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Making the Invisible Visible: The Effects of Gas Flaring on Artisanal Fisheries in the Down-Stream Area of Taylor Creek, Bayelsa State, Nigeria

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Funding: No specific funding was received for this work.

Potential competing interests: No potential competing interests to declare.

Abstract

Rationale: Gas flaring is a significant environmental concern in many regions, including the downstream area of Taylor Creek, Bayelsa State, Nigeria. Its impact on artisanal fisheries, a vital economic activity in the area, warrants investigation to understand the extent of its effects.

Objectives: This study aimed to assess the effects of gas flaring on artisanal fisheries in the downstream area of Taylor Creek, Bayelsa State, Nigeria, from August 2023 to January 2024.

Methods: Structured questionnaires were utilized in a descriptive survey research design to collect data during the specified period.

Results: The study found that gas flaring profoundly affects artisanal fisheries activities in the area. These effects include a drastic reduction in fish catch, extinction of certain fish species, increased fish prices, indiscriminate fish mortality, disrupted fishing schedules, altered water body dynamics, impaired spawning activities, fish migration, and economic hardships for fishers. Additionally, gas flaring contributes to fish size reduction, abandonment of the fishing sector by artisanal fishers, increased time spent on fishing, and accelerated degradation of fishing implements.

Conclusion: Gas flaring negatively impacts artisanal fisheries in the downstream area of Taylor Creek, Bayelsa State, Nigeria. Urgent measures are necessary to mitigate these effects and preserve the local ecosystem.

Recommendation: To address these issues, it is recommended that gas flaring be utilized for beneficial purposes such as gas injection or electricity generation. Government intervention is needed to restore extraction areas, and companies must adopt safe and environmentally friendly operations to prevent further environmental degradation. Additionally, new legislation should be enacted to protect the environment and control pollution caused by gas flaring in the study area. These measures are essential for safeguarding the environment and sustaining artisanal fisheries in the region.

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Keywords: Artisanal fisheries, Effects, Gas flaring, Taylor Creek, Core Niger Delta, Nigeria.

Introduction

Gas flaring, a common practice in oil-producing regions, involves the burning of natural gas mixed with crude oil during extraction and processing. Initially considered a precautionary measure during breakdowns or emergencies, it has evolved into a routine disposal method for excess gas. The process is often necessitated by the difficulty in separating associated gas from crude oil, leading to its combustion either directly from pits or through flare stacks. However, gas flares emit a range of pollutants, including nitrogen oxides, sulfur dioxide, ammonia, methane, carbon dioxide, and carcinogenic substances like benzene, toluene, xylene and hydrogen sulfide (Edino *et al.,* 2010; Worldbank, 2011; Premoboere and Raimi, 2018; Raimi, 2019; Raimi *et al.,* 2018, Raimi *et al.,* 2020; Raimi *et al.,* 2021; Obi *et al.,* 2021; Morufu *et al.,* 2021a; Omoyajowo *et al.,* 2022; Clinton-Ezekwe *et al.,* 2022; Omoyajowo *et al.,* 2024). In Nigeria, particularly in the Niger Delta Area, gas flaring has become a significant issue due to the operations of multinational oil companies such as Shell Petroleum Development Company (SPDC) and Agip. Despite Nigeria's substantial gas reserves, it ranks among the top countries globally for gas flaring, with approximately 16% of associated gas being flared annually. This practice not only wastes valuable energy resources but also contributes to environmental degradation and health hazards, affecting both the local ecosystem and human populations (Worldbank, 2002; 2004; Ekpoh and Obia, 2010; Raimi and Sabinus, 2017; Ebuete *et al.,* 2019; Font *et al.,* 2019; Raimi *et al.,* 2020b; Deinkuro *et al.,* 2021a, b; Olalekan *et al.,* 2022; Ifeanyichukwu *et al.,* 2022; Awogbami *et al.,* 2022; Stephen *et al.,* 2023). The Niger Delta Area, encompassing several states and serving as the economic hub of Nigeria due to its abundant oil reserves, bears the brunt of these impacts. Despite its economic importance, the region faces neglect from oil companies in prioritizing environmental and human health concerns

associated with gas flaring. Regulatory bodies like the Federal Environmental Protection Agency (FEPA) and the Department of Petroleum Resources (DPR) have failed to implement effective anti-gas flaring policies or monitor emissions adequately (Manby, 1999; Akindele *et al.,* 2016; Omidiji and Raimi, 2019; Suleiman *et al.,* 2019; Adedoyin *et al.,* 2020; Raimi *et al.,* 2020c; Olalekan *et al.,* 2020a, b). The core Niger Delta, covering approximately 70,000 square kilometers and comprising Bayelsa, Delta, and Rivers States, serves as Nigeria's economic nerve center owing to its immense oil reserves. Despite its relatively small landmass compared to other oil-producing regions globally, such as Saudi Arabia's Eastern Province, Siberia in Russia, Texas in the United States, or Venezuela's Orinoco Belt, the Niger Delta plays a crucial role in Nigeria's economy. Similar to these regions, the Niger Delta's oil industry significantly contributes to government revenue, GDP, and overall economic growth. However, its economic importance is notably concentrated within Nigeria, where it remains a primary driver of the country's energy sector and a key player in the global oil market (Olalekan *et al.,* 2019; Raimi *et al.,* 2019c). However, in 2000 the government of the Federation Republic of Nigeria included Abia, Akwa Ibom, Cross River, Edo, Imo and Ondo States in the region (Hamer, 2018). Obi *et al.* (2021) reported that gas flaring has being responsible for several health and environmental challenges and some of the adverse effects of gas flaring include climate change (Raimi *et al.,* 2018; Morufu *et al.,* 2021b), environmental pollution (Okoyen *et al.,* 2020; Kader *et al.,* 2023a, b; Glory *et al.,* 2023; Raheem *et al.,* 2023; Rauf and Raimi, 2023), global warming, loss of lives and respiratory problems (Raimi *et al.,* 2018; Raimi *et al.,* 2020; Morufu *et al.,* 2021a; Raimi *et al.,* 2021; Clinton-Ezekwe *et al.,* 2022). The effects of gas flaring on fishery refers to the influence of burning natural gas that is often released during oil extraction on aquatic ecosystems, particularly on fish populations (Ayibatonye *et al.,* 2024a, b). Gas flaring emits various pollutants, including greenhouse gases, which can affect the groundwater quality (Morufu and Clinton, 2017; Raimi and Sabinus, 2017; Olalekan *et al.,* 2018; Odipe *et al.,* 2018; Raimi *et al.,* 2019c; Olalekan *et al.,* 2020; Gift and Olalekan, 2020; Raimi *et al.,* 2021b; Afolabi and Raimi, 2021; Olalekan *et al.,* 2022b; Raimi and Sawyer, 2022; Raimi *et al.,* 2022a, b, c, Olalekan *et al.,* 2023; Raimi *et al.,* 2023), habitat, and overall health of the aquatic environments (Raimi *et al.,* 2019a, b; Olalekan *et al.,* 2021; Raimi *et al.,* 2022d, e; Dienye *et al.*, 2023; Sylvester *et al.,* 2023; Saliu *et al.,* 2023). According to Okonkwo (2017) gas flaring which the practice of burning off excess natural gas during oil extraction and processing, has turn out to be a substantial environmental concern in many oil-producing regions round the world (https://earthjournalism.net/stories/gas-flaring-in-the-niger-delta-harming-health-climate-and-environment). While, the downstream region of Taylor Creek emerges as a pivotal hub for fisheries activities within Bayelsa State, Nigeria. Renowned for its abundant aquatic biodiversity teeming with diverse fish species, crustaceans, and mollusks, this area holds significant importance. The fisheries operations here are not merely economic ventures; they embody a lifeline for local communities, fostering livelihoods by serving as crucial sources of income and nutrition. This symbiotic relationship between the fisheries and the communities underscores the pivotal role played by Taylor Creek's downstream area in sustaining the socio-economic fabric of the region (Ayibatonye *et al.,* 2024a, b; Kwen *et al.*, 2019). The fish species are essential for local diet and are also commercially important to the inhabitants of the down-stream area of Taylor Creek. The effects of gas flaring on the environment are well-documented and have been studied in various contexts, such as air quality (Premoboere and Raimi, 2018; Ajayi *et al.,* 2020; Kabiru *et al.*, 2020; Morufu *et al.,* 2021a, b; Raimi *et al.,* 2021; Clinton-Ezekwe *et al.,* 2022), health impacts (Nriagu, 2018; Omidiji and Raimi, 2019; Suleiman *et al.,* 2019; Raimi *et al.,* 2019; Adedoyin *et al.,* 2020; Raimi *et al.,* 2020c; Olalekan *et al.,* 2020a, b) and aquatic

pollution (Adedeji and Adetunji, 2011). However, its specific effects on local ecosystems, particularly fisheries in the down-stream area of Taylor Creek, Bayelsa State, Nigeria, has received limited or no attention (Ayibatonye *et al.,* 2024a, b). The down-stream area of Taylor Creek is a vital ecosystem for the local communities, providing a source of livelihood through fisheries. This area is situated in the heart of Bayelsa State, an area known for extensive oil and gas extraction activities. Environmental effects of oil and gas production may include alterations in water quality, temperature, and oxygen levels, which can affect aquatic life and fish populations (Morufu and Clinton, 2017; Raimi and Sabinus, 2017; Olalekan *et al.,* 2018; Odipe *et al.,* 2018; Raimi *et al.,* 2019c; Biney, 2019; Olalekan *et al.,* 2020; Gift and Olalekan, 2020; Gift *et al.,* 2020; Raimi *et al.,* 2021b; Afolabi and Raimi, 2021; Olalekan *et al.,* 2022b; Raimi and Sawyer, 2022; Raimi *et al.,* 2022a, b, c, Olalekan *et al.,* 2023; Raimi *et al.,* 2023). Likewise, contaminants from gas flaring, such as heavy metals and polycyclic aromatic hydrocarbons, can bioaccumulate in fish, potentially posing health risks to consumers (Adedeji *et al*., 2017). The socio-economic dimensions are pivotal, as local communities rely on fisheries for both sustenance and income. Given the gravity of these challenges, there's an urgent call for holistic policies and robust enforcement mechanisms aimed at tackling gas flaring in Nigeria and similar affected areas. These strategies must prioritize environmental preservation, safeguard public health, and advocate for sustainable energy practices. Furthermore, active engagement of local communities in decision-making processes and the promotion of alternative energy sources are imperative to reduce dependence on gas flaring. Only through unified efforts can the adverse effects of gas flaring be mitigated, paving the way for a more sustainable and just future for affected regions and communities. Thus, this study endeavors to explore the impacts of gas flaring on artisanal fisheries in the downstream region of Taylor Creek, Bayelsa State, Nigeria. The insights gained from this research will inform the formulation of sustainable environmental and fisheries management strategies in this region, which is pivotal due to its significant oil and gas activities.

Aim and objectives of the Study

The aim of the study is to investigate the effects of gas flaring on artisanal fisheries in the down-stream area of Taylor Creek, Bayelsa State, Nigeria. The specific objectives of the study are to:

1. Examine the bio-data of artisanal fishers in the down-stream area of Taylor Creek, Bayelsa State.
2. Determine the effects on fish catch in the study area.
3. Find out the negative effects of gas flaring on the social, economic and health of artisanal fishers in the study area.
4. Determine other challenges occasioned by gas flaring in the study area.
5. Provide possible measures to tackle the challenges encountered by artisanal fishers in the study area.

Methodology

Study Area

The study was conducted in the down-stream area of Taylor Creek in Yenagoa Local Government Area of Bayelsa State, Nigeria from August, 2023 to January, 2024. The stretch of the down-stream area of Taylor Creek goes beyond Polaku

and Okolobiri communities in Gbarain Kingdom. The down-stream area of Taylor Creek is situated between 5º 01'N; 6º 17 'E and 5º 02'N; 6º 18'E (Fig. 1). Several creeks and floods channels interconnect freshwater swamp forests, linking the Nun River and Taylor Creek at various points and form a mass of water body during the high flood. Okoso Creek is at present the most prominent creek connected to the Taylor Creek which subsequently empties into the Nun River at its confluence at Polaku town. In the dry and low water period, the Taylor Creek in the Zarama axis reduces to disjointed series of pools linked by sections of shallow water. The down-stream area of Taylor Creek is subject to mild tidal influence in the dry season (Kwen *et al*., 2019).

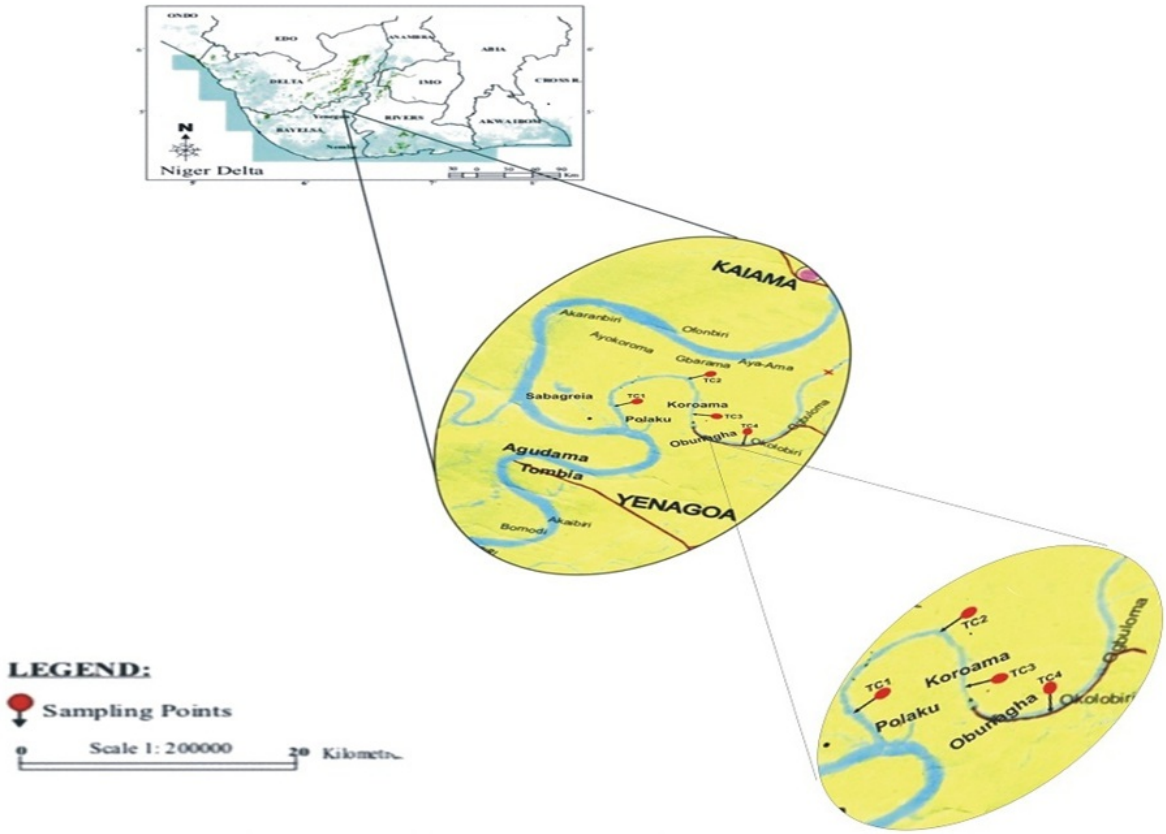

Fig. 3.1: Map of Niger Delta Showing Bayelsa and Lower Taylor Creek, the Study Area.

Figure 1.

Source: Kwen *et al*. (2019).

Research Design

For the study, an approach rooted in descriptive survey research design was meticulously chosen and implemented. This methodological framework offers a comprehensive and systematic approach to data collection and analysis, allowing for a detailed exploration and documentation of the phenomena under investigation. Through this design, researchers are equipped to gather pertinent information on various aspects of the subject matter, including characteristics, trends, and patterns. By employing such a design, the study aims to provide a rich and nuanced understanding of the targeted phenomenon, enabling insightful interpretation and informed decision-making.

Sampling Methods

A total of 120 structured questionnaires were administered to artisanal fishers operating within the study area, specifically drawn from the Polaku, Ogboloma, Koroama, and Obunagha communities situated along the downstream stretch of Taylor Creek. Each of these communities received thirty questionnaires, strategically selected due to their proximity to the gas flaring unit or area compared to other communities along the creek's downstream section. After a two-week period, the questionnaires were collected for analysis. The questionnaire comprised two sections: Section A focused on respondents' demographic information, encompassing details such as gender, age, marital status, religion, educational background, household size, years of fishing experience, and weekly income generation. On the other hand, Section B delved into various aspects relevant to the research topic, segmented into subsections from A to E. Utilizing a four-point rating scale, respondents were prompted to indicate their agreement with each statement, with numerical values assigned as follows: Strongly Agree (4) with a range of 3.50 to 4.49, Agree (3) with a range of 2.50 to 3.49, Disagree (2) with a range of 1.50 to 2.49, and Strongly Disagree (1) with a range of 0.50 to 1.49. Items with a mean value of 2.50 or higher were considered as agree, while those with mean values lower than 2.50 were deemed disagree, guiding the analysis process.

Data Analysis

The collected data underwent analysis employing straightforward descriptive statistical techniques, including percentage calculations, frequency distributions, and determination of mean scores. These analytical methods were instrumental in uncovering patterns, trends, and central tendencies within the dataset, offering a comprehensive understanding of the research findings. Through the utilization of these statistical tools, the researchers were able to distill the gathered information into meaningful insights, facilitating the interpretation and presentation of the research outcomes in a clear and concise manner.

Results

Bio-data of Respondents

The bio-data of artisanal fishers (respondents) in the down-stream area of Taylor Creek is presented in Table 1. It is apparent from the results that majority of the respondents were males (65.83%) while 34.17% were females. Out of which majority (37.50%) fall into the age bracket of 30-39years, 30.87% 40-49years, 17.50% 18-29years, while only 14.17% was above 50 years. Majority of them were married (56.67%), 33.34% single, 3.33% divorced while 5.00% were widow. Majority (60.00%) were Christians, 31.67% Islam while 8.33% were other religions. Majority (40.00%) of them had secondary education, 30.00% primary education, 16.67% no-formal education while 13.33% of them had tertiary education.

Table 1. Bio-data (Personal Data) of artisanal fishers in the down-stream area of Taylor Creek

Parameter	Frequency	Percentage (%)
Sex		
Male	79	65.83
Female	41	34.17
Total	120	100.00
Age		
18-29	21	17.50
30-39	45	37.50
40-49	37	30.87
50 and Above	17	14.17
Total	120	100.00
Marital Status		
Single	42	35.00
Married	68	56.67
Divorce	4	3.33
Widow	6	5.00
Total	120	100.00
Religion		
Christianity	72	60.00
Islamic	38	31.67
Others	10	8.33
Total	120	100
Educational Level		
No-Formal Education	20	16.67
Primary Education	36	30.00
Secondary Education	48	40.00
Tertiary Education	16	13.33
Total	120	100.00

Source: Field Survey, 2023-2024

The Household Size of Respondents

The results of house hold size are represented in Figure 2 and it shows that majority (45.00%) of the respondents had a household size 6-10 persons, followed by 1-5 persons (38.33%) and only 16.67% of them had over 11 persons.

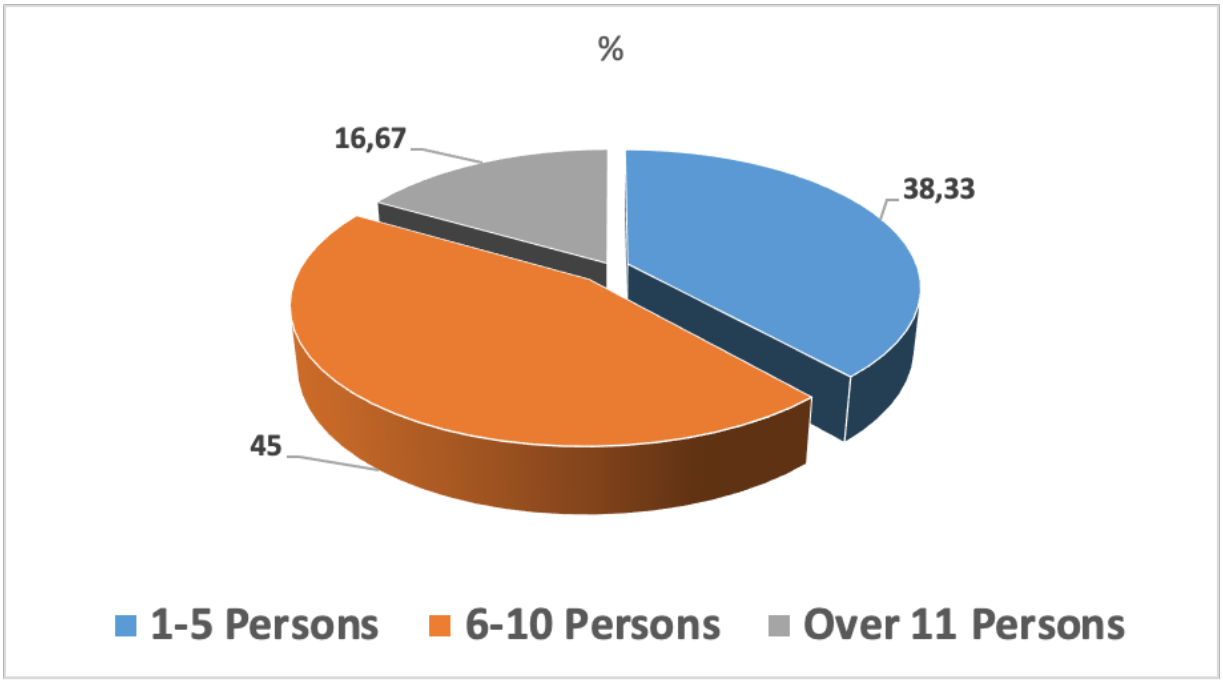

Figure 2. Household size of artisanal fishers in the down-stream area of Taylor Creek

Years of Fishing Experience of Artisanal Fishers

Results shows that majority (42.50%) of the artisanal fishers in the study area had 11-15 years fishing experience, followed by 6-10 years (30.83%), over 16 years (18.33%) and 8.33% alone had 1-5 years of fishing experience (Table 2).

Table 2. Years of fishing experience of artisanal fisher in the down-stream area of Taylor Creek

Year of Experience	Frequency	Percentage (%)
1-5 Yrs.	10	8.33
6-10 Yrs.	37	30.83
11-15 Yrs.	51	42.50
Over 16 Yrs.	22	18.33
Total	120	100.00

Source: Field Survey, 2023-2024.

Weekly Income Generated by Artisanal Fishers

The weekly income generated by artisanal fishers in the study area is shown in Figure 3. Majority (45.83%) of the fishers generated up to #21,000 to #30,000 weekly, followed by #31,000 to #40,000 (35.00%), #10,000 to #20,000 (15.00%) and only 4.17% generated #41,000 to #50,000.

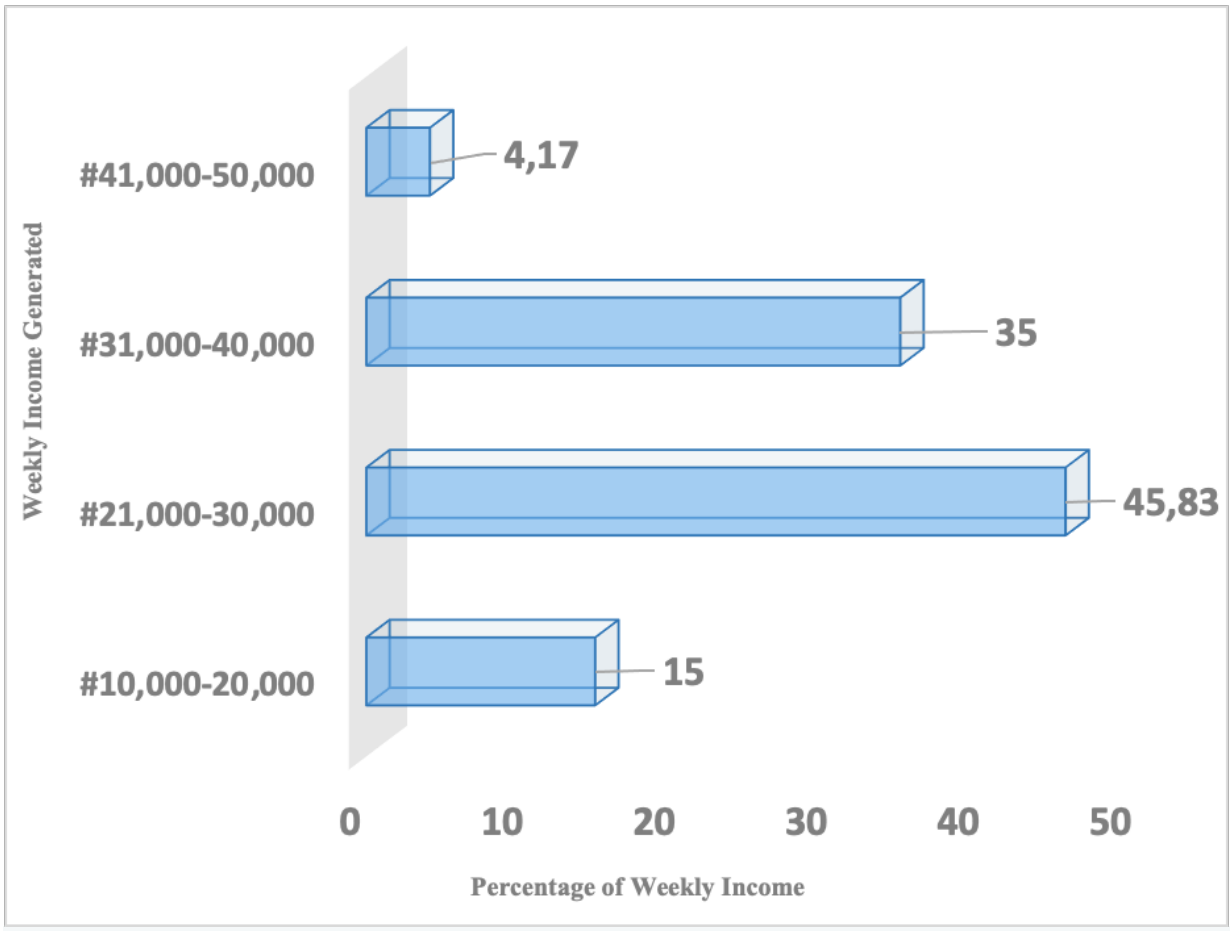

Figure 3. Weekly income generated by artisanal fishers in the down-stream area of Taylor Creek

Effects of Gas Flaring on Fish Catch

Table 3 describes the effects of gas flaring on fish catch in the study area. Out of the artisanal fishers interviewed, majority (46.18%) said gas flaring has resulted to low fish catch in the study area and 1.42% disagree with that view. Few (4.02%) persons said it has led to high fish catch and majority (31.34%) disagreed with that fact, 1.61% said gas flaring has made them to have moderate fish catch and 33.05% disagree with that opinion. All the respondents said that gas flaring has not led to no fish catch (34.19%) in the area for now. In the same vein, all the fishers interviewed unanimously said that gas flaring has resulted to high cost of fish prices in the study area.

Table 3. Effects of gas flaring on fish catch in the down-stream area of Taylor Creek

Effect	Yes	Percentage (%)	No	Percentage (%)
Low fish catch	115	46.18	5	1.42
High fish catch	10	4.02	110	31.34
Moderate fish catch	4	1.61	116	33.05
No fish catch	0	0.00	120	34.19
High cost of fish	120	48.19	0	0.00
Total Number	249		351	

Source: Field Survey, 2023-2024.

Negative Effects of Gas Flaring on Social, Economic and Health of Artisanal Fishers

Table 4 illustrates the multifaceted adverse impacts of gas flaring on the social, economic, and health aspects affecting artisanal fishers in the downstream vicinity of Taylor Creek. The findings reveal a consensus among respondents, with 7.71% unanimously acknowledging the significant reduction in fish catch resulting from gas flaring activities. Additionally, 7.26% of respondents concur that gas flaring indiscriminately leads to fish mortality within the creek, while 5.83% express disagreement with this notion. Notably, 6.87% of artisanal fishers agree that the altered dynamics of the water body due to gas flaring disrupt their fishing schedules, with 10.83% holding a contrary perspective. Furthermore, 6.68% of respondents acknowledge the detrimental effects of gas flaring on the reproductive functions and spawning activities of fish, while 5.00% express disagreement. Migration of fish fauna is also perceived as a consequence of gas flaring, with 6.29% in agreement and 23.33% opposed to this notion. Economically, all respondents (7.71%) unanimously affirm that gas flaring significantly impacts their daily, weekly, monthly, and annual income. Similarly, 7.46% acknowledge the role of gas flaring in causing diseases among both humans and fish, while 3.33% hold a differing perspective. Furthermore, all respondents (7.71%) agree that gas flaring disrupts the primary source of livelihood for fishers, and 7.58% express concerns about the potential extinction of certain fish species due to gas flaring, although 16.67% disagree with this assertion. Socially and economically, respondents unanimously (7.71%) agree that gas flaring imposes hardships on both fishers and the local populace. Moreover, 6.68% of respondents acknowledge the involvement of the ruling class in corrupt practices linked to oil and gas companies, while 13.33% refute this claim. Additionally, 6.04% agree that gas flaring poses risks of human and financial resource losses, with 21.67% holding a differing viewpoint. Concerns about the adverse impact of gas flaring on fishing activities are shared by all respondents (7.71%), while only 0.88% acknowledge its role in ecosystem destruction, and 15.00% contest this assertion.

Table 4. Negative effects of gas flaring on the social, economic and health of artisanal fishers

Effect	Agree	Percentage (%)	Disagree	Percentage (%)
Drastic reduction of fish catch	120	7.71	0	0.00
Causes death of fish in the creek indiscriminately	113	7.26	7	5.83
Fishers don't know the right time to go out for fishing again because it has changed the dynamics of the water body	107	6.87	13	10.83
Destruction of spawning activities and reproductive functions of the fish	104	6.68	6	5.00
Causes migration of fish fauna	98	6.29	28	23.33
Fishers daily, weekly, monthly and annual income is affected	120	7.71	0	0.00
Causes diseases to man and the fish	116	7.46	4	3.33
Fishers source of livelihood is affected	120	7.71	0	0.00
Causes the extinction (disappearance) of some fish species	118	7.58	2	1.67
Causes social and economic hardship to the fishers and the people in the area	120	7.71	0	0.00
Corruption of the ruling class in amassing wealth through collaborations with oil and gas companies	104	6.68	16	13.33
The fishers and people stands to lose both human and financially resources	94	6.04	26	21.67
Fishing is affected in the area	120	7.71	0	0.00
Causes destruction of the ecosystem	102	0.88	18	15.00
Total Number	1,556		120	

Source: Field Survey, 2023-2024

Other Challenges Occasioned by Gas Flaring on Artisanal Fisheries

Table 5 sheds light on additional challenges stemming from gas flaring impacting artisanal fisheries operating in the downstream region of Taylor Creek, Bayelsa State. The results unveil a spectrum of mean values ranging between 3.37 (the lowest) and 4.21 (the highest), derived from respondents' assessments. Notably, the mean scores signify varying degrees of severity attributed to each identified challenge. Among these challenges, the fluctuation of water temperature beyond normal stands at 3.45, indicating a significant concern for fishers. Moreover, the issue of low income rates garners a mean score of 3.85, highlighting the economic repercussions faced by artisanal fishers. Similarly, the destruction of fish size classes receives a mean score of 3.61, reflecting the detrimental impact on fish populations. Additionally, the phenomenon of many artisanal fishers abandoning the fishing sector registers a mean score of 3.93, suggesting the severity of this trend. Moreover, the necessity for artisanal fishers to spend extended hours hunting for fish is underscored by a mean score of 4.21, emphasizing the increased labor intensity imposed by gas flaring. Furthermore, the rapid degradation of fishing implements leading to spoilage is denoted by a mean score of 3.37, signifying material losses incurred by fishers. The destruction of aquatic micro and macro fauna and flora is highlighted by a mean score of 3.87, illustrating the ecological consequences of gas flaring. Finally, the introduction of trace and heavy metals into the creek receives a mean score of 3.43, pointing to environmental contamination concerns. These findings collectively underscore the multifaceted challenges faced by artisanal fisheries in the downstream area of Taylor Creek due to the impacts of gas flaring, necessitating comprehensive mitigation strategies to safeguard both the ecological and socio-economic well-being of the affected communities.

Table 5. Mean responses of artisanal fishers on other challenges occasioned by gas flaring in artisanal fisheries in the down-stream area of Taylor Creek

S/N	Item	SA	A	D	SD	TN	_X	Remark
1	Fluctuation of water temperature beyond normal	67	43	7	3	120	3.45	Agree
		268	129	14	3	414		
2	Low income rate	102	18	0	0	120	3.85	Strongly Agree
		408	54	0	0	462		
3	Destruction of size class of fish	83	31	2	4	120	3.61	Strongly Agree
		332	93	4	4	433		
4	Making many artisanal fishers abandoning the fishing sector	113	6	1	0	120	3.93	Strongly Agree
		452	18	2	0	472		
5	Making artisanal fishers spending more hours in hunting for fish	115	15	0	0	120	4.21	Strongly Agree
		460	45	0	0	505		
6	Fishing implements undergo quick degradation and leading to spoilage	53	62	2	3	120	3.37	Agree
		212	186	4	3	405		
7	Destruction of aquatic micro and macro fauna and flora	105	14	1	0	120	3.87	Strongly Agree
		420	42	2	0	464		
8	Introduction of trace and heavy metals into the creek	66	44	6	4	120	3,43	Agree
		264	132	12	4	412		

Criterion Mean = 2.50

Key: SA = Strongly Agree, A = Agree, SD = Strongly Disagree, D = Disagree, TN = Total Number

Possible Measures to Tackle the Challenges Encountered by Artisanal Fishers

Table 6 presents the collective response of artisanal fishers regarding potential measures aimed at addressing the challenges encountered within the downstream area of Taylor Creek. The findings elucidate a range of mean scores spanning from 3.70 (the lowest) to 4.00 (the highest), derived from the respondents' perspectives. These mean scores provide insights into the perceived efficacy and importance of each proposed measure in mitigating the identified challenges. Among the proposed measures, utilizing gas for either gas injection or gas lift emerges with a mean score of 3.70, highlighting its potential profitability and economic viability compared to gas flaring. Similarly, leveraging gas for electricity generation through cogeneration, gas turbines, and steam turbines garners the highest mean score of 4.00, underscoring its perceived effectiveness in addressing energy needs while minimizing environmental impact. Additionally, liquefying gas for storage in vessels or bottles as liquid natural gas receives a mean score of 3.95, indicating its feasibility as an alternative approach. Furthermore, compressing natural gas to reduce its volume to less than 1% of its standard atmospheric pressure registers a mean score of 3.93, suggesting its potential in facilitating efficient gas management practices. Government provision for the restoration of extraction areas garners a mean score of 4.00, emphasizing the importance of environmental remediation efforts. Similarly, ensuring companies carry out safe and environmentally friendly operations to prevent environmental degradation receives a mean score of 3.98, underscoring the necessity for

responsible industrial practices. Lastly, the implementation of new legislation aimed at environmental preservation, coupled with the recruitment of qualified personnel for enforcement, is highlighted with a mean score of 3.88, signaling the importance of regulatory frameworks and competent oversight in safeguarding the environment and promoting sustainable practices. These findings collectively underscore the significance of adopting multifaceted approaches encompassing technological, regulatory, and environmental restoration strategies to address the challenges faced by artisanal fishers in the downstream area of Taylor Creek.

Table 6. Mean responses of artisanal fishers on possible measures to tackle the challenges encountered by artisanal fishers in the study area

S/N	Item	SA	A	D	SD	TN	_X	Remark
1	Gas should be used for either gas injection or gas lift which is more profitable and economical compared to gas flaring	81	39	0	0	120	3.70	Strongly Agree
		324	117	0	0	441		
2	Gas should be used for electricity generation through the use of cogeneration, gas turbines and steam turbines	120	0	0	0	120	4.00	Strongly Agree
		480	0	0	0	480		
3	To liquefy the gas and stored in vessels or bottles as liquid natural gas	114	6	0	0	120	3.95	Strongly Agree
		456	18	0	0	474		
4	By compressing natural gas to less than 1% of the volume it occupies at standard atmospheric pressure	111	9	0	0	120	3.93	Strongly Agree
		444	27	0	0	471		
5	Government should make provision for the restoration of the extraction areas	120	0	0	0	120	4.00	Strongly Agree
		480	0	0	0	480		
6	Companies should carry out safe and environmentally friendly operation in order to prevent degradation of the environment	118	2	0	0	120	3.98	Strongly Agree
		472	6	0	0	478		
7	New laws should be made in order to preserve the environment and also get more qualified personnel to ensure that the laws are adhered to by the companies	105	15	0	0	120	3.88	Strongly Agree
		420	45	0	0	465		

Criterion Mean = 2.50

Key: SA = Strongly Agree, A = Agree, SD = Strongly Disagree, D = Disagree, TN = Total Number

Discussion

Bio-Data of Artisanal Fishers

The demographic profile of artisanal fishers observed in this study aligns closely with findings reported by several previous studies, including those conducted by Davies and Kwen (2013), Kwen and Nwabeze (2014), Ayanboye and Adedokun (2015), and Aghoghovwia *et al.* (2022). Consistent with these reports, artisanal fisheries emerge as a domain

engaged by individuals of both genders, with a noticeable prevalence of males, particularly within the economically active age bracket of 30 to 39 years. These studies collectively underscore the predominant participation of men in fishing activities, a trend that resonates with the observations made in the present study. Notably, the work of Kwen and Nwabeze (2014) accentuates the significant role played by women in the artisanal fisheries sector, emphasizing their active involvement in fish processing, marketing, and various social aspects related to fisheries within Nigerian fishing communities (Odubo, 2019a, b; Odubo *et al.,* 2019; Odubo and Anele, 2019; Raimi and Odubo, 2022; Raimi*et al.,* 2022f, g). This acknowledgment of women's contributions underscores the multifaceted nature of artisanal fishing activities, wherein both men and women play integral roles across different facets of the industry. Such insights underscore the importance of recognizing and valuing the diverse contributions of both genders within the artisanal fisheries sector, thereby fostering a more inclusive and equitable approach to fisheries management and development initiatives.

The prevalence of male fishers dominating the downstream region of Taylor Creek can be attributed to the influence of gender disparities in occupational choices, particularly within the fishing and fish farming sectors in this locale. This gender disparity arises due to the demanding nature of active fishing operations compared to passive fishing endeavors, where the labor intensity involved tends to favor male participation. These findings echo the observations of Tagago *et al.* (2011), Davies and Kwen (2013), and Ayanboye and Adedokun (2015), who similarly noted that fishing activities predominantly attract individuals within the age range of 30 to 40 years. This age distribution may stem from the inherent attributes of younger individuals, who exhibit higher levels of enthusiasm for exploring new practices in fisheries and fishing operations. Additionally, their mental acuity and receptiveness to innovative ideas in fishing gear development techniques contribute to their active engagement in the industry. The significant representation of married fishers observed in the study area mirrors the findings of Kwen *et al.* (2013) and Aghoghovwia *et al.* (2022), who documented a similar trend in the artisanal fisheries sector. This phenomenon could be attributed to the greater responsibilities and obligations typically borne by married individuals, as they navigate familial duties and financial commitments. Furthermore, the prevalence of artisanal fishers with primary and secondary education aligns with the observations of Adeparusi *et al.* (2003). This relatively high level of literacy among fishers in the study area empowers households with the capacity to implement effective income diversification strategies, thereby mitigating income fluctuations, averting income failures, and alleviating poverty within these communities. Such insights underscore the complex interplay of socio-economic factors shaping the occupational landscape of artisanal fisheries and highlight the importance of addressing gender disparities and promoting educational opportunities to foster inclusive and sustainable livelihoods within these communities.

Effects of Gas Flaring on Artisanal Fisheries

The findings of this study corroborate with the research findings of Omohimoria*et al.* (2014) and Udok and Akpan (2017), both of whom underscored the detrimental impact of gas flaring on the aquatic environment. Such adverse effects encompass the destruction of freshwater ecological systems, depletion of aquatic fauna, as well as socio-economic hardships and the loss of vital fishing grounds. Further validating these observations, an impact assessment conducted by Powell and White (1985) following the 1983 Oshika gas flare incident in Rivers State confirmed severe consequences, including the demise of floating and submerged aquatic vegetation such as water lettuce, along with mortality among fin

and shellfish, mangrove forest devastation, and detrimental effects on aquatic bird populations. Additionally, the development initiatives within the region have contributed to site degradation, diminishing their ecological value and utility. Supporting evidence from Ubani and Onyejekwe (2013) and Uwem and Enobong (2017) further underscores the multifaceted nature of gas flaring's impacts, with emphasis placed on environmental, health, and various other implications. These scholars highlight the far-reaching consequences of gas flaring beyond ecological degradation, encompassing adverse effects on human health and socio-economic well-being. Such comprehensive assessments underscore the urgent need for holistic approaches to address the challenges posed by gas flaring, encompassing environmental protection, public health interventions, and sustainable development strategies. These collective insights underscore the imperative for concerted action to mitigate the adverse effects of gas flaring and promote the sustainable management of natural resources in affected regions.

Over the past five decades, the persistent practice of gas flaring and venting associated with petroleum exploration and production activities in the Niger Delta region of Nigeria has perpetuated a multitude of complex consequences across various dimensions including energy, natural environment, socio-economic landscape, human health, and sustainable development. The prevalence of flaring gas has inflicted significant suffering and destruction upon human populations, flora, and fauna alike. Studies conducted by Kindzierski *et al.* (2000) and Ozogu-Agbe *et al.* (2020) have illuminated the detrimental effects of gas flaring in the Niger Delta, specifically noting adverse changes in the hematological attributes of aquatic organisms. These alterations, including negative impacts on blood and blood-forming cells, have been implicated in conditions such as aplastic anemia, pancytopenia, and leukemia. Beyond the immediate health and environmental ramifications, the nation also faces substantial economic losses, with billions of dollars' worth of gas wasted through routine flaring, literally incinerated into the atmosphere on a daily basis. This squandered resource could be harnessed for domestic consumption and electricity generation, potentially alleviating the nation's chronic energy deficits (Ebuete *et al.,* 2019; Ajayi *et al.,* 2020). Efforts directed towards gas utilization for power generation have the potential to significantly bolster electricity production (Gift and Olalekan, 2020; Gift *et al.,* 2020), thereby bridging the gap between supply and national demand. As underscored by Effiong and Etowa (2012), Nigeria has incurred considerable revenue losses as a direct consequence of gas flaring and oil spillages, further exacerbating economic challenges and hindering national development efforts. These revelations underscore the urgent imperative for comprehensive measures aimed at curbing gas flaring, optimizing resource utilization, and mitigating the far-reaching impacts on human health, environmental integrity, and economic sustainability within the Niger Delta region and beyond.

The investigation conducted in the study area unveiled the profound economic hardships inflicted upon its inhabitants by the practice of gas flaring. This observation resonates strongly with the findings documented by Arowolo and Adaja (2011), who similarly highlighted the adverse economic consequences associated with gas flaring in affected regions. Moreover, the research conducted by Osuagwu and Olaifa (2018) underscored the detrimental impact of environmental contamination resulting from gas flaring on fishing activities, manifesting in various detrimental outcomes such as fish mortality, depletion of fish stocks, reduced catch rates, and even prompting some fishers to discontinue their fishing endeavors altogether. Bayode *et al.* (2011) further corroborated these assertions, emphasizing the deleterious effects of gas flaring on aquatic ecosystems, including the pollution of water bodies (Morufu and Clinton, 2017; Raimi and Sabinus,

2017; Olalekan *et al.,* 2018; Odipe *et al.,* 2018; Raimi *et al.,* 2019c; Henry *et al.,* 2019; Biney, 2019; Olalekan *et al.,* 2020; Gift and Olalekan, 2020; Raimi *et al.,* 2021b; Afolabi and Raimi, 2021; Olalekan *et al.,* 2022b; Raimi and Sawyer, 2022; Raimi *et al.,* 2022a, b, c, Olalekan *et al.,* 2023; Raimi *et al.,* 2023), destruction of fish habitats (Ayibatonyo *et al.,* 2024a, b), and the degradation of mangrove forests (Olalekan *et al.,* 2019b, c; Olalekan *et al.,* 2021; Raimi *et al.,* 2022d, e; Sylvester *et al.,* 2023; Saliu *et al.,* 2023). Additionally, Bayode *et al.* (2011) highlighted the consequential decline in fish production and the abandonment of fishing grounds in Ondo State, further exacerbating the challenges faced by artisanal fishers and compromising their livelihoods. The repercussions of diminished fish production extend beyond economic concerns, posing a significant threat to the sustainability of fishing activities and the well-being of communities reliant on them. As articulated by Chijioke *et al.* (2018), the contamination of aquatic environments compels artisanal fishers in affected communities to forsake their traditional livelihoods, abandoning their fishing equipment, canoes, and even farmlands in search of alternative sources of income. This cascade of adverse effects underscores the urgent need for comprehensive interventions aimed at mitigating the impacts of gas flaring on both the economic viability and environmental integrity of affected regions. Such initiatives should prioritize the restoration of aquatic ecosystems, support for alternative livelihoods, and sustainable resource management practices to safeguard the welfare of communities' dependent on artisanal fisheries.

In addition to gas flaring, Osuagwu and Olaifa (2018) elucidated a myriad of other environmental factors that significantly impede fishing activities within aquatic environments. These factors encompass incidents such as oil well blowouts, pipeline seepages, and the inadequate disposal of drilling fluids. Furthermore, Ana *et al.* (2009) conducted a comprehensive study in the Eleme and Ahoada East areas of Rivers State, Nigeria, aimed at evaluating the prevalence of health consequences associated with exposure to various environmental risk factors stemming from oil pollution and gas flare incidents. Their findings underscored a stark discrepancy in morbidity rates between the two communities, with Eleme exhibiting notably higher incidences compared to Ahoada East. The documented morbidity cases encompassed a spectrum of health ailments, including skin diseases, respiratory disorders, and cancer. These revelations serve to underscore the profound health and environmental ramifications stemming from not only gas flaring but also the broader spectrum of environmental hazards prevalent within oil-producing regions. Such insights underscore the imperative for robust regulatory measures, effective environmental management strategies, and comprehensive health interventions to mitigate the adverse impacts on both human health and ecological integrity within affected communities.

Possible Measures to Tackle the Challenges Encountered by Artisanal Fishers

The potential measures identified to address the challenges confronted by artisanal fishers, as documented in this study, closely align with the recommendations put forth by Ozogu-Agbe *et al.* (2020) and Ajayi *et al.* (2020). These proposals advocate for governmental intervention aimed at intensifying strategic efforts to convert flared gases into viable resources, such as cooking/domestic gas and electricity generation. Similarly, the suggestions echo the sentiments expressed by Ibrahim *et al.* (2009), emphasizing the utilization of gas for purposes such as gas injection or gas lift, known for their profitability and economic viability compared to conventional gas flaring practices. Additionally, the utilization of gas for electricity generation through cogeneration, gas turbines, and steam turbines emerges as a pragmatic solution, in line with

the imperative to maximize energy efficiency and minimize environmental impact. Moreover, the proposals underscore the importance of liquefying gas for storage as liquid natural gas, as well as compressing natural gas to facilitate efficient utilization. Furthermore, the imperative for governmental provision for the restoration of extraction areas and the implementation of stringent regulations to ensure safe and environmentally friendly operations by companies are emphasized. These measures not only aim to mitigate environmental degradation but also seek to uphold ecological integrity and safeguard the well-being of local communities. Additionally, the global initiative spearheaded by the World Bank, in collaboration with countries, oil companies, and development institutions through the Global Gas Flaring Reduction Partnership, underscores the collective efforts towards mitigating the impact of gas flaring on a global scale. This collaborative endeavor aims to explore avenues for conserving gas resources, creating markets for its sale, or promoting its utilization in environmentally friendly applications. Such concerted efforts signify a paradigm shift towards sustainable resource management practices and underscore the imperative for global cooperation in addressing the challenges posed by gas flaring.

Conclusion

The environmental ramifications of gas flaring in the downstream area of Taylor Creek are profound and far-reaching. This study unequivocally demonstrates that gas flaring has precipitated a myriad of environmental crises, including the pollution of creek water, widespread ecosystem degradation, and mass mortality among fish and other aquatic organisms. The observed deterioration of the ecosystem underscores a concerning trend exacerbated by the lax enforcement of existing environmental protection laws and regulations. The failure of governmental bodies to ensure stringent compliance with these regulations has further compounded the pollution of the downstream area of Taylor Creek, perpetuating ecological imbalances and undermining the region's environmental integrity. Conclusively, the study advocates for a multifaceted approach to mitigate the environmental pollution resulting from gas flaring activities in the study area. It is recommended that the gas currently being flared be utilized more efficiently and sustainably. Specifically, gas injection or gas lift techniques should be prioritized due to their enhanced profitability and economic viability compared to traditional flaring practices. Furthermore, gas should be harnessed for electricity generation through cogeneration, employing gas turbines and steam turbines to maximize energy output.

Additionally, efforts should be directed towards liquefying gas and storing it in vessels or bottles as liquid natural gas, as well as compressing natural gas to occupy less than 1% of its volume at standard atmospheric pressure. These methods offer efficient means of storage and transportation, minimizing waste and environmental impact. Moreover, governmental intervention is imperative to facilitate the restoration of extraction areas affected by gas flaring activities. Strict enforcement of environmental regulations is essential to compel companies to undertake safe and environmentally friendly operations, thereby preventing further degradation of the environment. Finally, the enactment of new legislation aimed at preserving the environment and bolstering regulatory oversight is crucial. Strengthening the enforcement capacity through the recruitment of qualified personnel is essential to ensure compliance with environmental laws by companies operating in the region. By implementing these comprehensive measures, significant strides can be made in

curbing the environmental pollution associated with gas flaring activities in the study area, fostering a more sustainable and ecologically resilient environment for present and future generations.

Recommendations

Based on the research findings, the following recommendations are put forth:

1. Implementation of Modernized Technologies: Oil companies should adopt advanced technologies aimed at minimizing the release of pollutants into the environment, thereby reducing environmental degradation.
2. Enforcement of Environmental Laws: The government should rigorously enforce existing environmental laws and regulations. Additionally, there should be a review and adjustment of these regulations to incorporate innovative methods and practices employed in environmentally conscious countries such as Saudi Arabia, Russia (Siberia), United States (Texas), Venezuela (Orinoco Belt), Canada and Norway.
3. Enhancement of Corporate Social Responsibility (CSR) or Creating Shared Value (CSV): Oil companies should enhance their Corporate Social Responsibility initiatives to better address the socioeconomic needs of the local communities affected by their operations.
4. Establishment of Independent Environmental Regulatory Body: There is a need for the establishment of an independent regulatory body specifically dedicated to overseeing environmental matters within the oil and gas industry. This body should operate autonomously from entities like the Department of Petroleum Resources and the Nigerian National Petroleum Corporation.
5. Implementation of Greenhouse Emission Regulations: Stringent regulations should be instituted to monitor and regulate the greenhouse gas emissions resulting from gas flaring activities conducted by oil companies.
6. Public Awareness Campaigns: Public enlightenment campaigns should be conducted to educate individuals about the adverse impacts of operations such as gas flaring on human health and the environment. Many individuals may not fully comprehend the risks associated with these activities.
7. Inclusion of Gas Storage Facilities in Contracts: The government should mandate the inclusion of provisions for the construction of gas storage facilities in contracts with International Oil Companies (IOCs) and other oil-producing entities. This initiative can help address the electricity shortage in the country by utilizing gas for power generation.

By implementing these recommendations, stakeholders can collectively work towards mitigating the environmental and socioeconomic challenges associated with oil and gas operations, fostering a more sustainable and equitable future for all.

Statements and Declarations

Conflict of interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgments

This manuscript did not receive any specific grant from any funding agencies. Authors are thankful to Federal University Otuoke for providing all necessary administrative supports.

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