

Assessing Pollution Sources and Impacts in Gbarnga: A Case Study of Barwrór and Kortu Quarters

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Abstract:- The rapid urbanization and industrialization of Gbarnga have brought forth significant environmental challenges, including pollution. This study, titled "Assessing Pollution Sources and Impacts in Gbarnga: A Case Study of Barwrór and Kortu Quarters," aims to investigate public awareness and participation in pollution reduction initiatives within these communities.

The background of the study encompasses the pressing need to address pollution in urban areas like Gbarnga, where industrial activities and urbanization have intensified environmental pressures. Previous research has highlighted the detrimental effects of pollution on public health, ecosystem integrity, and overall well-being, emphasizing the urgency of proactive measures to mitigate pollution levels.

The objectives of this research include assessing the level of public awareness regarding environmental regulations and policies aimed at pollution reduction, as well as gauging community willingness to participate in pollution reduction initiatives. Additionally, the study seeks to identify factors influencing public engagement in environmental actions and to provide recommendations for enhancing community involvement in pollution mitigation efforts.

The findings reveal a significant gap in public awareness of environmental regulations and policies, with just over half of the population informed about such initiatives. However, there exists a strong willingness among community members to actively engage in pollution reduction initiatives, with over 97% expressing readiness to participate. Further statistical analysis indicates a moderate level of public awareness regarding pollution-related issues, underscoring the need for targeted educational campaigns and enhanced communication strategies.

In conclusion, the study emphasizes the importance of strengthening communication channels, launching educational campaigns, fostering inclusive community engagement, encouraging community-research partnerships, and integrating public awareness initiatives into environmental policy frameworks. These recommendations aim to empower communities to actively participate in pollution reduction efforts, ultimately contributing to the attainment of sustainable

environmental goals in Gbarnga and similar urban settings.

I. INTRODUCTION

A. Background of Gbarnga City, Bong County, Liberia

Gbarnga City serves as the capital of Bong County, one of the 15 counties in Liberia, a country situated in West Africa. Understanding the background of Gbarnga City is crucial for comprehending the socio-economic and environmental dynamics that influence pollution within the urban landscape.

Historically, Gbarnga City has a rich historical background, closely tied to Liberia's history as a nation founded by freed African-American slaves in the early 19th century. Initially established as a settlement for repatriated African-Americans, Liberia underwent periods of colonization and territorial expansion. Gbarnga evolved from a small settlement to a significant urban center over time. The City is strategically located in the central region of Liberia, within Bong County. Its geographical position contributes to its importance as a transportation hub and a commercial center. Situated amidst lush greenery and tropical forests, the city experiences a humid tropical climate with distinct wet and dry seasons.

Over the years, Gbarnga City has experienced significant urban development driven by population growth, economic activities, and infrastructural expansion. The city's development trajectory reflects both challenges and opportunities associated with rapid urbanization in a developing country context.

Gbarnga City serves as a commercial and economic hub in Bong County, hosting various businesses, markets, and institutions. Agriculture, trade, and small-scale industries play crucial roles in the city's economy, providing livelihood opportunities for its residents. Additionally, Gbarnga's strategic location along major transportation routes facilitates trade and commerce. The City is characterized by its diverse population, consisting of indigenous Liberians, settlers, and ethnic groups from across the country. This cultural diversity contributes to the city's vibrant social fabric, reflected in its traditions, languages, and customs. Additionally, Gbarnga serves as an educational center, hosting schools, colleges, and vocational training institutions.

Understanding the background of Gbarnga City provides essential context for analyzing the factors influencing pollution within the urban environment. By examining the city's historical, geographical, economic, and social dimensions, researchers can gain insights into the complex interplay of factors shaping pollution dynamics and inform targeted interventions for sustainable urban development.

A. Significance of Studying Pollution in Urban Areas

The significance of studying pollution in urban areas is multifaceted and underscores the urgent need for effective environmental management strategies. Several key points highlight the importance of this endeavor: Pollution in urban areas poses significant risks to public health. Poor air quality, contaminated water sources, and exposure to hazardous chemicals contribute to a range of health problems, including respiratory diseases, cardiovascular issues, and increased mortality rates. Understanding the sources and impacts of pollution is essential for protecting public health and promoting well-being in urban communities.

Urban pollution contributes to environmental degradation, affecting ecosystems, biodiversity, and natural resources. Pollution from industrial activities, transportation, and waste disposal harms soil quality, water bodies, and vegetation, leading to habitat destruction and loss of biodiversity. Studying pollution in urban areas is critical for mitigating these environmental impacts and preserving ecological balance. Pollution imposes significant socioeconomic costs on urban communities, including healthcare expenditures, reduced productivity, and damage to infrastructure. The economic burden of pollution disproportionately affects marginalized populations and exacerbates social inequalities. By assessing the economic implications of pollution, policymakers can prioritize interventions that promote sustainable development and equitable access to resources.

In summary, studying pollution in urban areas is essential for safeguarding public health, protecting the environment, promoting socioeconomic development, mitigating climate change, informing policy decisions, and empowering communities. By addressing the complex challenges of urban pollution, stakeholders can work towards creating sustainable, livable cities that prioritize the well-being of present and future generations.

B. Objectives

- To identify the primary sources and drivers of pollution in Barror Quarter and Kortu Quarter.
- To assess the environmental, health, and socioeconomic impacts of pollution on residents of the two quarters.

C. Research Questions

- What are the main sources of pollution in Barror Quarter and Kortu Quarter, and how do they contribute to environmental degradation?

- How does pollution impact the health and well-being of residents in the two quarters, and are certain demographic groups more vulnerable to its effects?

II. LITERATURE REVIEW

A. Definition and Types of Pollution

Pollution is commonly defined as the introduction of harmful or undesirable substances into the environment, resulting in adverse effects on ecosystems, human health, and well-being (Sawyer et al., 2002). It encompasses a wide range of pollutants, including gases, particulate matter, chemicals, and biological agents, which contaminate air, water, soil, and other environmental components (Baldasano et al., 2014).

There are several types of pollution, each characterized by its sources, pathways, and impacts on the environment and human health. Air pollution, for instance, refers to the presence of harmful substances in the atmosphere, such as nitrogen oxides (NO_x), sulfur dioxide (SO₂), carbon monoxide (CO), and particulate matter (PM), emitted from industrial processes, vehicle exhausts, and combustion activities (Kampa & Castanas, 2008). These pollutants can cause respiratory diseases, cardiovascular disorders, and adverse effects on vegetation and ecosystems (Lelieveld et al., 2015).

Water pollution occurs when contaminants are introduced into water bodies, such as rivers, lakes, and oceans, compromising water quality and rendering it unsafe for human consumption, aquatic life, and recreational activities (Schindler, 2006). Common sources of water pollution include industrial discharges, agricultural runoff, sewage effluents, and oil spills, which can lead to eutrophication, habitat destruction, and the spread of waterborne diseases (Huang et al., 2019).

Soil pollution involves the accumulation of toxic substances in the soil, resulting from industrial activities, improper waste disposal, and chemical contamination (Alloway, 2013). Heavy metals, pesticides, and industrial chemicals are among the pollutants that can degrade soil quality, reduce agricultural productivity, and pose risks to human health through food chain contamination (Kabata-Pendias, 2010).

Noise pollution, another form of environmental pollution, refers to excessive or unwanted sound levels that disrupt human activities, disturb wildlife, and impair communication and hearing (Basner et al., 2014). Sources of noise pollution include transportation systems, industrial machinery, construction activities, and urban development, which can lead to stress, sleep disturbances, and adverse effects on psychological well-being (Guski et al., 2017).

Lastly, light pollution results from the excessive or misdirected use of artificial light, leading to the illumination of the night sky and the obscuring of celestial objects (Gaston et al., 2014). Urbanization, outdoor lighting, and advertising signage contribute to light pollution, disrupting natural

ecosystems, altering circadian rhythms, and affecting wildlife behavior and migration patterns (Gaston et al., 2015).

B. Factors Influencing Pollution in Urban Areas

Urban areas are characterized by diverse activities and processes that contribute to pollution, impacting environmental quality and public health. Understanding the factors influencing pollution in urban areas is essential for devising effective mitigation strategies and promoting sustainable urban development. This section discusses key factors influencing pollution in urban areas based on previous research findings. Industrial activities, including manufacturing, processing, and energy production, are significant sources of pollution in urban areas (OECD, 2019). Emissions from industrial facilities, such as factories and power plants, release pollutants such as particulate matter (PM), sulfur dioxide (SO₂), nitrogen oxides (NO_x), and volatile organic compounds (VOCs) into the atmosphere (Gurjar et al., 2016). Industrial pollution contributes to air and water contamination, soil degradation, and ecosystem disruption, affecting both urban and surrounding rural areas (Han et al., 2019).

We have and continue to see that systems, such as vehicles, airplanes, trains and ships contribute significantly to urban pollution. The Combustion of fossil fuels in vehicles releases air pollutants such as carbon monoxide (CO), nitrogen dioxide (NO₂), and particulate matter (PM), contributing to poor air quality and respiratory health problems (WHO, n.d.). Traffic jamming, ineffective public transportation, and old cars worsen pollution that comes as result of transportation in urban areas like Monrovia, the capitol of Liberia, and more traffic congested city than Gbarnga.

Domestic activities are important contributors to urban pollution and also represent significant energy use and resource consumption. Urban households generate approximately 7 million tonnes of solid waste annually and consume about 40% of national energy use. In recent decades, pollution concerns have shifted from localized, noticeable problems such as industrial smog and river contamination to more diffuse and complex contaminants such as acid rain and toxic air and land pollutants. Urban pollution has been perceived as a less important environmental issue than rural or wilderness problems, and yet it is increasingly realized that much of the pollution burden that afflicts rural areas and ecosystems is generated in urban areas. This includes "natural" resources such as clean water and clean air, which are often transported into urban areas, used and contaminated, and then returned to rural environments where they cause problems in downstream ecosystems. The nature of domestically derived pollution and the pollution trajectory process has strong implications for mobilizing community-based mitigation strategies and generating multiple co-benefits for public and environmental health. (Sharma & Jain, 2020). Burning of solid fuels such as biomass, coal, and charcoal for cooking and heating purposes releases indoor air pollutants such as carbon monoxide (CO), particulate matter (PM), and volatile organic compounds (VOCs), posing health risks to occupants (He et al., 2015).

Socioeconomic factors, including income inequality, education levels, and access to resources, influence pollution levels and exposure risks in urban areas (Sarkar et al., 2018). Low-income communities often bear a disproportionate burden of pollution due to the location of hazardous facilities, lack of environmental regulations, and limited access to healthcare services (Bullard & Wright, 2019). Environmental justice concerns underscore the need for equitable distribution of environmental benefits and burdens in urban planning and policy-making processes (Schlosberg & Collins, 2014).

In summary, multiple factors influence pollution in urban areas, including industrial activities, transportation emissions, domestic practices, land use patterns, and socioeconomic disparities. Addressing these factors requires integrated approaches that consider environmental, social, and economic dimensions of urban development, aiming to promote environmental health, equity, and resilience in urban communities.

III. METHODOLOGY

The research design incorporates a mixed-methods approach, purposive sampling, diverse data collection methods, rigorous data analysis techniques, and ethical considerations to investigate pollution in Barror Quarter and Kortu Quarter comprehensively. By employing a systematic and structured approach, the study aims to generate evidence-based insights that inform pollution management strategies and contribute to environmental sustainability in urban communities.

A. Sampling Technique

The sampling technique employed in the study on pollution in Barror Quarter and Kortu Quarter in Gbarnga City, Bong County, Liberia, is crucial for ensuring the representation and relevance of the data collected. Given the diverse nature of the study area and the need to capture various perspectives on pollution issues, a purposive sampling technique will be utilized.

Purposive sampling involves the deliberate selection of participants or sites based on specific criteria relevant to the research objectives (Palinkas et al., 2015). In the context of this study, purposive sampling allows for the targeted selection of individuals and locations that are most pertinent to understanding pollution sources, impacts, and mitigation strategies in Barror Quarter and Kortu Quarter.

B. Data Collection Methods

The study on pollution in Barror Quarter and Kortu Quarter in Gbarnga City, Bong County, Liberia, employed a combination of data collection methods to gather comprehensive and diverse information on pollution sources, impacts, and mitigation strategies. The selected data collection methods include interviews, surveys, and observations, each serving a specific purpose in addressing the research objectives.

C. Data Analysis Approach

The data analysis approach for the study on pollution in Barror Quarter and Kortu Quarter in Gbarnga City, Bong County, Liberia, will involve systematic and rigorous

methods to analyze the qualitative and quantitative data collected through interviews, surveys, and observations. The analysis aims to derive meaningful insights, identify patterns, and address the research objectives effectively.

D. Data Analysis, Presentation and Discussion

Table 1: Provides Insights into the Demographic Composition of the Population under Study. Here's an Interpretation of the Data

Category	Range	Frequency	Percent	Cumulative Percent
Age Range	18-25			22.67%
	26-40			57.33%
	41-50			84.00%
	51+			100.00%
Gender	Female	99	66.00%	66.00%
	Male	51	34.00%	100.00%
Household Size	1	10	6.67%	6.67%
	2	37	24.67%	31.33%
	3	16	10.67%	42.00%
	4	21	14.00%	56.00%
	5	14	9.33%	65.33%
	6	16	10.67%	76.00%
	7	14	9.33%	85.33%
	8	9	6.00%	91.33%
	9	2	1.33%	92.67%
	10	2	1.33%	94.00%
	11	1	0.67%	94.67%
	12	1	0.67%	95.33%
	13	2	1.33%	96.67%
	16	1	0.67%	97.33%
18	1	0.67%	98.00%	
20	1	0.67%	98.67%	
25	1	0.67%	99.33%	
32	1	0.67%	100.00%	
Education Level	None	81	54.00%	54.00%
	Primary	52	34.67%	88.67%
	Secondary	16	10.67%	99.33%
	Tertiary	1	0.67%	100.00%
TOTAL		150	100.00%	100.00%

The data presented from Table 1 reveals several compelling aspects of the demographic composition of the study population that merit a detailed discussion within the context of broader research findings and implications. It is, however, crucial to address a likely clerical error in the reported percentages for age groups, where ages 41 to 50 are mistakenly reported as constituting 84.00% of the population. This figure is not feasible given the other percentages provided. Assuming this to be a typographical error, let us proceed with an analysis that abstracts from this inconsistency.

E. Age Range Analysis

The distribution indicating a predominant age range of 26 to 40 years (57.33%) suggests that the population under study is largely composed of young adults to middle-aged individuals. This age demographic is often associated with active labor force participation and, in many societies, constitutes a significant portion of the parental demographic.

When comparing these findings with existing literature, it is evident that the implications for socio-economic research are profound, particularly in understanding workforce dynamics, consumer behavior, and family planning trends. Previous studies have shown that populations with a larger proportion of individuals in this age bracket can have varying impacts on economic growth, depending on factors like employment rates, productivity, and the balance between dependents and working-age individuals (Bloom et al., 2015).

F. Gender Disparity

The pronounced gender imbalance, with females representing 66.00% of the population and males 34.00%, offers a significant avenue for gender studies. Such disparities might influence the study's outcomes, especially if the research touches on areas directly affected by gender distribution, such as health care accessibility, employment opportunities, and education. Literature on gender disparities often discusses the implications of such imbalances on

societal structures, policy-making, and resource allocation (Doyal, 2000).

G. Household Size Dynamics

The predominance of households with 2 to 4 members aligns with global trends towards smaller family units, reflecting socio-economic factors including urbanization, increased cost of living, and changing societal norms regarding family size (Nations, 2019). The implications of these findings on consumption patterns, housing market demands, and social services are substantial, necessitating further exploration within the specific context of the study's geographic and cultural setting.

H. Educational Attainment

The distribution of educational attainment, particularly the high percentage of individuals with no formal education (54.00%), poses critical questions regarding access to education, literacy rates, and long-term socio-economic development. This contrasts starkly with global efforts and

progress in improving educational access and attainment as delineated in the Sustainable Development Goals (United Nations). The low percentage of individuals with tertiary education (0.67%) further accentuates the educational gap, potentially limiting the population's access to high-skilled employment opportunities and contributing to broader socio-economic implications.

In conclusion, while the demographic composition provided offers a rich ground for analysis, it is paramount that the data be scrutinized for accuracy, especially regarding the reported percentages. Assuming the data's integrity, except for the noted discrepancy, the findings offer a basis for in-depth discussions on socio-economic dynamics, policy implications, and future research directions. Further studies might consider comparative analyses with populations of different demographic compositions to elucidate the impacts of age, gender, household size, and education level on various socio-economic outcomes.

Table 2: Average Household Size

HHS											
	Obs	Total	Mean	Var	Std Dev	Min	25%	Median	75%	Max	Mode
HHS	150	750	5.0000	17.9195	4.2331	1.0000	2.0000	4.0000	6.0000	32.0000	2.0000

The statistical delineation provided in Table 2 yields an intriguing narrative about the living arrangements within the surveyed population, underscoring the heterogeneity and complexity of household composition. The mean household size of 5.00, juxtaposed against a wide-ranging variance and standard deviation, highlights not only the prevalence of larger family units but also the significant diversity in household sizes. This is emblematic of a multifaceted societal structure where traditional extended families may coexist with a myriad of other living arrangements.

The reported variance and standard deviation are pivotal for understanding the dispersion within the dataset. The pronounced variance suggests a substantial spread in household sizes, implying that the population does not conform to a homogenous pattern in terms of living arrangements. This is further substantiated by the maximum reported household size of 32, which, while an outlier, signifies the presence of extremely large households that could be indicative of multigenerational living situations or communal housing setups. Such outliers, while skewing average metrics, are critical for acknowledging the full spectrum of societal norms and living conditions within the study's demographic.

The quartile distribution and the median household size of four individuals offer a granular perspective on the population's distribution, indicating that a significant fraction of the population resides in moderately sized households. This median value, when viewed in concert with the 25th and 75th percentiles, outlines a societal trend where half of the population exists within a range of smaller to medium-sized living units, highlighting a potential inclination towards nuclear family setups or equivalent living arrangements.

The mode of 2 underscores the prevalence of two-person households, a finding that, while seemingly at odds with the average household size, illuminates the diversity of household configurations prevalent within the community. This suggests the existence of a considerable demographic segment that either prefers or is necessitated to live in smaller units, possibly reflecting economic, cultural, or demographic factors influencing living arrangements.

In juxtaposition with broader demographic trends, these findings reveal significant insights into the socio-economic and cultural underpinnings of the population. Comparatively, regions with lower average household sizes may reflect different socio-economic structures, cultural norms, or stages of demographic transition. The statistical measures provided—mean, variance, standard deviation, and the distribution across quartiles—serve as a rich tapestry for understanding the complexities of household composition, offering a nuanced lens through which to examine societal norms and living arrangements.

Such detailed statistical analysis, especially the consideration of outliers and the range of household sizes, emphasizes the importance of adopting a holistic approach when interpreting demographic data. Understanding the dynamics of household composition within the context of existing literature on family structures and living arrangements can enrich our comprehension of social fabric and the myriad factors that influence it. This analysis not only contributes to the academic discourse on household demographics but also offers a foundational basis for policy formulation, urban planning, and social services delivery, aimed at accommodating the diverse needs of the population.

Table 3: Overall Air Quality

Responses	Freq.	Per	Cum. Per	Exact 95% LCL	Exact 95% UCL
Excellent	1	0.67	0.67	0.02	3.66
Fair	6	4.00	4.67	1.48	8.50
Good	9	6.00	10.67	2.78	11.08
Poor	77	51.33	62.00	43.05	59.57
Very poor	57	38.00	100.00	30.21	46.28
TOTAL	150	100.00	100.00		

Table 3 presents the results of a question from a survey or questionnaire, labeled "overall air quality," which likely refers to the overall air quality perception in a specific area. The table breaks down the responses into five categories: Excellent, Fair, Good, Poor, and Very Poor. For each category, it provides the frequency (number of responses), percentage of the total responses, cumulative percentage, and the exact 95% lower confidence limit (LCL) and upper confidence limit (UCL). Here's an analysis and interpretation of the key findings:

I. Interpretation

The data clearly indicates a prevalent concern regarding air quality among the respondents, with the overwhelming majority rating it as "Poor" or "Very Poor." This negative perception could be indicative of significant air pollution issues in the area, affecting the residents' quality of life and potentially their health.

The minimal positive responses ("Excellent" and "Good") highlight a critical need for intervention to improve air quality, as they suggest that satisfactory air conditions are currently perceived to be almost non-existent.

The confidence intervals provide a statistical basis for the reliability of these findings, though they also underscore the presence of some uncertainty, as is typical in survey data. The wide range in some of the confidence intervals, particularly in categories with fewer responses ("Excellent" and "Fair"), reflects greater variability and less certainty about the exact proportion of the population holding these views.

The results from the OAQ survey, which indicates a predominantly negative perception of air quality, can be contextualized within the broader discourse on air quality perception research. A study focusing on Portuguese citizens' perception of air quality revealed significant concern about air pollution, particularly among sub-populations from urban-industrial areas who have experienced frequent air pollution

events. This study found that 61% of the urban-industrial sub-population rated local air quality as poor or very poor, compared to only 14% in the general population. This disparity underscores the influence of direct experience and awareness on public perception of air quality (Canha et al., 2022).

Moreover, the study highlighted a gap in knowledge about air pollutants, with 50% of the general population unable to identify any air pollutants. This lack of awareness could contribute to misperceptions about air quality levels and the sources of pollution. The study emphasized the need for increased public education and awareness efforts to improve understanding and engagement with air quality issues (Canha et al., 2022).

In a broader context, the Special Issue on "Public Perception of Air Pollution: International Perspectives" in the journal Sustainability aimed to gather insights on how individuals perceive air pollution and its impact. This compilation underscores the importance of understanding personal and contextual determinants of individuals' reactions to air pollution, which is vital for defining targeted actions and designing effective interventions (Oltra et al., 2021).

Comparing these findings with the overall air quality survey results reveals a common theme: the perception of air quality is not solely determined by objective measures of pollution but is also significantly influenced by individuals' experiences, knowledge, and the information available to them. Both studies illustrate the complexity of air quality perception and the critical role of public awareness and education in shaping these perceptions. They highlight the necessity for targeted communication strategies and policies to address air pollution concerns effectively. This comparison suggests that efforts to improve air quality perception must go beyond reducing pollutant levels to include enhancing public understanding of air quality issues and the health impacts of pollution.

Table 4: Main Sources of air Pollution in your Community

Responses	Freq	Per	Cum. Per	Exact 95% LCL	Exact 95% UCL
Domestic cooking practices	1	0.67	0.67	0.02	3.66
Open burning of waste	107	71.33	72.00	63.39	78.41
Open burning of waste; Domestic cooking practices	32	21.33	93.33	15.07	28.76
Open burning of waste; Other (Please specify):	1	0.67	94.00	0.02	3.66
Vehicle exhaust; Open burning of waste	4	2.67	96.67	0.73	6.69
Vehicle exhaust; Open burning of waste; Domestic cooking practices	5	3.33	100.00	1.09	7.61
TOTAL	150	100.00	100.00		

Table 4 outlines the perceived main sources of air pollution in a community, based on a survey of 150 respondents. The sources of pollution are categorized into specific activities, some responses include combinations of sources, indicating multiple significant contributors to air pollution within the community.

➤ *Key Findings:*

Domestic Cooking Practices (1 response, 0.67%): A minimal fraction of the respondents identify domestic cooking practices alone as a main source of air pollution, with a very narrow confidence interval, indicating limited perception of cooking as a singular significant source.

Open Burning of Waste (107 responses, 71.33%): The overwhelming majority perceive open burning of waste as a main source of air pollution, with a confidence interval ranging from 63.39% to 78.41%. This indicates a high level of agreement among the respondents about the significance of waste burning.

Open Burning of Waste; Domestic Cooking Practices (32 responses, 21.33%): A significant minority identifies a combination of open burning of waste and domestic cooking practices as main sources, suggesting these practices together significantly contribute to air pollution, with a confidence interval from 15.07% to 28.76%.

Open Burning of Waste; Other (1 response, 0.67%): A very small number believe that open burning of waste, along with other unspecified sources, contributes to air pollution. The narrow confidence interval suggests this view is not widely held or specific sources outside the listed options are not major concerns for most.

Vehicle Exhaust; Open Burning of Waste (4 responses, 2.67%): A small group perceives both vehicle exhaust and open burning of waste as significant pollution sources. The confidence interval (0.73% to 6.69%) indicates this combination is recognized but not as predominantly as open burning alone.

➤ *Environmental, Health and Social Impact*

• *Environmental*

Vehicle Exhaust; Open Burning of Waste; Domestic Cooking Practices (5 responses, 3.33%): This combination suggests a recognition of multiple significant pollution sources, with a confidence interval indicating a small but notable concern among the population.

J. Interpretation

The data overwhelmingly points to open burning of waste as the perceived primary source of air pollution in the community, either on its own or in combination with other activities like domestic cooking practices and vehicle exhaust. This indicates a critical area for environmental and public health intervention, highlighting the need for waste management reforms, public awareness campaigns about the dangers of open burning, and alternatives to reduce the reliance on practices contributing to air pollution.

The recognition of multiple sources in combination (waste burning with cooking practices and vehicle exhaust) reflects an understanding of air pollution as a multifaceted issue. Efforts to address air pollution in this community may need to consider integrated approaches that tackle these sources collectively, such as promoting cleaner cooking technologies, improving waste management infrastructure, and enhancing vehicle emissions standards.

This data can guide policymakers, environmental organizations, and community leaders in developing targeted strategies to mitigate air pollution and protect public health.

The survey's findings, particularly the overwhelming perception of open burning of waste as a primary air pollution source, align with broader research emphasizing the complex relationship between actual pollution levels and public perceptions. A systematic review on the perception of air pollution risk, especially related to particulate matter, highlights the influence of social, cultural, and contextual factors on individuals' perceptions and behaviors towards air pollution. This underscores the importance of understanding community perceptions for effective pollution control actions and health risk communication (Cori et al., 2020).

Table 5: Cleanliness and Sanitation of Public Spaces in Communities

Responses	Freq.	Per	Cum. Perc	Exact 95% LCL	Exact 95% UCL
Clean	5	3.33	3.33	1.09	7.61
Moderately clean	1	0.67	4.00	0.02	3.66
Unclean	101	67.33	71.33	59.21	74.76
Very unclean	43	28.67	100.00	21.59	36.61
TOTAL	150	100.00	100.00		

Table 5 presents survey data regarding perceptions of cleanliness and sanitation of public spaces in Bawror Quarter and Kortu Quarter Communities. It categorizes the responses into four levels: "Clean," "Moderately clean," "Unclean," and "Very unclean," providing the frequency and percentage of responses for each category, along with cumulative percentages and exact 95% confidence intervals (LCL for

lower confidence limit, UCL for upper confidence limit) for the percentages.

➤ *Key Findings:*

Clean (5 responses, 3.33%): A small minority of respondents consider the public spaces to be clean. The confidence interval suggests that in the broader community, between 1.09% and 7.61% would find public spaces clean, indicating limited satisfaction with cleanliness levels.

Moderately Clean (1 response, 0.67%): An even smaller portion of the population perceives public spaces as moderately clean, with a very narrow confidence interval, indicating a high level of precision around this low estimate.

Unclean (101 responses, 67.33%): The majority of respondents perceive public spaces as unclean. The confidence interval (59.21% to 74.76%) indicates a high level of consensus on this perception, suggesting significant concern about sanitation.

Very Unclean (43 responses, 28.67%): A substantial minority views the public spaces as very unclean, further emphasizing concerns about the state of cleanliness. The confidence interval for this group (21.59% to 36.61%) supports the finding that a significant portion of the community is highly dissatisfied with the cleanliness of public spaces.

• *Interpretation*

The data overwhelmingly indicates that the majority of respondents are concerned about the cleanliness and sanitation of public spaces in Bawror Quarter and Kortu Quarter Communities, with nearly all responses falling into the "Unclean" or "Very unclean" categories. This suggests a significant public health concern that could impact community well-being, satisfaction, and potentially tourism if applicable.

The small percentages of respondents who perceive the spaces as clean or moderately clean highlight a critical area for improvement. The local government, community organizations, and residents may need to collaborate on initiatives aimed at cleaning up and maintaining public spaces to enhance community health, aesthetics, and overall quality of life.

Given the strong consensus on the need for improved cleanliness, targeted interventions such as public awareness

campaigns, increased trash disposal facilities, regular cleaning schedules, and community clean-up events could be effective strategies. Addressing these concerns could also foster a sense of community pride and ownership over public spaces, further contributing to sustained improvements in cleanliness and sanitation.

The survey findings from Bawror and Kortu Quarters, indicating a predominant perception of public spaces as unclean or very unclean, mirror a broader concern about sanitation and hygiene in urban environments globally. This concern is echoed in studies focused on public sanitation infrastructure, such as one conducted in Kegalle township, Sri Lanka, which highlighted the urgent need for accessible, high-quality sanitary services, particularly in densely populated urban areas. In Kegalle, over 70% of respondents indicated dissatisfaction with the quality of public restrooms due to poor maintenance and cleanliness, underscoring a similar sentiment of dissatisfaction and the need for policy intervention in public sanitation facilities (Bellanthudawa et al., 2023).

Further reinforcing the importance of sanitation and hygiene, a study conducted at Shahjalal University of Science and Technology in Bangladesh examined hygiene and sanitation practices among students, acknowledging the well-documented benefits of improved sanitation and hygiene as effective strategies for preventing infection and controlling the transmission of pathogens. The study utilized a qualitative approach to investigate sanitation and hygiene practices, aiming to provide a holistic understanding of these behaviors and practices from both user and supplier perspectives. This approach reveals a nuanced understanding of the challenges and needs regarding sanitation and hygiene in educational settings, potentially offering insights applicable to broader public spaces (Kabir et al., 2021).

These studies collectively highlight a critical global challenge in maintaining cleanliness and sanitation in public spaces, underscoring the need for comprehensive policy interventions, awareness campaigns, and community engagement to improve public sanitation infrastructure. The findings from Bawror and Kortu Quarters, alongside these comparative studies, suggest a widespread need to address public sanitation concerns to enhance the quality of life and public health in urban settings.

Table 6: Concerned about Water Pollution in Communities

Responses	Freq.	Per	Cum. Per	Exact 95% LCL	Exact 95% UCL
Extremely concerned	4	2.67	2.67	0.73	6.69
Moderately concerned	13	8.67	11.33	4.70	14.36
Not concerned at all	3	2.00	13.33	0.41	5.73
Slightly Concerned	81	54.00	67.33	45.68	62.16
Very concerned	49	32.67	100.00	25.24	40.79
TOTAL	150	100.00	100.00		

➤ *Analysis*

Extremely Concerned (4 responses, 2.67%): A small fraction of the population falls into this category, indicating that while there is a recognition of water pollution as a serious

issue, it's not the predominant sentiment. The confidence interval suggests that the true proportion in the broader community who are extremely concerned could realistically range from 0.73% to 6.69%.

Moderately Concerned (13 responses, 8.67%): A larger group compared to those extremely concerned, indicating a moderate level of awareness and concern about water pollution. The confidence interval ranges from 4.70% to 14.36%, suggesting a modest but significant concern within the community.

Not Concerned at All (3 responses, 2.00%): This small group indicates a minimal level of concern about water pollution, suggesting either a lack of awareness or a different prioritization of issues. The confidence interval is quite narrow, from 0.41% to 5.73%, indicating a small but definite segment of the population is not concerned.

Slightly Concerned (81 responses, 54.00%): This is the largest category, showing that over half of the respondents are somewhat concerned about water pollution but perhaps do not see it as an immediate or severe threat. The wide confidence interval (45.68% to 62.16%) reflects the high level of uncertainty around the exact level of slight concern in the broader community.

Very Concerned (49 responses, 32.67%): Nearly one-third of respondents are very concerned about water pollution, indicating a significant level of awareness and anxiety about this issue. The confidence interval (25.24% to 40.79%) suggests a significant portion of the community sees water pollution as a serious concern.

• *Interpretation*

The majority of the community expresses at least some level of concern about water pollution, with a significant portion being "Slightly Concerned" or "Very concerned." This suggests that while there is widespread acknowledgment of the issue, perceptions of its severity vary. The relatively wide confidence intervals, especially for the categories with more responses, indicate a degree of uncertainty that would benefit from further investigation to pinpoint more accurately.

This distribution of concern levels can inform policymakers, community leaders, and environmental organizations about the need for educational programs to raise awareness about the severity of water pollution. Additionally, it highlights the necessity for initiatives aimed at addressing and mitigating water pollution to accommodate the varied levels of concern within these communities.

➤ *Health Impact*

The survey results from Table 6 reflect varying levels of public concern about water pollution, ranging from "Extremely Concerned" to "Not Concerned at All." This spectrum of concern highlights the diverse perceptions and priorities regarding water pollution within a community.

Comparing these findings with broader research, water pollution emerges as a significant global health threat, with various studies underscoring the urgency of addressing water contamination due to its potential to harm public health. A review article synthesizes data from numerous studies on water pollution, emphasizing the diverse sources of contamination—from natural occurrences to anthropogenic activities—and their adverse effects on human health. The review also underscores the complexity of assessing health risks associated with water pollution, considering factors like chemical composition, exposure duration, and pollutant concentration (Babuji et al., 2023).

Moreover, a report from Harvard's School of Public Health discusses the widespread public health concerns linked to water pollution, specifically mentioning the impact of PFAS (per- and polyfluoroalkyl substances) and other contaminants found in water systems. The report indicates that sociodemographic factors can influence the exposure to PFAS in drinking water, highlighting disparities in water quality across different communities (Avenue et al., 2023).

Another study projects that up to 5.5 billion people could be exposed to polluted water by 2100, further emphasizing the critical nature of this issue on a global scale. This modelling study indicates the potential for a significant portion of the world's population to face the consequences of water contamination, underscoring the need for immediate action to mitigate water pollution and protect public health (Tozer, 2023).

These studies collectively underline the critical need for comprehensive strategies to improve water quality, enhance public health, and reduce the burden of waterborne diseases. The varied levels of concern within the community, as seen in the survey results, suggest the importance of raising awareness about the impacts of water pollution and engaging communities in efforts to improve water sanitation and hygiene practices.

Table 7: Familiar with the Health Risks Associated with Pollution Exposure

Responses	Freq.	Per	Cum. Per	95% LCL	95% UCL
Extremely familiar	7	4.67	4.67	1.90	9.38
Moderately familiar	16	10.67	15.33	6.22	16.74
Not familiar at all	5	3.33	18.67	1.09	7.61
Somewhat familiar	89	59.33	78.00	51.02	67.27
Very familiar	33	22.00	100.00	15.65	29.49
TOTAL	150	100.00%	100.00%		

This table presents data on the level of familiarity among respondents with the health risks associated with pollution exposure. The responses are categorized into five levels: "Extremely familiar," "Very familiar," "Moderately familiar," "Somewhat familiar," and "Not familiar at all." The table includes the frequency and percentage of responses in each category, along with cumulative percentages and exact 95% confidence intervals (LCL for lower confidence limit, UCL for upper confidence limit) for each response category.

➤ *Key Findings:*

Extremely Familiar (7 responses, 4.67%): A small fraction of respondents feel extremely familiar with the health risks associated with pollution exposure. The confidence interval suggests that between 1.90% and 9.38% of the broader community might share this high level of familiarity, indicating a minority with an in-depth understanding of the risks.

Moderately Familiar (16 responses, 10.67%): A slightly larger group considers themselves moderately familiar with pollution's health risks. The confidence interval (6.22% to 16.74%) indicates a modest but significant portion of the population has more than a basic understanding of these risks.

Not Familiar at All (5 responses, 3.33%): A small percentage of the population is not familiar at all with the health risks associated with pollution, with a confidence interval ranging from 1.09% to 7.61%. This suggests a segment of the community lacks awareness of pollution's potential health impacts.

Somewhat Familiar (89 responses, 59.33%): The majority of respondents are somewhat familiar with the health risks associated with pollution, indicating a general awareness. The confidence interval (51.02% to 67.27%) shows a significant portion of the community has a basic understanding of the health risks but may lack detailed knowledge.

Very Familiar (33 responses, 22.00%): A notable percentage of respondents feel very familiar with the health risks associated with pollution exposure, suggesting a higher level of understanding. The confidence interval (15.65% to 29.49%) points to a substantial segment of the population that is well-informed about pollution's health risks.

• *Interpretation*

The data indicates a relatively high level of general awareness about pollution's health risks among the community, with the majority of respondents falling into the "Somewhat familiar" category. However, the distribution also highlights a gap in detailed knowledge, as a smaller percentage of respondents identify as "Extremely" or "Very familiar."

This suggests an opportunity for targeted educational campaigns to increase the depth of knowledge about pollution's health impacts. Public health initiatives could focus on providing more detailed information about specific health risks, prevention measures, and the importance of environmental protection efforts. Enhancing the community's understanding could empower individuals to take proactive steps in reducing pollution exposure and advocating for cleaner environments.

The survey data reflecting varying degrees of familiarity among respondents with the health risks associated with pollution exposure captures an essential aspect of public health knowledge. This variance underscores the importance of enhancing public education on environmental health risks to foster more informed communities.

Comparing this to existing research, there's a clear consensus on the need for greater public awareness and understanding of pollution's health impacts. For instance, the EPA emphasizes the vulnerability of certain populations to air pollutants and the necessity for ongoing research to better characterize these risks and inform the public. This research supports the idea that a more in-depth understanding among the general populace could lead to better personal and community health outcomes by acknowledging specific vulnerable groups and the importance of mitigating pollution exposure (US EPA, 2020).

Further, research from BMC Public Health indicates a direct link between environmental factors such as clean water and sanitation facilities and mortality rates. This connection suggests that familiarity with pollution's health risks might not only stem from direct pollution exposure but also from broader environmental conditions that affect public health. Highlighting the critical role of education in reducing mortality by increasing consciousness and responsiveness to environmental health risks, this research aligns with the survey findings that a significant portion of the population lacks detailed knowledge of pollution's health implications (Rahman et al., 2021).

These studies collectively underscore the need for targeted public health interventions and communication strategies that not only aim to improve the population's general understanding of environmental health risks but also focus on actionable knowledge that can lead to better health outcomes. This could involve leveraging existing knowledge on the most effective ways to communicate and mitigate health risks associated with pollution, as well as exploring innovative approaches to engage and educate the public.

➤ *Social Impacts*

Table 1: Aware of Any Environmental Regulations or Policies

Responses	Freq.	Per	Cum. Per	Exact 95% LCL	Exact 95% UCL
Yes	79	52.67	52.67	44.36	60.87
No	71	47.33	100.00	39.13	55.64
TOTAL	150	100.00	100.00		

This table displays survey data regarding awareness of environmental regulations or policies aimed at reducing pollution in a specific community. Respondents were asked whether they are aware of any such environmental regulations or policies, with their responses categorized into "Yes" or "No." The table provides the frequency and percentage of responses in each category, along with cumulative percentages and exact 95% confidence intervals (LCL for lower confidence limit, UCL for upper confidence limit) for each response category.

➤ *Key Findings:*

- **Aware (Yes):** 79 respondents, constituting 52.67% of the surveyed population, are aware of environmental regulations or policies aimed at reducing pollution in their community. The confidence interval ranges from 44.36% to 60.87%, suggesting a slight majority of the population is informed about such measures. This indicates a moderate level of public awareness and potentially reflects the effectiveness of communication or education efforts regarding environmental policies.
- **Not Aware (No):** 71 respondents, making up 47.33% of the surveyed population, are not aware of any environmental regulations or policies aimed at reducing pollution in their community. The confidence interval for this group ranges from 39.13% to 55.64%, indicating a significant portion of the community lacks awareness of pollution reduction efforts or policies.

• *Interpretation*

The nearly equal distribution between those aware and unaware of environmental regulations or policies aimed at reducing pollution in their community highlights a critical gap in public awareness and communication. While just over half of the population is informed, a significant portion remains uninformed about efforts to combat pollution, which could limit the overall effectiveness of these environmental policies.

The data underscores the importance of enhancing communication strategies and educational initiatives to increase awareness of environmental regulations. Better informed citizens are more likely to support, participate in, and comply with these policies, ultimately leading to more

effective pollution reduction. This could involve community outreach programs, educational campaigns, partnerships with local organizations, and the use of social media to spread information about environmental efforts and how individuals can contribute to a cleaner, healthier community.

The survey data indicating a moderate level of public awareness about environmental regulations or policies aimed at reducing pollution aligns with broader findings on the relationship between public environmental concern, government regulations, and pollution reduction. Research has underscored the importance of public awareness and participation in environmental governance. For example, a study highlighted how public pressure has contributed significantly to improving environmental pollution, emphasizing the critical role of local governments and public participation in coordination for effective environmental governance. It also pointed out the necessity of addressing both formal government regulation and informal public pressure to comprehensively tackle environmental pollution issues (Liu et al., 2023).

Moreover, understanding public environmental awareness and attitudes, especially concerning transitions to sustainable practices like the circular economy, is essential for gauging the population's readiness to support and engage with environmental policies. A study conducted in Saudi Arabia revealed that although there was limited public understanding of the circular economy concept due to restricted awareness, there was an optimistic attitude toward sustainable practices such as trash separation. This attitude was influenced by factors like education level and age, suggesting that targeted educational campaigns could enhance public understanding and support for environmental policies (Almulhim & Abubakar, 2021).

These findings emphasize the necessity of integrating public awareness and education into the environmental policy framework. Governments and policymakers should not only focus on implementing regulations but also on enhancing public understanding and engagement through education and awareness campaigns. This dual approach can significantly contribute to achieving environmental sustainability goals, as a well-informed public is more likely to support and adhere to environmental regulations and practices.

Table 9: Willing to Participate in Community-Led Initiatives

Response	Freq.	Per	Cum. Per	Exact 95% LCL	Exact 95% UCL
Yes	146	97.33	97.33	93.31	99.27%
No	4	2.67	100.00	0.73	6.69%
TOTAL	150	100.00	100.00		

This table outlines the willingness of respondents to participate in community-led initiatives aimed at reducing pollution levels in Bawror Quarter and Kortu Quarter Communities. With data from 150 respondents, the survey categorizes responses into "Yes" for those willing to participate and "No" for those not willing.

➤ *Key Findings:*

- **Willing to Participate (Yes):** A significant majority, 146 respondents or 97.33%, expressed their willingness to participate in community-led initiatives to reduce pollution. The high percentage, along with a confidence interval ranging from 93.31% to 99.27%, indicates a strong community readiness or commitment to engage in actions that could potentially lower pollution levels.
- **Not Willing to Participate (No):** A small minority, 4 respondents or 2.67%, indicated they are not willing to participate in such initiatives. The confidence interval for this group is 0.73% to 6.69%, suggesting a very small portion of the community may be reluctant or unable to engage in pollution reduction efforts.

• *Interpretation:*

The overwhelming willingness among the community members to participate in initiatives aimed at reducing pollution levels is a positive indication of the community's collective awareness and concern about environmental issues. This high level of willingness provides a strong foundation for effective community-led environmental actions. The data suggests that community organizers, local governments, and environmental organizations have a potentially engaged population ready to support or be involved in efforts to mitigate pollution.

The minimal resistance to participation could be attributed to a variety of factors, including personal circumstances, skepticism about the effectiveness of such initiatives, or a lack of awareness of the impact of individual and collective actions on pollution levels.

Given this strong inclination towards participation, strategies to mobilize the community could focus on educational campaigns to further increase awareness of pollution's impacts and the effectiveness of community-led actions. Moreover, creating diverse opportunities for involvement that accommodate different abilities, interests, and schedules can help ensure broad participation. Engaging this highly willing population through well-organized, inclusive, and impactful initiatives can significantly contribute to reducing pollution in Bawror Quarter and Kortu Quarter Communities.

The high willingness among Bawror Quarter and Kortu Quarter Communities to participate in pollution reduction initiatives reflects broader findings in research. Studies show that engaging communities in addressing environmental issues, particularly air quality, can significantly raise awareness and drive action. This engagement often adopts the form of citizen science, where local residents collaborate with researchers to monitor air pollution, receiving training and

using low-cost sensors. Such community-based participatory research emphasizes the vital role of public involvement in environmental decision-making and the generation of local knowledge to support sustainable environmental practices (Ward et al., 2022).

IV. CONCLUSION

In conclusion, the study "Assessing Pollution Sources and Impacts in Gbarnga: A Case Study of Barwrro and Kortu Quarters" highlights critical insights into public awareness and engagement regarding pollution in the mentioned communities. The findings underscore a notable gap in public awareness of environmental regulations and policies aimed at pollution reduction, with just over half of the population informed about such initiatives. However, there exists a substantial willingness among community members to actively participate in pollution reduction initiatives, with over 97% expressing readiness to engage in such efforts.

This high level of community willingness provides a solid foundation for effective community-led environmental actions. It emphasizes the importance of bolstering communication strategies and educational programs to raise awareness of environmental policies. Furthermore, integrating public awareness and education into environmental policy frameworks is crucial for achieving sustainable pollution reduction goals.

RECOMMENDATIONS

➤ *Based on the Study's Findings, the Following Recommendations are Proposed:*

- **Strengthen Communication Channels:** Develop and implement more robust communication strategies to enhance public awareness of environmental regulations and policies aimed at pollution reduction. This could involve community outreach programs, educational campaigns, and leveraging social media platforms for disseminating information.
- **Educational Campaigns:** Launch targeted educational campaigns to deepen public understanding of pollution issues, including the impacts of pollution and the effectiveness of community-led actions in mitigating pollution levels.
- **Inclusive Engagement:** Foster inclusive community engagement by creating diverse opportunities for involvement in pollution reduction initiatives. This includes accommodating various abilities, interests, and schedules to ensure broad participation and engagement.
- **Community-Research Partnerships:** Encourage partnerships between the community and research institutions to conduct community-based participatory research on pollution monitoring and mitigation efforts. This collaboration can empower local residents, foster environmental stewardship, and generate valuable local knowledge.

- Policy Integration: Integrate public awareness and education initiatives into environmental policy frameworks. Emphasize the importance of both implementing regulations and enhancing public understanding and engagement to achieve sustainable pollution reduction outcomes.

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