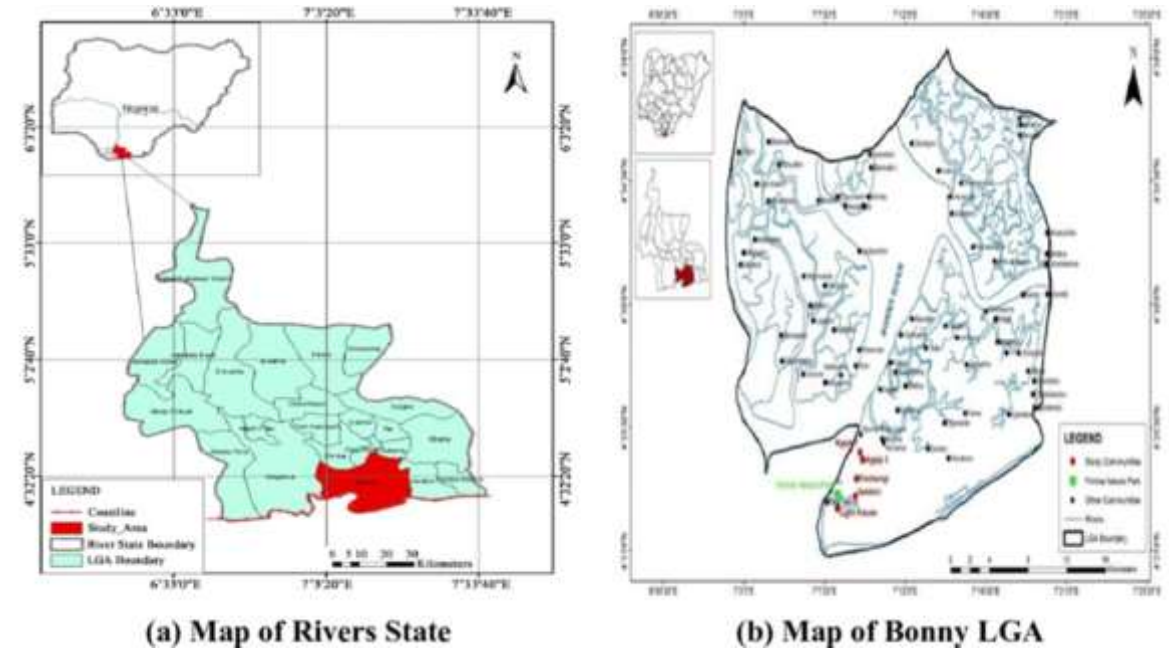


Figure 1: Rivers State and Bonny Local Government Area as Study Locations

MATERIALS AND METHODS

Study Area

The study was conducted in Bonny Local Government Area (LGA), Rivers State, Nigeria. Bonny Island is situated on the bight of Bonny in the outer Niger Delta, defined by geographic coordinates approximately between latitude 4°26' N and longitude 7°8' to 7°15' E (Abam et al., 2002). The region experiences a tropical monsoon climate characterized by distinct wet (April to October) and dry (November to March) seasons, with high annual rainfall exceeding 3,000 mm. Figure 2b shows the location map of the study.

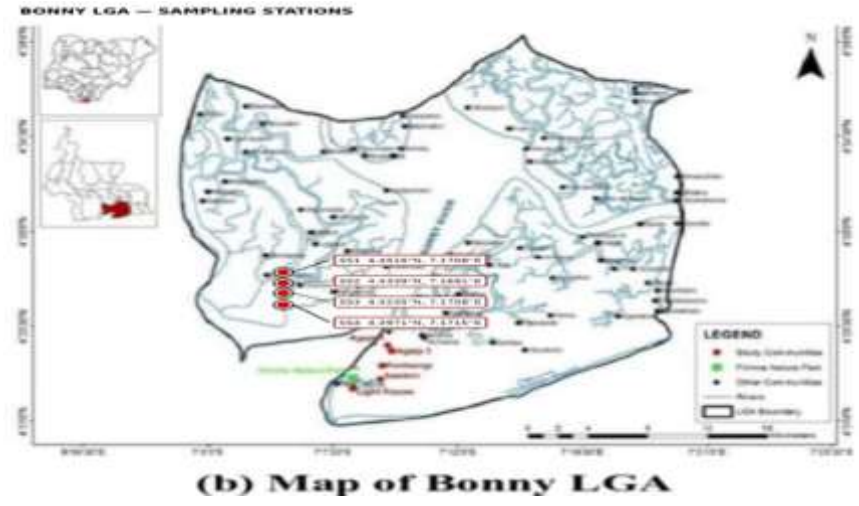


Figure 2b: The Location Map of the Study

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Population Projection and Sample Size Determination

To ensure statistical rigor and representative sampling across the municipality, the local demographic baseline was established using official census data adjusted for exponential demographic growth. The population of Bonny Local Government Area was projected from the baseline census using an annual population growth rate projection of 3.2% per annum, expressed mathematically as:

$$P_t = P_0 (1 + r)^t \quad (1)$$

Where P_t is the projected population, P_0 is the base census population, r is the annual growth rate (3.2% or 0.032), and t represents the projection period in years.

To determine an adequate and statistically valid sample size from the projected target population, Yamane's (1967) mathematical formula for finite populations was employed at a 95% confidence level and a 5% margin of error (e = 0.05):

$$n = N / [1 + N(e)^2] \quad (2)$$

Where n is the sample size, N is the total projected population, and e is the level of precision (0.05). Application of Yamane's formula yielded a standardized sample size of n = 384 respondents. Structured questionnaires were systematically administered across residential zones in Bonny LGA to capture socio-demographic characteristics, rainwater usage patterns, risk perceptions, and treatment practices.

Water Sampling and Analytical Framework

In parallel with the social survey, direct rainwater samples were collected across four strategic spatial sampling stations (SS1, SS2, SS3, and SS4) during both dry (November–March) and wet (April–October) seasons. In-situ parameters including Temperature (°C), pH, Electrical Conductivity (EC in µS/cm), Total Dissolved Solids (TDS in ppm), Dissolved Oxygen (DO in ppm), and Turbidity (NTU) were measured in accordance with standard APHA (2018) guidelines. Heavy metal contents (Cadmium, Zinc, Copper, Arsenic, Mercury, and Lead) were determined using Atomic Absorption Spectrophotometry (AAS). Statistical analysis and correlation matrices were executed using SPSS version 26.0.

RESULTS AND DISCUSSION

Socio-Demographic Profile of Respondents

The socio-demographic characteristics of the 384 surveyed respondents are summarized in Table 1. The age distribution shows that the largest cohort was aged 46–55 years (31.5%; n = 121), followed closely by young adults aged 18–25 years (30.5%; n = 117), 36–45 years (24.2%; n = 93), and individuals aged 56 years and above (13.8%; n = 53). Educational attainment was high, with 36.5% (n = 140) attaining secondary education, 34.9% (n = 134) holding university degrees (BSc/HND), and 27.1% (n = 104) possessing tertiary diplomas/NCE, while only 1.6% (n = 6) lacked formal education.

Occupational breakdown revealed that civil/public servants constituted the predominant group (41.7%; n = 160), followed by unemployed individuals (24.0%; n = 92), students (21.4%; n = 82), other vocations (11.5%; n = 44), and traders/artisans (1.6%; n = 6). Crucially, 38.0% (n = 146) of respondents had resided in Bonny Island for over 20 years, with an additional 38.0% having lived there between 11 and 20 years. This long-term residency and high literacy rate indicate that the study cohort possesses mature, contextual knowledge of local environmental trends.

Table 1: Socio-Demographic Characteristics of Surveyed Respondents in Bonny Island (n = 384)

Variable	Category	Frequency (n)	Percentage (%)
Age Group	18–25 years	117	30.5

ISSN No. 2454-6194 | DOI: 10.51584/IJRIAS |Volume XI Issue X October 2026

	36–45 years	93	24.2
	46–55 years	121	31.5
	56 years and above	53	13.8
	Total	384	100
Education	No formal education	6	1.6
	Secondary education	140	36.5
	Tertiary education (Diploma/NCE)	104	27.1
	University education (BSc/HND)	134	34.9
	Total	384	100
Occupation	Civil/Public Servant	160	41.7
	Artisan/Trader	6	1.6
	Student	82	21.4
	Unemployed	92	24
	Others	44	11.5
	Total	384	100
Residence Duration	Less than 5 years	54	14.1
	5–10 years	38	9.9
	11–15 years	73	19
	16–20 years	73	19
	Above 20 years	146	38
	Total	384	100

Note. Field Survey, 2026.

Rainwater Usage, Physical Perceptions, and Quality Dynamics

Data presented in Table 2 illustrates that rainwater harvesting is embedded in household routines, with 85.6% (n = 329) actively collecting rainwater. Multi-purpose usage was prominent: 83.9% utilized it for culinary purposes/Personal Hygiene /Laundry/Agriculture, 68.5% for toilet flushing/laundry/cooking, 55.2% for laundry/hygiene/cooking, and 14.3% directly for drinking. Sachet/bottled water (19.3%), borehole/wells (16.9%), and tanker supplies (16.9%) represented primary drinking sources, while rainwater accounted for 14.8%.

Physical perception evaluations revealed notable sensory degradation in collected rainwater. Only 29.7% of respondents reported clear rainwater appearance, whereas 26.8% detected visible particles/sediment, 24.7% observed slight cloudiness/turbidity, and 18.8% reported noticeable discoloration. Sensorial assessments showed that 24.5% experienced a mild unusual smell/taste, and 22.7% detected a strong unpleasant odor/taste. Regarding historical trends, 38.1% of respondents affirmed that rainwater quality had worsened (19.3% significantly; 18.8% slightly) over recent years.

Table 2: Rainwater Collection Practices, Utilization, and Sensory Perceptions in Bonny Island

Variable	**Category**	**Frequency (n)**	**Percentage (%)**
Rainwater Collection	Yes	329	85.6
	No	55	14.3
	Total	384	100
Primary Collection Purpose	Drinking	55	14.3
	Cooking and Drinking	56	14.6
	Personal Hygiene/Cooking	158	41.1
	Laundry/PH/Cooking	212	55.2

	Toilets/Laundry/PH/Cook	263	68.5
	Gardening/Agriculture	322	83.9
	Others	384	100
Primary Drinking Source	Borehole/Well water	65	16.9
	Piped/Treated water	60	15.6
	Sachet/Bottled water	67	19.3
	Tanker supplied water	65	16.9
	Other	70	18.2
	Rainwater	57	14.8
	Total	384	100
Physical Appearance	Clear	114	29.7
	Slightly cloudy/turbid	95	24.7
	Noticeably discolored	72	18.8
	Contains visible particles/sediment	103	26.8
	Total	384	100
Sensory Odor/Taste	Strong, unpleasant smell/taste	87	22.7
	Mild, unusual smell/taste	94	24.5
	Smells/tastes normal	96	25
	Do not use for detectable purposes	107	27.9
	Total	384	100
Perceived Temporal Trend	Significantly worsened	74	19.3
	Slightly worsened	72	18.8
	Remained largely same	96	25
	Improved	69	18
	Haven't noticed change	73	19
	Total	384	100

Note. Field Survey, 2026.

Community Awareness and Risk Perception of Contamination

As outlined in Table 3, 34.6% (n = 133) of respondents acknowledged being aware that rainwater in Bonny Island may be contaminated, while 32.8% were unsure and 32.6% reported non-awareness. A high awareness of pollution sources was perceived when asked about primary contamination sources, respondents identified waste burning/incineration (13.5%), vehicle exhaust (11.7%), non-oil industrial emissions (11.2%), atmospheric dust (10.9%), and natural sources (9.6%). Remarkably, oil and gas exploration/production activities were directly cited by 46.6% (n = 179) in general listing, though specific secondary forced choices elevated oil/gas flaring association to 52.6%.

Health concern regarding contaminated rainwater usage was fragmented across the community: 25.8% were very concerned, 22.7% moderately concerned, 25.8% slightly concerned, and 25.8% not concerned at all. Information dissemination was highly dispersed across health workers (11.5%), NGOs (10.9%), schools (10.9%), social media (10.2%), and traditional leaders (10.4%), with formal government agencies (9.4%) and oil companies (9.4%) contributing minimally. Consequently, 25.8% felt current interventions were sufficient, 25.3% demanded enhanced action, 23.2% stated action was inadequate, and 25.8% expressed complete uncertainty.

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Table 3: Respondent Awareness, Perceived Sources, Health Concerns, and Information Channels Regarding Rainwater Contamination

Variable	Category	Frequency (n)	Percentage (%)
Contamination Awareness	Yes	133	34.6
	No	125	32.6
	Not sure	126	32.8
	Total	384	100
Perceived Primary Source	Oil and gas exploration/production	179	46.6
	Industrial emissions (other)	23	6
	Vehicle exhaust fumes	25	6.5
	Dust and atmospheric particulates	22	5.7
	Roof material contamination	23	6
	Waste burning/incineration	16	4.1
	Agricultural activities	2	0.5
	Natural sources	37	9.6
	Don't know	22	5.7
	Other sources	35	9.1
	Total	384	100
Health Risk Concern	Very concerned	99	25.8
	Moderately concerned	87	22.7
	Slightly concerned	99	25.8
	Not concerned at all	99	25.8
	Total	384	100
Information Source	Friends/Family/Neighbors	40	10.4
	Community leaders/Traditional rulers	40	10.4
	Local media	28	7.3
	Online sources/Social media	39	10.2
	Environmental NGOs/Organizations	42	10.9
	Government agencies	36	9.4
	Health workers/Hospitals	44	11.5
	Religious organizations	37	9.6
	Oil and gas companies	36	9.4
	Schools/Educational institutions	42	10.9
	Total	384	100
Institutional Assessment	Sufficient efforts are being made	99	25.8
	Some efforts made, but more needed	97	25.3
	No, not enough is being done	89	23.2
	I don't know	99	25.8
	Total	384	100

Note. Field Survey, 2026.

ISSN No. 2454-6194 | DOI: 10.51584/IJRIAS |Volume XI Issue X October 2026

Rainwater Treatment and Household Management Practices

Table 4 outlines household rainwater mitigation practices. While 27.1% (n = 104) consistently treat harvested water before consumption and 26.0% treat it occasionally, 25.5% never execute any form of treatment. Adopted treatment options among practitioners included unstandardized settlement/sedimentation (20.3%), boiling (20.8%), chemical disinfection (19.3%), and filtration (16.7%). Catchment hygiene was similarly deficient: only 24.7% regularly clean roof gutters, while 24.2% rarely or never perform maintenance. Furthermore, 27.9% believed roofing materials do not influence water quality, and 25.3% were uncertain, highlighting critical gaps in domestic water safety management.

Table 4: Rainwater Treatment Methods and Roof Catchment Hygiene Practices

Variable	Category	Frequency (n)	Percentage (%)
Water Treatment Practice	Yes, always	104	27.1
	Yes, sometimes	100	26
	No, never	98	25.5
	Not applicable	82	21.4
	Total	384	100
Treatment Method Used	Boiling	80	20.8
	Filtering	64	16.7
	Adding chemicals	74	19.3
	Letting it settle	78	20.3
	Others	88	22.9
	Total	384	100
Catchment Maintenance	Yes, regularly	95	24.7
	Yes, sometimes	103	26.8
	No, rarely/never	93	24.2
	Not applicable	93	24.2
	Total	384	100
Roof Material Perception	Yes, significantly affects	94	24.5
	Yes, slightly affects	86	22.4
	No, not at all	107	27.9
	Not sure	97	25.3
	Total	384	100

Note. Field Survey, 2026.

Seasonal Physicochemical Parameters and Acid Rain Verification

Empirical testing of rainwater samples across sampling points (SS1–SS4) confirmed severe atmospheric acidification in Bonny Island across both seasons (Tables 5 and 6; Figures 1–6). During the dry season (Table 5), mean temperature was 19.48 ± 1.02 °C, electrical conductivity averaged 3.00 ± 0.07 µS/cm, total dissolved solids averaged 6.95 ± 2.06 ppm, dissolved oxygen recorded 8.87 ± 0.21 ppm, and turbidity was 2.34 ± 0.90 NTU. All physical parameters conformed to WHO limits except pH, which exhibited a severely acidic mean of 4.31 ± 0.39 (ranging from 3.83 at SS1 to 4.73 at SS2).

ISSN No. 2454-6194 | DOI: 10.51584/IJRIAS |Volume XI Issue X October 2026

In the wet season (Table 6), atmospheric scrubbing intensified rainwater acidification. Mean pH deteriorated to 3.62 ± 0.99, reaching an extreme acidic minimum of 2.42 at SS4 (Figure 2). Mean wet season EC increased to 6.01 ± 0.84 µS/cm (Figure 3), TDS averaged 9.75 ± 11.50 ppm (peaking at 27.00 ppm at SS4 due to heavy atmospheric washouts; Figure 4), DO averaged 8.31 ± 0.29 ppm (Figure 5), and turbidity averaged 1.77 ± 0.70 NTU (Figure 6). Across both seasons, 100% of rainwater samples failed the WHO standard pH threshold (6.5–8.5), confirming chronic acid rain conditions induced by regional oil flaring and industrial emission loads.

Comparison with previous studies. The seasonal pH pattern observed in Bonny Island is consistent with evidence that rainwater in oil-producing parts of the Niger Delta is frequently acidic. Nduka et al. (2008) reported acidic rainfall in Warri and Port Harcourt and identified oil exploration and other anthropogenic emissions as plausible contributors. Efe (2010) similarly reported widespread acid rain in the oil-producing region, with pH values of 4.98–5.15 (mean 5.06), and described spatial variation with distance from flare sites. The Bonny Island mean values (4.31 in the dry season and 3.62 in the wet season) are more acidic than those reported by Efe, particularly during the wet season. This agreement in direction, but difference in magnitude, may reflect local source intensity, sampling design, meteorology, or differences in collection and analytical procedures; the present data alone do not isolate the cause.

Seasonal interpretation and areas of disagreement. The lower mean pH during the wet season in Bonny (3.62 versus 4.31 in the dry season) indicates stronger acidity in the wet-season samples, whereas Ubuoh et al. (2021) found that rainwater acidity varied seasonally across southern Nigerian oil-producing communities and reported a mean pH of about 5.5 in oil-producing locations and about 6.5 in non-oil locations. Their reported values are less acidic than those measured in Bonny, so the studies agree that season and oil-producing context matter but differ in the severity of acidity. Seasonal differences should not automatically be attributed to rainfall washout alone: ionic composition, neutralization by sea-salt or alkaline dust, air-mass direction, and the timing of sample collection can all influence pH. The present study did not measure sulphate, nitrate, or neutralizing ions, so the precise chemical drivers remain unconfirmed.

The other physicochemical parameters were comparatively low: dry-season mean EC was 3.00 µS/cm and wet-season mean EC was 6.01 µS/cm; mean TDS was 6.95 and 9.75 ppm, respectively. This broadly supports the view that rainwater in the region can have low dissolved-ion loads even when it is acidic, but the wet-season SS4 TDS value (27.00 ppm) and the reported wet-season TDS standard deviation (11.50 ppm) indicate substantial spatial variability. Efe (2010) also found that several physicochemical parameters remained within reported safe limits while pH and selected constituents such as turbidity, suspended solids, lead and nitrate varied spatially. Nduka and Orisakwe (2010) documented seasonal variation in rainwater ions and TDS in Warri and Port Harcourt. These studies therefore support the need to interpret pH alongside conductivity, dissolved solids and site-level variation rather than using any single parameter as a complete measure of rainwater safety.

Interpretation of correlations requires caution. The strong correlations reported here (for example, wet-season EC–turbidity, r = 0.99, and copper–arsenic, r = 0.91) indicate co-variation within the dataset but do not, by themselves, prove a common industrial source or a causal pathway. With only four sampling stations represented in each seasonal matrix, correlation coefficients can be highly sensitive to individual observations. The source-attribution statements in this section should therefore be treated as hypotheses requiring confirmation through a larger sample set, chemical speciation, and source-apportionment methods.

Table 5: Seasonal Average Physicochemical Parameters of Rainwater During the Dry Season (November–March)

Sampling Point	Temp (°C)	pH	EC (µS/cm)	TDS (ppm)	DO (ppm)	Turbidity (NTU)
SS1	18.27	3.83	3	9	9.17	3
SS2	19.47	4.73	2.93	7	8.87	2.67
SS3	19.4	4.47	2.97	7.67	8.73	2.67
SS4	20.77	4.19	3.1	4.13	8.7	1

ISSN No. 2454-6194 | DOI: 10.51584/IJRIAS |Volume XI Issue X October 2026

MEAN	19.48	4.31	3	6.95	8.87	2.34
SD	1.02	0.39	0.07	2.06	0.21	0.9
WHO LIMITS	25	6.5–8.5	10000	600	6.5–8.0	5

Note. Researcher's Computation, 2026. EC = Electrical Conductivity; TDS = Total Dissolved Solids; DO = Dissolved Oxygen; NTU = Nephelometric Turbidity Units.

Figure 1: Spatial Distribution of Seasonal Average Temperature

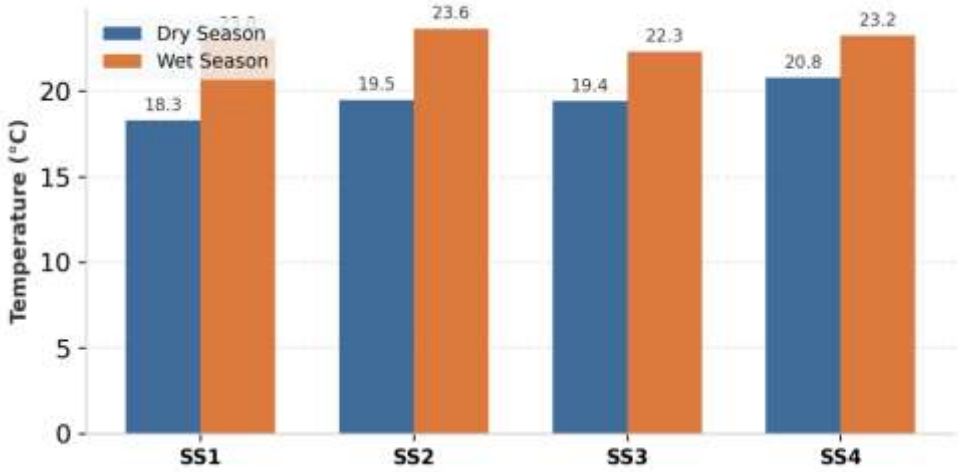


Figure 2: Spatial Distribution of Seasonal Average pH

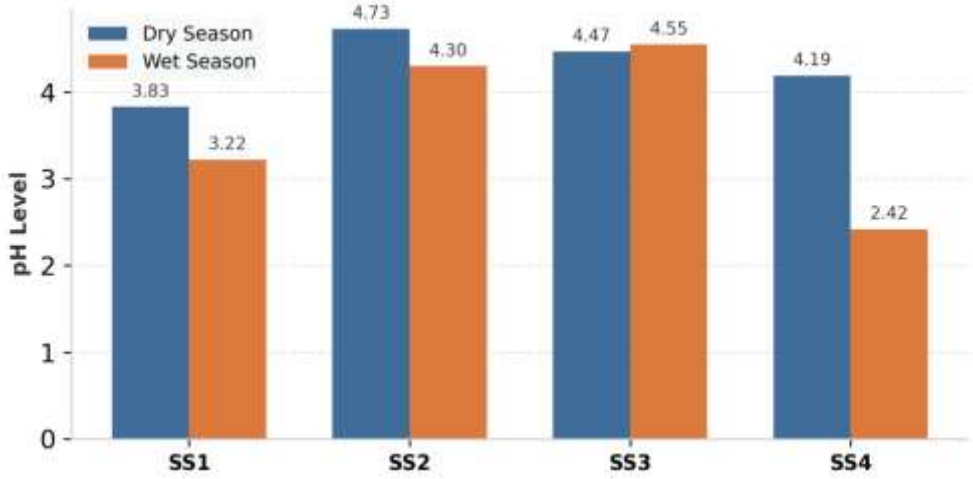
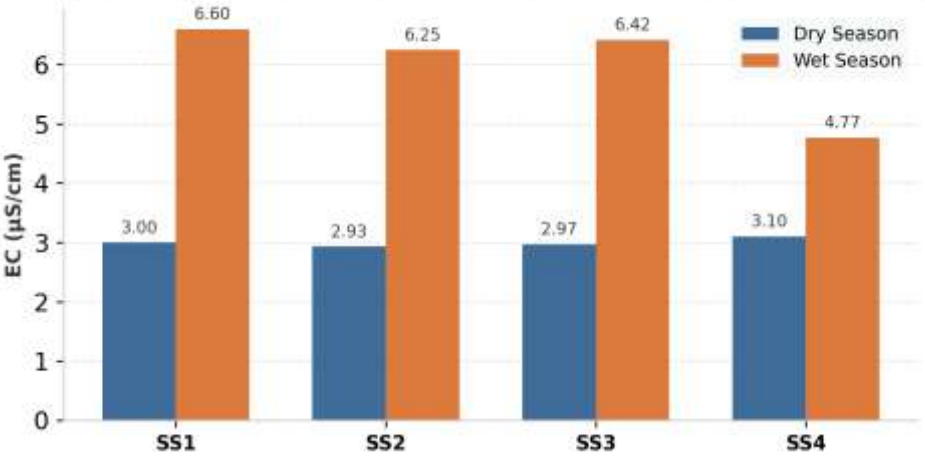


Figure 3: Spatial Distribution of Seasonal Mean Electrical Conductivity



ISSN No. 2454-6194 | DOI: 10.51584/IJRIAS |Volume XI Issue X October 2026

Table 6: Seasonal Average Physicochemical Parameters of Rainwater During the Wet Season (April–October)

Sampling Point	Temp (°C)	pH	EC (µS/cm)	TDS (ppm)	DO (ppm)	Turbidity (NTU)
SS1	23.03	3.22	6.6	4.33	8.65	2.33
SS2	23.63	4.3	6.25	3.67	8.05	2
SS3	22.3	4.55	6.42	4	8.1	2
SS4	23.23	2.42	4.77	27	8.45	0.75
MEAN	23.05	3.62	6.01	9.75	8.31	1.77
SD	0.56	0.99	0.84	11.5	0.29	0.7
WHO LIMITS	25	6.5–8.5	10000	600	6.5–8.0	5

Note. Researcher's Computation, 2026. EC = Electrical Conductivity; TDS = Total Dissolved Solids; DO = Dissolved Oxygen; NTU = Nephelometric Turbidity Units.

Figure 4: Spatial Distribution of Seasonal Average Total Dissolved Solids

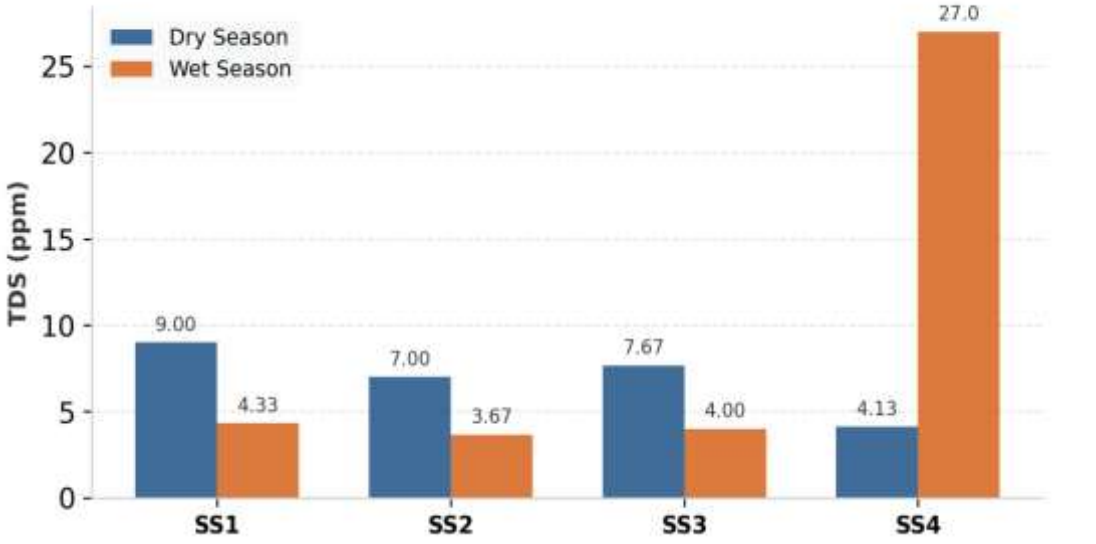
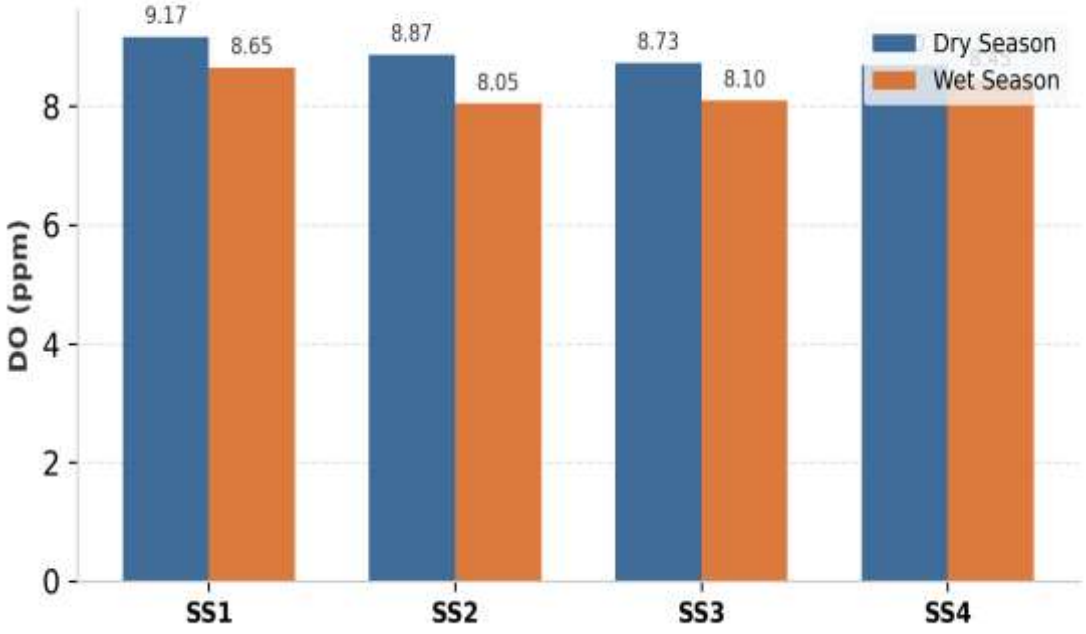
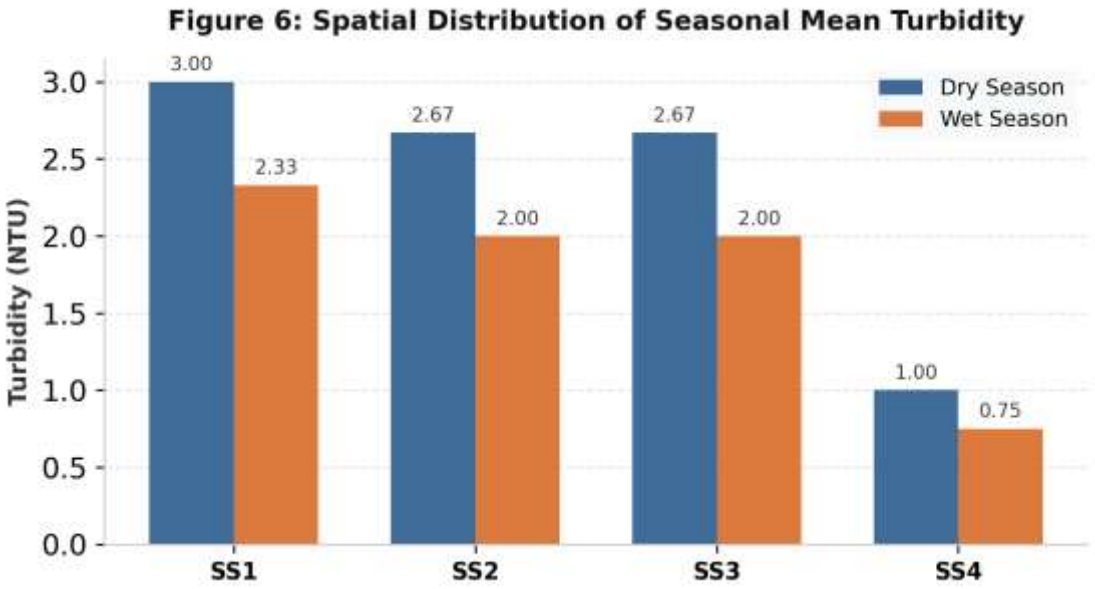


Figure 5: Spatial Distribution of Seasonal Average Dissolved Oxygen



ISSN No. 2454-6194 | DOI: 10.51584/IJRIAS |Volume XI Issue X October 2026



Correlation Matrices of Physicochemical Parameters and Heavy Metals

Table 7 gives the summary of the heavy metal concentrations during both dry and wet seasons while correlation matrices for dry and wet seasons (Tables 8 and 9) demonstrate complex hydrogeochemical interrelationships between physical parameters and toxic heavy metal concentrations. In the dry season (Table 8), temperature correlated negatively with TDS (r = -0.98), DO (r = -0.87), and turbidity (r = -0.92). EC displayed strong positive correlation with cadmium (r = 0.85) and negative correlation with mercury (r = -0.91). Critically, heavy metal inter-correlations revealed very strong positive associations between copper and arsenic (r = 0.71), copper and lead (r = 0.79), arsenic and lead (r = 0.66), and mercury and lead (r = 0.86), pointing to common industrial combustion sources.

In the wet season (Table 9), pH exhibited a powerful inverse relationship with cadmium (r = -0.94), indicating elevated heavy metal dissolution under extreme acidic conditions. EC correlated almost perfectly with turbidity (r = 0.99). Among metallic pollutants, copper exhibited exceptional positive correlations with arsenic (r = 0.91), mercury (r = 0.60), and lead (r = 0.84). Mercury again demonstrated a strong positive correlation with lead (r = 0.87). These synergistic co-occurrences of toxic metals confirm that industrial atmospheric emissions deposit persistent chemical hazardous complexes into the local rainwater supply.

Table 7: Summary of Seasonal Heavy Metal Concentrations for the Study

Heavy Metals (mg/l)	Dry	Wet	WHO Limits
Cd	0.009	0.04	0.003
Zn	0.236	0.183	3
Cu	0.036	0.025	2
As	7.732	5.911	0.01
Hg	1.474	1.157	0.006
Pb	0.45	0.371	0.01

Table 8: Correlation Matrix of Physicochemical Parameters and Heavy Metals During the Dry Season

Parameter	Temp	pH	EC	TDS	DO	Turb	Cd	Zn	Cu	As	Hg	Pb
Temp (°C)	1											
pH	0.35	1										
EC (µS/cm)	0.59	-0.55	1									

TDS (ppm)	-0.98	-0.21	-0.69	1								
DO (ppm)	-0.87	-0.59	-0.27	0.75	1							
Turb (NTU)	-0.92	0.03	-0.85	0.97	0.65	1						
Cadmium	0.18	-0.8	0.85	-0.35	0.26	-0.54	1					
Zinc	0.36	-0.19	0.5	-0.26	-0.55	-0.38	0.08	1				
Copper	0.07	0.6	-0.46	-0.1	0.06	0.1	-0.29	-0.87	1			
Arsenic	0.13	-0.06	0.16	-0.29	0.31	-0.25	0.46	-0.77	0.71	1		
Mercury	-0.73	0.3	-0.91	0.74	0.59	0.86	-0.56	-0.76	0.59	0.18	1	
Lead	-0.52	0.15	-0.6	0.44	0.65	0.55	-0.16	-0.98	0.79	0.66	0.86	1

Note. Researcher's Computation, 2026.

Table 9: *Correlation Matrix of Physicochemical Parameters and Heavy Metals During the Wet Season*

Parameter	**Temp**	**pH**	**EC**	**TDS**	**DO**	**Turb**	**Cd**	**Zn**	**Cu**	**As**	**Hg**	**Pb**
Temp (°C)	1											
pH	-0.31	1										
EC (µS/cm)	-0.29	0.72	1									
TDS (ppm)	0.21	-0.82	-0.98	1								
DO (ppm)	0.05	-0.8	-0.17	0.34	1							
Turb (NTU)	-0.2	0.66	0.99	-0.97	-0.1	1						
Cadmium	0.17	-0.94	-0.45	0.59	0.96	-0.38	1					
Zinc	-0.82	-0.13	-0.31	0.38	0.05	-0.39	0.1	1				
Copper	0.74	0.23	-0.22	0.04	-0.63	-0.2	-0.48	-0.6	1			
Arsenic	0.58	0.04	-0.54	0.37	-0.61	-0.55	-0.37	-0.26	0.91	1		
Mercury	0.34	0.77	0.65	-0.77	-0.62	0.66	-0.73	-0.73	0.6	0.26	1	
Lead	0.75	0.39	0.26	-0.4	-0.46	0.31	-0.46	-0.91	0.84	0.55	0.87	1

Note. Researcher's Computation, 2026.

CONCLUSION AND POLICY IMPLICATIONS

Conclusion on Physicochemical Dynamics

The physicochemical results show a consistent and pronounced acidity problem across the four stations in both seasons. Mean pH declined from 4.31 in the dry season to 3.62 in the wet season, and the minimum recorded value was 2.42 at SS4 during the wet season. All station pH values reported in Tables 5 and 6 were below the stated guideline range of 6.5–8.5. By contrast, the reported temperature, EC, TDS, DO and turbidity values were below the comparison limits listed in the tables. EC increased in the wet season, mean DO decrease slightly, and mean turbidity was lower in the wet season; TDS showed marked spatial variation because of the SS4 wet-season value. The results therefore point to acidity as the clearest physicochemical concern in this dataset, while the measured values of the other parameters do not establish that the water is safe for drinking. Heavy-metal concentrations are not displayed in the main results tables, so their compliance with drinking-water limits cannot be independently assessed from the information presented here. The data establish acidic rainwater conditions, but do not by themselves prove that a particular facility or emission source caused them.

This study integrated socio-demographic survey data with empirical physicochemical analysis to evaluate community awareness, health perception, and acid rain contamination dynamics in Bonny Island, Nigeria. The

research established that while rainwater harvesting is vital for domestic survival (practiced by 85.6% of households), rainwater in Bonny Island suffers from severe chronic atmospheric acidification (mean wet season pH = 3.62; SS4 minimum = 2.42), failing WHO standards without exception. A high level of public awareness exists within the community regarding contamination from oil and gas infrastructure and gas flaring, indicating that petroleum-related industrial emissions are widely recognized as potential sources of environmental pollution.

RECOMMENDATIONS

Based on these findings, the following recommendations are proffered:

1. Targeted Public Health Risk Communication: Regulatory agencies and environmental NGOs must deploy public education campaigns clarifying atmospheric pollution pathways, flaring impacts, and the necessity of pre-consumption water treatment.

2. Household Water Treatment Interventions: State and local authorities should distribute standardized point-of-use neutralization and filtration kits to buffer acidic rainwater and remove heavy metal traces.

3. Industrial Flaring Regulations: Federal environmental enforcement agencies (e.g., NESREA, NOSDRA) must enforce stringent emission limits and mandate stack gas scrubbing among oil and gas operators on Bonny Island.

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