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CONTRIBUTION OF GAS FLARE ON THE RAINWATER OF THE BRACED STATES IN THE NIGER DELTA

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ABSTRACT: *Gas flaring contaminates rainwater, which harms the ecology. Exposure to flared gas turns rainwater acidic. The study examined the rainwater quality in gas flare areas of the BRACED states of the Niger Delta. The study employed an ex-post facto research design to assess the quality of rainwater in the industrial regions of the BRACED Niger Delta states. Rainwater samples were collected from twelve (12) locations in the BRACED Niger Delta states near refineries and gas flaring sites. The results show that the rainwater near GHG-impacted areas of the BRACED states has an average pH of 6.7, which is below the guidelines set by the World Health Organisation (WHO). A pH lower than the required WHO standards suggests acidic rainwater. The temperature is 27.4 °C, the conductivity is 37.1µS/cm, and the phosphate concentration exceeds WHO guidelines. Nitrate and sulphate levels are below WHO guidelines. P<0.05 indicates substantial changes in pH value and temperature amount in rainwater quality. Acidic rains, high temperatures, and high phosphate concentrations characterise the BRACED States, raising concerns about the suitability of rainwater for drinking. The study underscores the need for a comprehensive approach to controlling gas flaring, which includes taxation, anti-acidic coating measures, and infrastructure upgrades.*

KEYWORDS: Rainwater, Environmental Deterioration, Acidic, Pollutants, BRACED States.

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INTRODUCTION

Flare gases such as carbon dioxide (CO_2), methane (CH_4), and nitrogen dioxide (N_2O) are accountable for rainwater pollution (Boyitie et al, 2024). Gas flaring has a substantial influence on climate change, food insecurity, low income, vegetation loss, and water body pollution (Boyitie et al., 2024). The BRACED Niger Delta States have demonstrated a persistent inability to adequately tackle the problem of greenhouse gases emission from flaring activities. Rainfall physicochemical characteristics and acidity are concerns caused by greenhouse gas emissions. Gas flare plants located in proximity to human settlements, release particulate matter which tends to accumulate on the rooftops of buildings.

Several studies have been conducted on the gas flaring effect on rainwater quality (Ezenwaji et al., 2013; Afangideh & Udokpoh, 2021). Greenhouse gas impacts on water quality have been extensively studied, but few have addressed their geographical pattern in the BRACED Niger Delta states. There have been water quality studies in this area, but little on greenhouse gases and precipitation. This research fills a literature vacuum by giving policymakers and stakeholders' tools for targeting actions and resources to BRACED states' greenhouse gas-affected regions. This study evaluates the contribution of gas flaring on rainwater quality in the BRACED states of the Niger Delta. The findings may also inform land use planning and resource management to ensure local community sustainability. The discoveries can provide direction for future studies and actions aimed at mitigating pollution in the area.

Conceptual Issues

Vulnerability is an essential and significant concept in the fields of policymaking and environmental sciences (Paul, 2013; Thomas et al., 2019). The definition of vulnerability has faced criticism for its lack of clarity and challenges in practical implementation. However, it has gained widespread acceptance in vulnerability studies because of its multifaceted nature. According to Tucker et al. (2014), this definition is broad and can be applied to make improvements in sustainable development and ecological-social systems. Birkmann (2007) introduced a theoretical structure for evaluating vulnerability, with a specific emphasis on both internal and external factors. Internally, adaptation is required, while externally, there is exposure to risks.

Vulnerability can be categorised into two types: outcome-based vulnerability and contextual vulnerability. Vulnerability stems from individuals' capacity to mitigate changes and their incapability to promptly respond and implement long-term adaptive measures. Greenhouse gas emissions impact rains, potable water, agricultural output, and ecological health in the BRACED Niger Delta states. These modifications may have a greater impact on disadvantaged communities, which have limited resources or infrastructure to address the repercussions. Understanding adaptability and vulnerability is crucial to managing rainwater quality in greenhouse gas-impacted BRACED Niger Delta States.

MATERIALS AND METHOD

The BRACED states are situated in the Niger Delta coastal plain, covering an area of 8600 square kilometres and encompassing wetlands that stretch between latitudes 3°N to 6°N and longitudes 5°E to 8°E (see Fig 1). The BRACED states are inherent sedimentary basins characterised by the presence of sand, silt, clay, shale, and peat layers. The area is situated at a

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low altitude, has a lot of wetlands, and is distinguished by a complex system of meandering rivers and small streams. The climate is characterised by a semi-hot, humid equatorial climate with elevated temperatures and abundant rainfall. Efe et al. (2013) observed that May and September have the most rainfall, whereas August has less.

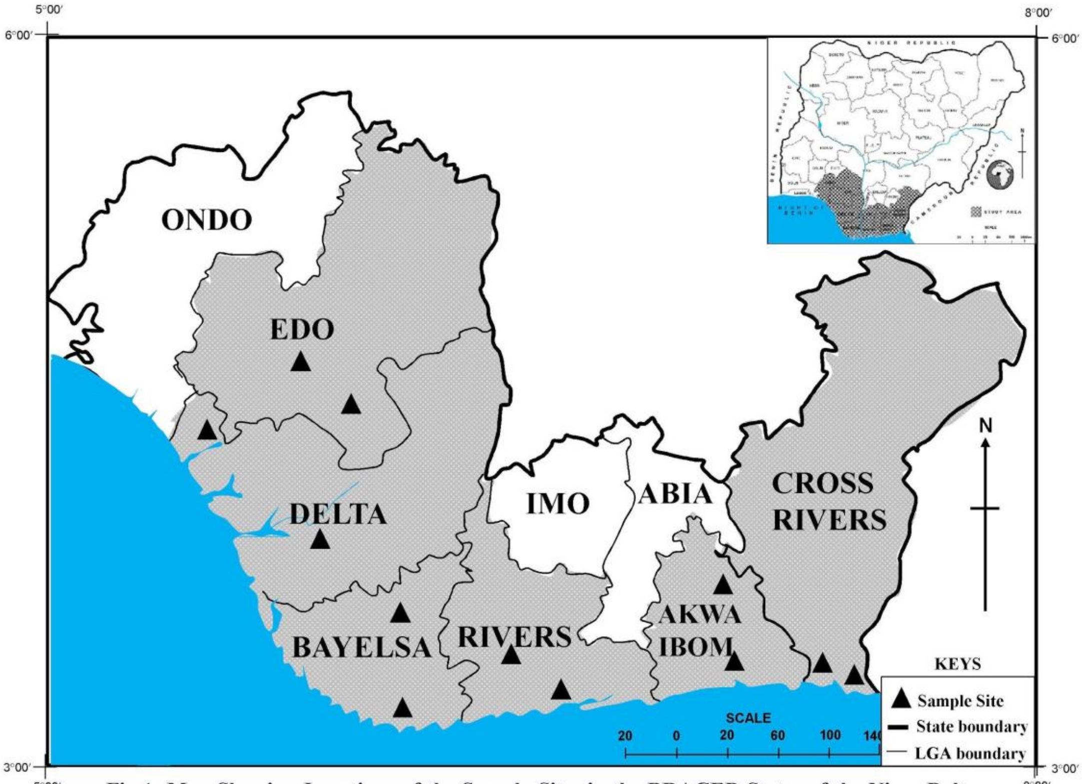

Fig 1: Map Showing Locations of the Sample Sites in the BRACED States of the Niger Delta
Source: Cartographic Unit of Department of Urban and Regional Planning, Dennis Osadebay University, Asaba

This study used an ex-post facto research design, incorporating field measurements of rainwater quality. Rainwater data were collected from twelve (12) locations close to refineries and gas flaring sites in the BRACED states (see Fig 1 and Table 1). Rainwater samples were collected using plastic vases placed in the various sample locations. To reduce rain splashing, the plastic canisters were placed 1.5m above ground level in each location. The specimens were gathered at time intervals of 10 and 20 minutes following the rainfall occurrence.

Table 1: Sampling locations

Sample States	Sample Areas	GPS Location	
Delta	Forcados, and Warri	$5^{0}21^{1}35$”N $5^{0}20^{1}48$”E	$5^{0}32^{1}17^{11}$N $5^{0}41^{1}33^{11}$E
Rivers	Bonny, and Port Harcourt	$4^{0}26^{1}17$”N $7^{0}09^{1}46$”E	$4^{0}55^{1}39$”N $6^{0}39^{1}14$”E
Cross Rivers	Calabar, and Ikang	$5^{0}00^{1}42$”N $8^{0}19^{1}35$”E	$4^{0}58^{1}22$”N $8^{0}20^{1}27$”E
Akwa Ibom	Uyo, and Eket	$5^{0}02^{1}30$”N $7^{0}52^{1}14$”E	$4^{0}39^{1}06$”N $7^{0}57^{1}04$”E

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Bayelsa	Brass, and Yenagoa	$4^{0}18^{1}23$”N $6^{0}14^{1}52$”E	$4^{0}55^{1}40$”N $6^{0}17^{1}15$”E
Edo	Ologbo, Oredo	$6^{0}04^{1}37$”N $5^{0}39^{1}33$”E	$6^{0}03^{1}41$”N $5^{0}34^{1}42$”E

The mean value of the physical and chemical properties of the rainwater were recorded. The data were recorded at an interval of two weeks. During this, collecting time-lapse samples were refrigerated at a temperature of 4°C for 24 hours and taken to the laboratory for analysis. The samples underwent analysis for cations, anions, and trace metals and the results were compared to WHO water quality guidelines. ANOVA statistical tool was used to compare and establish where the difference in the rainwater quality exists in the BRACED Niger Delta States. The data were validated and analysed using SPSS version 21.

RESULTS AND DISCUSSION

Table 2: Physicochemical Properties of Rainwater Quality

Acid Rain Parameters	Mean/Range	WHO
pH	6.7 ± 3.0	7.0-8.5
Temperature (^{0}C)	27.4 ± 2.7	30
Conductivity(uS/cm)	37.1 ± 7.7	50
Sulphate (mg/l)	3.1 ± 1.7	<250 (mg/l)
Phosphate (mg/l)	1.7 ± 0.9	<0.5 (mg/l)
Nitrate (mg/l)	1.4 ± 1.5	<50 (mg/l)

Table 2 presents the physical and chemical properties of rainwater in BRACED states of the Niger Delta. The mean pH value is 6.7, which is lower than the standards established by the World Health Organisation (WHO), suggesting a mildly acidic characteristic. The mean conductivity is 37.1µS/cm, which is lower than the standards established by the World Health Organisation (WHO). This indicates a decreased concentration of ions and a minimal quantity of dissolved minerals and salts. The results suggest that the water in the area is primarily acidic due to its close proximity to refinery flare stacks.

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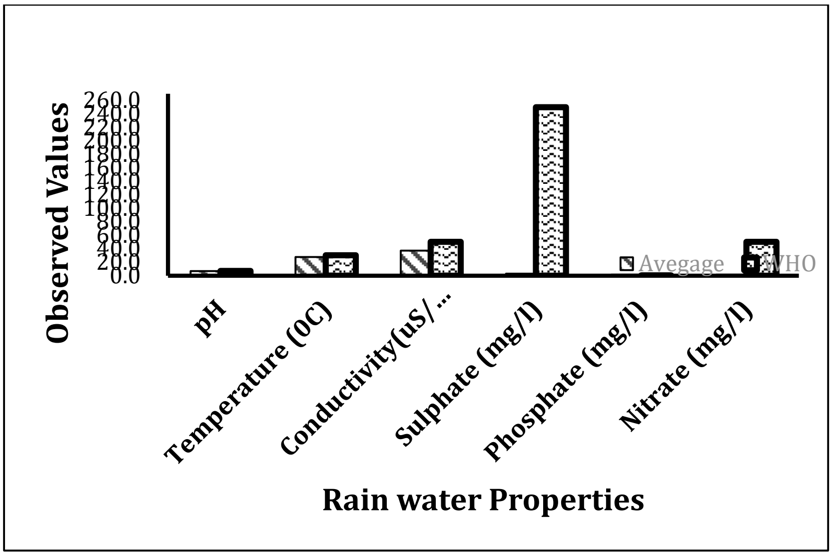

Fig 2: Mean Concentration of Physicochemical Parameters of Rain water

The mean concentration of phosphate in rainfall exceeded the recommended standards set by the World Health Organisation, measuring 1.7 mg/l, which is higher than the maximum threshold for ensuring the quality of drinking water (see Fig 2). Nevertheless, the levels of nitrate and sulphate were found to be lower than the standards set by the World Health Organisation (WHO). The presence of phosphate levels in the rainwater exceeds the WHO recommended standards. This implies that the rainwater is not suitable for drinking and household purposes.

Table 3: State Distribution of Rain Water Quality in the Niger Delta

States	**pH**	**Temp (^{0}C)**	**Conductivity(uS/cm)**	**Sulphate (mg/l)**	**Phosphate (mg/l)**	**Nitrate (mg/l)**
Akwa Ibom	8.3	27.2	35.1	2.7	1.3	0.9
Bayelsa	6.5	28.3	37.8	3.6	1.9	2.0
Cross Rivers	8.0	27.5	35.6	2.9	1.5	1.1
Delta	6.2	27.3	37.1	3.0	1.7	1.4
Rivers	5.7	28.4	42.3	4.2	2.2	2.4
Edo	5.3	25.7	34.6	2.5	1.6	0.9
Mean	6.7	27.4	37.1	3.2	1.7	1.5
WHO	7.0-8.5	30	50	<250	<0.5	<50

Source: Author's Computation, (2022)

The physicochemical characteristics of rainwater in the BRACED states of the Niger Delta exhibit variations, while maintaining a consistent pH level across all locations (see Table 3). Edo exhibited the most acidic conditions with a pH value of 5.3, whereas Akwa Ibom displayed

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the highest alkalinity with a pH value of 8.3 (see Fig 3). These findings indicate that Akwa Ibom and Cross Rivers have a higher level of alkalinity in their rainwater, whereas Edo, Bayelsa, Delta, and Rivers States experience more acidic rainwater, which falls below the WHO recommended standards. This phenomenon may be attributed to the gas-flaring activities occurring in these areas.

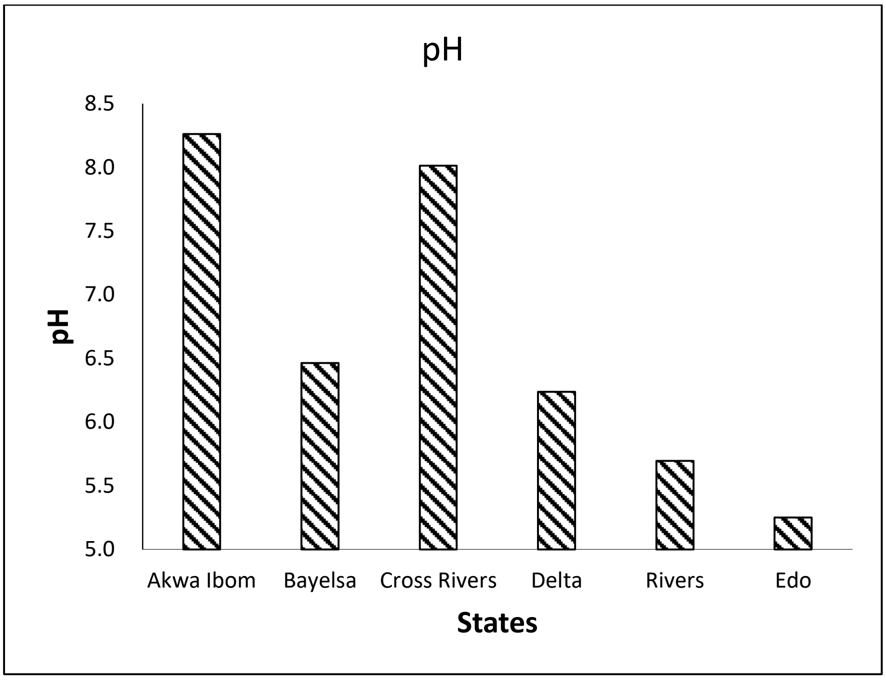

Fig 3: pH Composition of the Rainwater

The temperature range of rainwater in Edo ranged from 25.7^{0}C to 28.4^{0}C, with Rivers State having the highest temperature and Edo State having the lowest (see Fig. 4). Bayelsa and Rivers States had temperatures below the WHO standards. Edo state rainwater had a mean value of 34.6 mg/l for conductivity, while Rivers state had a mean value of 42.3 mg/l (Fig 5). Bayelsa State and Rivers States demonstrated the highest level of electrical conductivity. However, the mean conductivity value of 37.1uS/cm in the BRACED states in the Niger Delta was below the WHO recommended standards.

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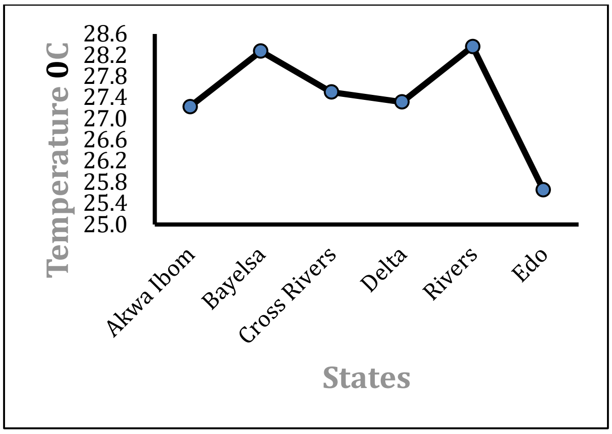

Fig 4: Temperature of the Rainwater

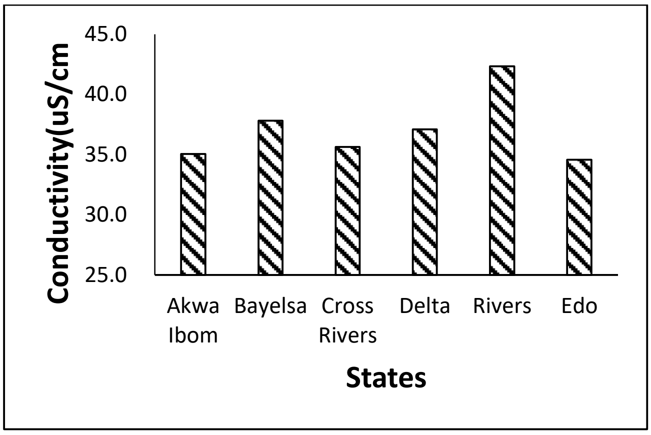

Fig 5: Conductivity of the Rainwater

The sulphate concentration of rainwater exhibits variations, with Edo recording the lowest value of 2.5mg/l and Rivers State measuring 4.2mg/l (see Fig 6). Akwa Ibom exhibits the most minimal concentration. Despite being below the WHO threshold, Bayelsa and Rivers States have the highest sulphate concentrations in the BRACED states. The regional variation in phosphate concentration in rainwater is evident, with Akwa Ibom exhibiting the lowest level at 1.3 mg/l and Rivers State displaying the highest level at 2.2 mg/l (see Fig 7). However, these levels exceed the WHO threshold, which could cause unpleasant tastes and odours in the rainwater in Bayelsa and Rivers States.

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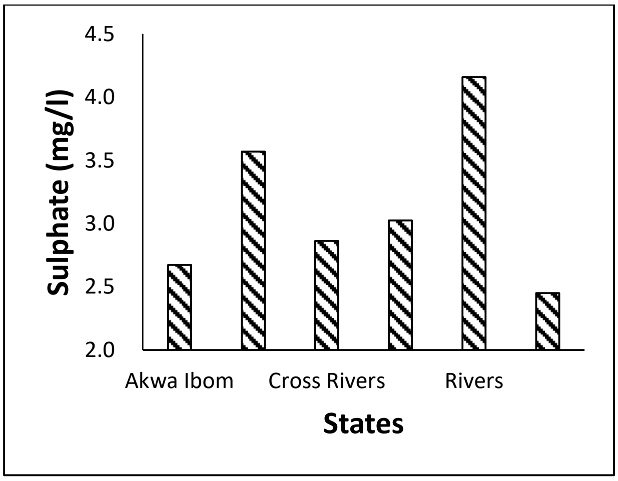

Fig 6: Sulphate Composition of the Rainwater

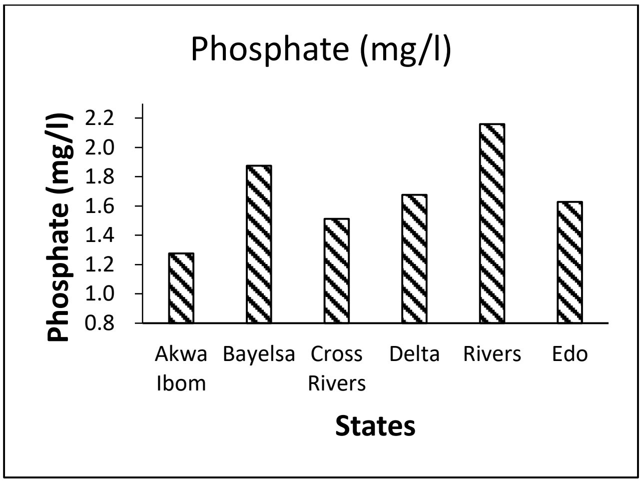

Fig 7: Phosphate Composition of the Rainwater

The study revealed variations in the nitrate concentrations of rainwater. Akwa Ibom and Edo exhibited the lowest concentration of 0.9mg/l, while Rivers State had the highest concentration at 2.4mg/l (Fig 8). Bayelsa and Rivers States exhibited the most significant concentrations of Nitrate in the BRACED states of the Niger Delta, although it remained below the limit recommended by the World Health Organisation (WHO).

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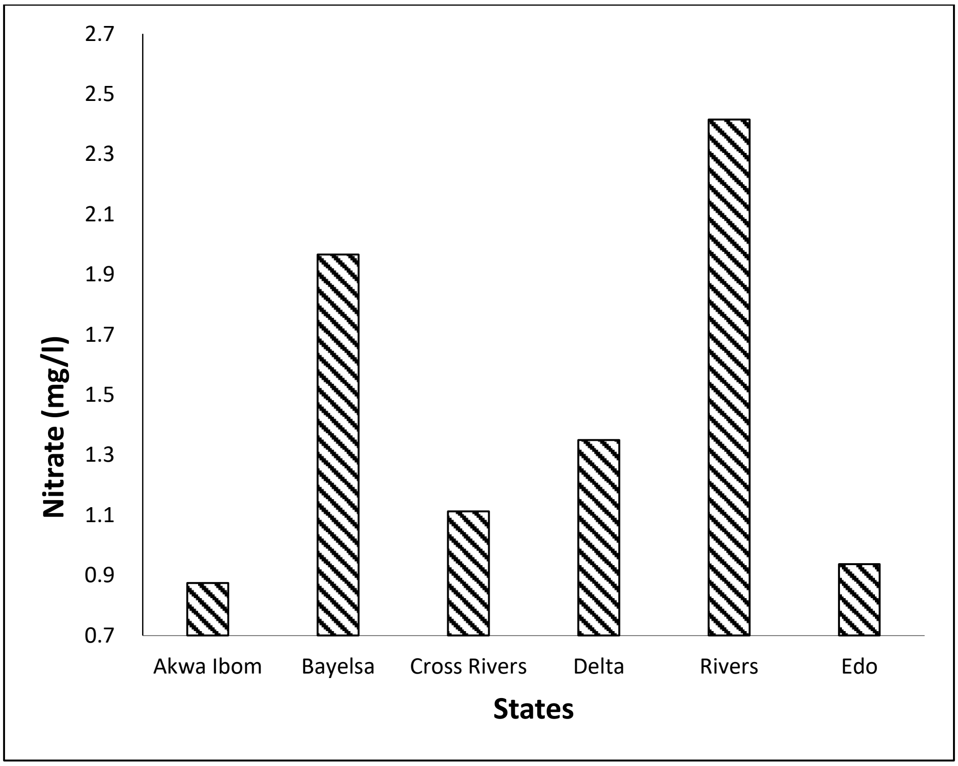

Fig 8: Nitrate Composition of the Rainwater

Table 4 presents a statistical analysis of the physicochemical characteristics of rainwater in the Niger Delta region. At P<0.05 the model is significant, expressing a difference in the quality of rainwater. This difference is significant in the temperature and pH values spread across the BRACED states of the Niger Delta.

Table 4: ANOVA analysis of Rain Water Quality variations in the Niger Delta

		Sum of Squares	Df		Mean Square	F	Sig.
P^H	Between Groups	30.528	5		6.106	24.84	.000
	Within Groups	4.425	18		.246		
	Total	34.953	23				
Temperature	Between Groups	19.319	5		3.864	6.12	.002
	Within Groups	11.368	18		.632		
	Total	30.686	23				
Conductivity	Between Groups	163.439	5		32.688	.94	.481
	Within Groups	628.708	18		34.928		
	Total	792.146	23				
Sulphate	Between Groups	7.935	5		1.587	.27	.923
	Within Groups	105.505	18		5.861		
	Total	113.440	23				
Phosphate	Between Groups	1.732	5		.346	.34	.879
	Within Groups	18.127	18		1.007		
	Total	19.860	23				
Nitrate	Between Groups	7.393	5		1.479	.886	.511

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	Within Groups	30.040	18		1.669		
	Total	37.433	23				

The Scheffe post hoc test revealed significant differences in the pH values of Akwa Ibom and Cross Rivers states, which differs from Bayelsa, Delta, Rivers and Edo states, and the pH concentration of Edo state differs from Bayelsa (see Table 5). Akwa Ibom and Cross Rivers exhibit markedly elevated values of rainwater pH compared to Bayelsa, Delta, Rivers, and Edo. This implies that the rainwater in Akwa Ibom and Cross Rivers states is highly Alkaline. Furthermore, there is a substantial difference in the values of rainwater temperature across the BRACED states of the Niger Delta. The rainwater temperature value in Edo State differs significantly from Bayelsa and Rivers States (see Table 5). This implies that the rainwater temperature in Bayelsa and Rivers states is significantly different from that of Edo state.

Table 5: Scheffe Post Hoc Tests

Multiple Comparisons							
Scheffe							
Dependent Variable	(I) Location	(J) Location	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
P^H	1 Akwa Ibom	1 Bayelsa	1.8000*	.3506	.004	.495	3.105
		2 Delta	2.0250*	.3506	.001	.720	3.330
		3 Rivers	2.6000*	.3506	.000	1.295	3.905
		4 Edo	3.0250*	.3506	.000	1.720	4.330
	2 Cross Rivers	1 Bayelsa	1.5500*	.3506	.014	.245	2.855
		2 Delta	1.7750*	.3506	.004	.470	3.080
		3 Rivers	2.3500*	.3506	.000	1.045	3.655
		4 Edo	2.7750*	.3506	.000	1.470	4.080
	3 Edo	1 Bayelsa	-1.2250	.3506	.074	-2.530	.080
Temperature	1 Edo	1 Bayelsa	-2.6500*	.5619	.008	-4.742	-.558
		2 Rivers	-2.7000*	.5619	.007	-4.792	-.608

The rainwater in the Niger Delta has an average pH of 6.7, which is below the guidelines set by the World Health Organisation (WHO). This indicates that the precipitation is slightly acidic. The temperature is 27.4°C, and the conductivity is 37.1µS/cm, which falls below the acceptable threshold set by the World Health Organisation (WHO). The mean phosphate concentration exceeds the guidelines set by the World Health Organisation, with an average value of 1.7 mg/l. The mean levels of nitrate and sulphate are 1.4mg/l and 3.1mg/l, respectively, which fall below the standards set by the World Health Organisation (WHO). Rivers experience the highest amount of rainfall, whereas Edo State has the lowest precipitation levels. In Edo, the maximum concentration of sulphate is 2.5 mg/l, whereas the maximum concentration of phosphate is 1.3 mg/l. The model demonstrates notable disparities in the quality of rainwater, specifically in terms of pH and temperature, suggesting varying levels of precipitation.

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CONCLUSION

The study highlights the effect of heightened levels of greenhouse gas emissions on rainwater quality, leading to a range of detrimental consequences within the Niger Delta region. The average pH of rainwater in the Niger Delta falls below the guidelines set by the World Health Organisation (WHO), indicating that the precipitation is slightly acidic. The temperature, conductivity, and phosphate concentration surpass the standards set by the World Health Organisation (WHO). The levels of nitrate and sulphate are also within the limits set by the World Health Organisation (WHO). The study serves as a poignant reminder to key actors, urging them to give precedence to initiatives addressing the effect of GHG on water quality in the Niger Delta with the aim of safeguarding the region's unique ecology, customs, and means of sustenance for succeeding cohorts. The recommendations include a comprehensive policy to tackle gas flaring in the Niger Delta, including controlling flared natural gas, heavily taxing upstream petroleum producers, offering tax holidays, coating structures with anti-acidic chemicals, treating acidified water bodies, encouraging continuous studies, involving the Niger Delta Development Commission in infrastructure provision, and initiating a regional development plan to improve people's lives. Further studies should investigate efficient mitigation strategies in the Niger Delta area, with a specific emphasis on technological and policy interventions aimed at effectively decreasing greenhouse gas emissions.

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