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Article

Awareness and Perceptions of Bio-digester Toilet Technology in Port Harcourt's Waterfront Settlements

Chibuzor Chika[1]* and Alete Favour Ndidi[1]

[1]Department of Health and Safety Education, Ignatius Ajuru University of Education, Rumuolumeni, Port Harcourt, Rivers State, Nigeria.
*Correspondence: chika.chibuzor@iaue.edu.ng; Tel.: +23408038545545.

Abstract: This study examined the level of awareness and nature of perceptions regarding bio-digester toilet technology among residents of waterfront settlements in Port Harcourt, Nigeria. Despite the severe sanitation crisis in these flood-prone communities and the proven suitability of bio-digester systems for such contexts, adoption rates remain negligible. A community-based cross-sectional design was employed, surveying 300 household heads across three waterfront communities (Bundu, Okrika waterfront, and Iwofe) using structured questionnaires, complemented by six focus group discussions with 50 residents. Data were analyzed using descriptive statistics, mean scores, and chi-square tests. Findings revealed extremely low awareness levels, with only 9.3% having heard of bio-digester toilets and merely 1.7% having seen a working model. Knowledge of specific functions such as biogas production (5.0%) and fertilizer generation (3.3%) was virtually non-existent. Perception analysis demonstrated a striking duality: residents strongly acknowledged the technology's potential benefits regarding improved dignity (mean=3.45), household cleanliness (mean=3.60), health protection (mean=3.52), and economic savings (mean=3.10). However, equally strong negative perceptions emerged, including fear of explosion (mean=3.65), disgust regarding waste-to-energy conversion (mean=3.40), perceived technical complexity (mean=3.30), and cultural reservations (mean=2.95). Chi-square analysis confirmed a significant relationship between awareness level and willingness to adopt ($\chi^2=25.48$, df=1, $p<0.05$). The study concluded that the adoption bottleneck begins at the most fundamental level—complete unfamiliarity with the technology—and is compounded by negative perceptual filters that even positive benefit recognition cannot overcome. Recommendations include intensive community-based awareness campaigns utilizing local languages and trusted messengers, establishment of visible demonstration units, and targeted messaging to address specific fears, particularly regarding explosion safety and cultural compatibility.

Keywords: Bio-digester; awareness; perception; sanitation; waterfront communities; Port Harcourt; Technology adoption.

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1. Introduction

Sanitation remains one of the most pressing public health challenges confronting urban slums and informal settlements across sub-Saharan Africa. The global sanitation crisis affects approximately 3.6 billion people who lack access to safely managed sanitation services, with the burden falling disproportionately on vulnerable populations in low-income countries (World Health Organization & UNICEF, 2021). Nigeria exemplifies this crisis, ranking second globally in the prevalence of open defecation, with over 46 million people practicing this hazardous behavior. The situation is particularly acute in urban waterfront settlements, where poverty, high population density, inadequate infrastructure, and environmental vulnerability converge to create conditions of chronic sanitation deprivation (Nwankwoala, 2020).

Port Harcourt, the economic hub of Rivers State and the Niger Delta region, hosts numerous waterfront settlements including Bundu, Okrika, Iwofe, and others. These communities, built on reclaimed swampland along creeks and rivers, developed organically without formal planning or municipal infrastructure. Residents predominantly rely on pit latrines, which frequently overflow during seasonal floods, contaminating groundwater and surface water bodies. A substantial proportion still practices open defecation directly into waterways—the same waters used for bathing, washing, fishing, and sometimes drinking (Dappa & Tamuno, 2021). The Rivers State Ministry of Health (2022) documented recurrent epidemics of cholera, typhoid, and dysentery in these communities, with children under five bearing the heaviest disease burden.

Bio-digester toilet technology presents a scientifically validated, sustainable sanitation solution uniquely suited to the constraints of waterfront environments. Unlike conventional sewerage systems that require extensive piping networks, significant water volumes, and centralised treatment plants—infrastructure entirely absent from informal settlements—bio-digesters operate as on-site, decentralised treatment units. The system consists of a sealed underground tank where anaerobic bacteria digest human waste, producing two valuable outputs: biogas (primarily methane and carbon dioxide) that can be captured for cooking or lighting, and nutrient-rich effluent suitable as liquid fertilizer. The technology requires minimal water, produces no offensive odors, prevents groundwater contamination, and requires desludging only once every 5-10 years (Singh et al., 2022; Oluwasanya & Ogunkunle, 2021).

Despite these compelling advantages and successful implementation in countries including India, Kenya, Rwanda, and Bangladesh, bio-digester adoption in Nigerian waterfront settlements remains virtually non-existent. This disconnect between technological potential and actual uptake constitutes a significant implementation science gap. Understanding the cognitive and perceptual determinants of adoption behavior is essential for designing effective promotion strategies.

Awareness represents the foundational prerequisite for any innovation adoption process. According to Rogers' (2003) Diffusion of Innovations theory, the knowledge stage constitutes the initial phase of the innovation-decision process, during which an individual learns of an innovation's existence and gains some understanding of its functions. Without this awareness, adoption cannot occur regardless of the technology's technical merits or potential benefits. In the sanitation sector, research across multiple contexts has consistently identified lack of awareness as a primary barrier to technology adoption. Jenkins and Scott (2007), investigating household sanitation decisions in Ghana, found that awareness of improved sanitation options was significantly associated with eventual adoption behavior. Similarly, O'Reilly and Louis (2014), in their study of rural Indian sanitation programs, documented that households exposed to information about toilet technologies were substantially more likely to construct facilities than those without such exposure.

In the Nigerian context, Udom (2023) examined perceptions of environmental technologies in the Niger Delta and concluded that awareness campaigns have been grossly inadequate, particularly for innovations addressing household-level sanitation. Adeyemi (2022) assessed farmers' perceptions of biogas technology in Ogun State and reported that lack of awareness was the single most frequently cited reason for non-adoption, with 78% of respondents indicating

they had never encountered information about biogas systems. However, these studies did not specifically examine waterfront settlements, which present unique demographic, geographic, and socio-cultural characteristics that may influence both awareness levels and perceptual formation.

Perception, the process by which individuals interpret and make sense of sensory information, fundamentally shapes technology adoption decisions. The Diffusion of Innovations theory posits that adoption is determined not by the objective characteristics of an innovation but by potential adopters' subjective perceptions of five key attributes: relative advantage, compatibility, complexity, trialability, and observability. Individuals assess whether an innovation appears better than existing alternatives, whether it aligns with their values and needs, whether it seems easy to understand and use, whether they can experiment with it before committing, and whether its benefits are visible to themselves and others (Rogers, 2003).

The Theory of Planned Behavior (Ajzen, 1991) complements this framework by illuminating the psychological pathways through which perceptions translate into behavioral intentions. According to this model, behavioral intention is determined by three constructs: attitude toward the behavior (the individual's positive or negative evaluation of performing the behavior), subjective norm (perceived social pressure to perform or not perform the behavior), and perceived behavioral control (perceived ease or difficulty of performing the behavior, reflecting past experience and anticipated impediments). Each of these constructs is itself a function of underlying behavioral, normative, and control beliefs. Thus, understanding the specific beliefs waterfront residents hold about bio-digester toilets is essential for predicting and influencing adoption behavior.

Perceptions of sanitation technologies are profoundly influenced by cultural context. Chukwu (2021) investigated socio-cultural factors affecting biogas adoption in Plateau State, Nigeria, and identified significant religious and traditional beliefs regarding purity, pollution, and the appropriate handling of human waste. Some Christian and Muslim respondents expressed discomfort with using biogas derived from human excreta for cooking, associating it with ritual impurity or spiritual contamination. These findings suggest that cultural compatibility may be a particularly salient perceptual dimension for bio-digester toilets, which explicitly reframe human waste from a discarded pollutant into a valuable resource for energy and agriculture.

Emotional responses also constitute important perceptual components. Fear, disgust, and anxiety can powerfully inhibit adoption even when cognitive appraisals of an innovation's benefits are favorable. Rozin and Fallon (1987), in their foundational work on disgust psychology, demonstrated that the "ideational" component of disgust—knowledge of an object's origin or nature—can elicit strong aversion even when no sensory contact occurs. For bio-digester toilets, the knowledge that cooking gas originates from human waste may trigger such ideational disgust, potentially overriding rational calculations of economic and health benefits.

The waterfront settlements of Port Harcourt present a distinctive context for examining these perceptual dynamics. These communities are characterized by high levels of poverty, limited formal education, strong traditional authority structures, and dense social networks. Residents share common occupations (fishing, petty trading), face collective environmental challenges (flooding, land erosion, water pollution), and have developed shared cultural frameworks for interpreting health and environmental risks (Okon, 2021). Understanding how these contextual factors shape awareness and perceptions is essential for developing culturally competent sanitation interventions.

Previous research on bio-digester technology in Nigeria has predominantly focused on technical design parameters, engineering specifications, and institutional applications. Studies have examined digester efficiency, gas yield optimization, and effluent quality (Oluwasanya & Ogunkunle, 2021). However, there has been remarkably little investigation of the human dimensions of bio-digester adoption—what potential users know, think, feel, and believe about this technology. This gap is particularly pronounced for urban poor populations, who constitute the primary target beneficiaries for decentralized sanitation solutions but whose voices have been largely absent from the scholarly literature.

Furthermore, existing studies on sanitation perceptions in Nigeria have typically employed either purely quantitative or purely qualitative methodologies, limiting either the generalizability or depth of findings. Mixed-methods approaches that combine the breadth of survey research with the richness of qualitative inquiry are needed to capture both the distribution and meaning of perceptions within communities. This study addresses these methodological and substantive gaps.

The present study was therefore conducted to assess the level of awareness and examine the perceptions of bio-digester toilet technology among residents of Port Harcourt's waterfront settlements. Specifically, the study assessed the level of awareness and knowledge about bio-digester toilet technology among residents and examined their perceptions (attitudes, beliefs, feelings) towards the adoption and use of bio-digester toilets. The research was guided by two research questions: (1) What is the level of awareness and knowledge about bio-digester toilet technology among residents of waterfront settlements? and (2) What are the perceptions of residents towards the adoption and use of bio-digester toilets? One null hypothesis was tested at 0.05 level of significance: There is no significant relationship between the level of awareness about bio-digesters and the willingness to adopt the technology.

2. Research Methodology

The overall research strategy and research design is summarised in Figure 1. The methodology described in this study can be applied by other researchers to investigate other animals and other management themes exhibited by plants or animals. First, the hypothesis was that it is plausible that biomimetics can be applied to management science considering its valuable applications that were already recorded in Science, Technology, Engineering and Mathematics, as presented in Section 1. By exploring bioinspired teamwork and leadership, biomimetics is intended to be applied in behavioural science which is more indeterministic compared to pure science and engineering. Thus, the study explores bioinspired behaviours within the field of engineering which requires teamwork and leadership skills.

2.1 Research Design

This study employed a community-based descriptive cross-sectional design utilizing mixed methods. The design was appropriate for systematically describing the current state of awareness and perceptions regarding bio-digester technology among a defined population at a single point in time, while also capturing the depth and nuance of community members' beliefs and attitudes through qualitative inquiry.

2.2 Study Area

The research was conducted in three purposively selected waterfront settlements in Port Harcourt metropolis, Rivers State, Nigeria: Bundu, Okrika waterfront axis, and Iwofe. These communities were selected because they exemplify the characteristic features of Niger Delta waterfront settlements: location along water bodies, high population density, predominance of informal housing, absence of formal sanitation infrastructure, regular flooding, and reliance on fishing and petty trading as primary livelihoods. Bundu is situated along the Bonny River and houses approximately 15,000 residents; the Okrika waterfront extends along the Okrika creeks with an estimated population of 12,000; Iwofe, located along the Port Harcourt waterfront, has approximately 10,000 residents. All three communities have been documented as sanitation hotspots by the Rivers State Ministry of Health.

2.3 Target Population

The target population comprised all household heads or their spouses residing in the selected waterfront settlements. A household was operationally defined as a group of individuals who live together and share meals from a

common cooking pot. Based on community health department records and local government enumeration data, the estimated total number of households across the three settlements was 10,000.

2.4 Sample Size Determination

The sample size of 300 households was calculated using the Taro Yamane formula: $n = N/(1+N(e)^2)$, where N = estimated population (10,000) and e = margin of error (0.05). This calculation yielded $n = 10,000/(1+10,000\times0.0025) = 10,000/26 = 384.6$. To account for anticipated non-response and incomplete questionnaires, and considering resource constraints, a sample of 300 was determined to be adequate, with 100 households systematically selected from each of the three settlements.

2.5 Sampling Technique

A multi-stage sampling procedure was implemented. Stage one involved purposive selection of the three waterfront settlements based on the criteria described above. Stage two comprised random selection of streets within each settlement: five streets were randomly selected from each community's street listing obtained from the local development council. Stage three employed systematic sampling of households: on each selected street, the research team identified a starting point and selected every fifth household. Where the household head was unavailable after two visits, the spouse or another adult household member aged 18 years or older who participates in household decision-making was interviewed. This process continued until the quota of 100 households per settlement was achieved.

2.6 Instrumentation

The study utilized two complementary data collection instruments.

2.6.1 Quantitative Instrument

The Perceptions and Barriers to Bio-digester Adoption Questionnaire (PBBAQ) was developed by the researchers following extensive literature review and theoretical framework analysis. For this paper focusing on awareness and perceptions, sections B and C of the questionnaire were primarily utilized. Section B assessed Awareness and Knowledge through five items measuring: (1) prior hearing of bio-digester/biogas toilet terminology, (2) knowledge of biogas production function, (3) knowledge of fertilizer production function, (4) understanding of on-site treatment mechanism, and (5) prior observation of a working system. Response options were dichotomous (Yes/No/Don't Know). Section C measured Perceptions through ten items addressing both positive and negative perceptual dimensions: relative advantage (modernity, dignity, health improvement, economic savings), compatibility (cultural/religious acceptability, social approval), complexity (perceived difficulty of management), and emotional responses (disgust, fear of explosion, pride). Items were measured on a 4-point Likert scale (Strongly Agree=4, Agree=3, Disagree=2, Strongly Disagree=1). The 4-point scale was deliberately chosen to eliminate neutral responses and force directional expression of opinion.

2.6.2 Qualitative Instrument

Six Focus Group Discussion (FGD) sessions were conducted, two in each community, segregated by gender (one male group, one female group per community). Each FGD comprised 8-10 participants recruited through community health volunteers. A semi-structured FGD guide explored: current sanitation practices and satisfaction levels; exposure to information about new sanitation technologies; immediate reactions to bio-digester description and photographs; perceived benefits and concerns; cultural and religious considerations; and social influences on sanitation decisions. FGDs were conducted in the local languages (Ikwerre and Ijo) by trained moderators, with sessions lasting 60-90 minutes.

2.7 Validity and Reliability

Content and face validity of the PBBAQ were established through review by a panel of three experts: an environmental health specialist with sanitation research expertise, a sociologist specializing in technology adoption, and a renewable energy engineer with bio-digester installation experience. The experts evaluated item relevance, clarity, comprehensiveness, and alignment with theoretical constructs. Their feedback informed revision of several items to enhance clarity and cultural appropriateness. The perception scale was pilot-tested with 30 respondents in Borokiri waterfront settlement, a community with characteristics similar to the study sites but excluded from the main study. Cronbach's Alpha coefficient was calculated to assess internal consistency reliability, yielding $\alpha = 0.82$ for the perception items, indicating good reliability.

2.8 Data Collection Procedures

Twelve research assistants with prior survey experience and fluency in Ikwerre, Ijo, and English languages were recruited and trained intensively over two days. Training covered study objectives, ethical protocols, questionnaire administration techniques, and standardized explanation of bio-digester technology (including use of a laminated photograph showing a typical household system). Data collection occurred over eight weeks (February-March 2024). Questionnaires were administered through face-to-face interviews to accommodate varying literacy levels. Each interview lasted approximately 25-35 minutes. For FGDs, separate male and female moderators facilitated sessions in community halls, with sessions audio-recorded with participants' explicit consent. A note-taker documented non-verbal communication and group dynamics.

2.9 Data Analysis

Quantitative data were entered into SPSS version 25. Descriptive statistics (frequencies, percentages) were computed for awareness items. For perception items, mean scores were calculated; on the 4-point scale, a mean score of 2.50 or above was interpreted as indicating agreement/positive perception (for positively worded items) or strong barrier (for barrier items), following established convention in Likert scale analysis. The chi-square test of independence was employed to test the hypothesis regarding the relationship between awareness level and willingness to adopt, with statistical significance set at $p < 0.05$. Qualitative data from FGDs underwent thematic analysis following Braun and Clarke's six-phase framework: familiarization, initial coding, theme search, theme review, theme definition, and report writing. Transcripts were read repeatedly, codes were generated inductively and deductively (informed by theoretical frameworks), and themes were refined through iterative discussion among researchers. Representative verbatim quotes were selected to illustrate themes.

2.10 Ethical Considerations

Ethical approval was obtained from the Research Ethics Committee of the University of Port Harcourt (Approval Number: UPHREC/2024/017). Permission was secured from community leaders and the chairpersons of the community development councils in each settlement. All participants provided informed consent after receiving detailed explanation of the study purpose, procedures, risks, and benefits. Confidentiality was assured through anonymization of data, use of participant codes rather than names, and secure data storage. Participants were informed of their right to withdraw without penalty. No financial incentives were provided, though refreshments were offered during FGD sessions.

3. Result

3.1 Socio-Demographic Characteristics of Respondents

A total of 300 respondents participated in the quantitative survey, with complete data obtained from all participants (100% response rate). Table 1 presents the socio-demographic characteristics. The demographic profile reveals a predominantly male respondent sample (62.3%), reflecting the cultural pattern of male household headship in the region. The majority were within the economically active age brackets (31-45 years: 41.7%; 46-60 years: 24.0%). Educational attainment was low, with 51.7% having primary education or less, and only 10.0% having any tertiary education. Occupational distribution reflected the waterfront economy: fishing (35.0%) and petty trading (31.7%) predominated. Income levels were extremely low, with 88.3% earning below ₦50,000 monthly (approximately $33 USD), substantially below the Nigerian national minimum wage. Sanitation infrastructure was overwhelmingly basic: 73.3% used pit latrines, and 21.7% reported open defecation as their primary sanitation practice. Only 5.0% had flush toilets, typically connected to septic tanks rather than sewer systems. This demographic profile confirms the vulnerability and sanitation deprivation of the study population.

Table 1: Socio-Demographic Characteristics of Respondents (N=300)

Variable	Category	Frequency	Percentage
Settlement	Bundu	100	33.3
	Okrika Waterfront	100	33.3
	Iwofe	100	33.3
Gender	Male	187	62.3
	Female	113	37.7
Age	18-30 years	78	26.0
	31-45 years	125	41.7
	46-60 years	72	24.0
	Above 60 years	25	8.3
Educational Level	No Formal Education	45	15.0
	Primary Education	110	36.7
	Secondary Education	115	38.3
	Tertiary Education	30	10.0
Occupation	Fishing	105	35.0
	Petty Trading	95	31.7
	Artisan	70	23.3

	Unemployed	30	10.0
Monthly Income	< ₦30,000	165	55.0
	₦30,000 - ₦50,000	100	33.3
	> ₦50,000	35	11.7
Current Toilet Type	Pit Latrine	220	73.3
	Open Defecation	65	21.7
	Flush Toilet	15	5.0

3.2 Research Question One: Level of Awareness and Knowledge about Bio-digester Toilet Technology

Table 2 presents respondents' awareness and knowledge of bio-digester technology across five dimensions.

Table 2: Awareness and Knowledge of Bio-digester Technology (N=300)

S/N	Item	Yes n (%)	No n (%)	Don't Know n (%)
1	Have you ever heard of a "bio-digester toilet" or "biogas toilet"?	28 (9.3)	272 (90.7)	-
2	Do you know it can turn waste into cooking gas?	15 (5.0)	285 (95.0)	-
3	Do you know it produces liquid fertilizer?	10 (3.3)	290 (96.7)	-
4	Do you understand it treats waste without a big septic tank?	8 (2.7)	292 (97.3)	-
5	Have you ever seen one working in person?	5 (1.7)	295 (98.3)	-

The findings reveal profoundly low levels of awareness and knowledge across all measured dimensions. Only 28 respondents (9.3%) had ever encountered the term "bio-digester toilet" or "biogas toilet." Knowledge of specific functional attributes was even more limited: 5.0% were aware of biogas production capability, 3.3% knew of fertilizer production, and 2.7% understood that the system treats waste without a conventional septic tank. Most strikingly, only 5 individuals (1.7%) had ever observed a functioning bio-digester system. These figures indicate that awareness is not merely low but virtually absent; the technology exists completely outside the cognitive landscape of the overwhelming majority of waterfront residents.

The qualitative findings from FGDs powerfully corroborated and illuminated these quantitative results. Across all six focus groups, participants consistently expressed complete unfamiliarity with bio-digester technology. A male participant from Bundu stated: *"I have lived in this waterfront for forty years. I know pit latrine. I know bucket toilet from long ago. I know the public toilet the government built and abandoned. But this thing you are describing—toilet that gives gas for cooking? I have never heard of such a thing in my life. Not on radio, not from my neighbor, not from anyone."* (Male, Bundu FGD). A female participant from Okrika expressed similar astonishment: *"You mean there is a

toilet that does not smell? That does not need water? That gives you free cooking gas? Why have we not been told about this before now? Our leaders, the health workers, the people from the local government—they come to tell us about malaria, about HIV, about COVID-19. Nobody ever mentioned this toilet."* (Female, Okrika FGD).

The few respondents who had encountered the technology described exposure through indirect and often unreliable channels. One Iwofe resident reported: *"My son who works in Port Harcourt town told me he saw something like this in his boss's house. The boss is a big man, a professor. He said the toilet has no smell and they use the gas for cooking. I thought he was joking. I did not believe such a thing could be true."* (Male, Iwofe FGD)

This testimony reveals not only low awareness but also active disbelief when information is received through informal channels without credible demonstration or endorsement.

3.3 Research Question Two: Perceptions of Residents towards Adoption and Use of Bio-digester Toilets

Following provision of standardized information about bio-digester technology accompanied by photographic illustration of a household system, respondents rated their agreement with ten perception statements. Table 3 presents the mean scores for these perception items.

Table 3: Mean Scores of Perceptions towards Bio-digester Toilets (N=300)

S/N	Item (Perception Statement)	Mean ($\bar{x}$)	Remark
Positive Perceptions			
1	It is a more modern and dignified toilet than a pit latrine	3.45	Strongly Agree
2	It would greatly improve the cleanliness around my home	3.60	Strongly Agree
3	It could reduce sickness in my family from diarrhea and cholera	3.52	Strongly Agree
4	Using the biogas for cooking is a good way to save money on kerosene	3.10	Agree
5	I would feel proud to have such a toilet in my compound	3.25	Strongly Agree
Overall Mean for Positive Perception Items	**3.38**	**Positive**	
Negative Perceptions			
6	The idea of cooking with gas from human waste is disturbing to me	3.40	Strongly Agree
7	I would be afraid the gas might explode	3.65	Strongly Agree
8	This technology is too complicated for someone like me to manage	3.30	Strongly Agree

9	My religious or cultural beliefs would make it hard to accept this	2.95	Agree
10	My neighbors might laugh at me or say I am doing something strange	2.80	Agree
Overall Mean for Negative Perception Items	**3.22**	**Strong Negative**	

The perception analysis reveals a striking and consequential pattern of dual cognition. Respondents strongly endorsed all positive perception statements, with overall mean of 3.38 indicating strong agreement with the technology's potential benefits. The highest-rated positive perceptions were household cleanliness (mean=3.60), health protection (mean=3.52), and modern dignity (mean=3.45). Pride in ownership (mean=3.25) and economic savings (mean=3.10) also received strong positive endorsement.

However, respondents simultaneously and equally strongly endorsed negative perception statements, with overall mean of 3.22 indicating strong negative attitudes. Fear of explosion emerged as the single most powerful perception overall (mean=3.65), exceeding all positive item scores. Disgust regarding waste-to-energy conversion was also strongly endorsed (mean=3.40), as was perceived technical complexity (mean=3.30). Cultural and religious reservations, while slightly less intense (mean=2.95), still exceeded the agreement threshold. Social approval concerns regarding neighbor ridicule, though moderate (mean=2.80), remained above the neutral point.

This perceptual duality—simultaneous strong positive evaluation of benefits and strong negative emotional and cognitive responses—was vividly illustrated in FGD discussions. Participants frequently expressed this ambivalence within single utterances: *"This toilet sounds like a very good thing. It will stop our children from falling into the dirty latrine when it floods. It will stop the smell. It will even give us gas so we don't buy kerosene. But... gas from human waste? To cook my family's food? My spirit tells me this is not right. And what if it explodes? I have seen a kerosene stove explode. A woman in my street was burned. Gas is even more dangerous."* (Female, Iwofe FGD)

The fear of explosion was remarkably pervasive and intense across all demographic subgroups. Analysis of FGD discourse revealed that this fear was not merely abstract but grounded in concrete community experiences with household energy accidents: *"My neighbor's son was killed by a generator gas explosion. Another woman lost her kitchen to kerosene fire. We know gas is powerful. Now you want to put gas from our toilet inside our kitchen? What if the children play with the pipe? What if it leaks while we are sleeping? We will die."* (Male, Okrika FGD)

Perceived technical complexity emerged as another substantial barrier, reflecting respondents' self-assessment of their capabilities relative to perceived technological sophistication: *"This is not for people like us. We are fishermen and market women. We know how to dig a pit and put planks across it. That is simple. But this thing has pipes, valves, bacteria, gas storage. If it breaks, who will fix it? There is no engineer in this community."* (Male, Bundu FGD).

Cultural and religious reservations, while not universally expressed, were salient for many participants and appeared to draw on deep-seated conceptual frameworks regarding purity, pollution, and appropriate use of human waste: *"In our tradition, human waste is something to be buried and forgotten. It is not something to touch, not something to use. My grandmother would turn in her grave if she knew we were cooking with it. I am a Christian, and I know God made everything, but this still feels... unclean."* (Female, Okrika FGD). However, not all participants shared these reservations, and some explicitly rejected cultural barriers: *"I don't see the problem. The waste goes into the ground, the bacteria eat it, the gas comes out. It is science, not magic. The gas is not waste anymore. It is like firewood—God gave us firewood, God gave us this gas. It is all creation."* (Male, Iwofe FGD). This divergence suggests that cultural

and religious beliefs, while influential for many, are not monolithic within communities and may be amenable to reframing through appropriate messaging and trusted messengers.

Social norms regarding neighbor approval emerged as a more subtle but still detectable concern: *"People here talk. If I build something strange in my compound, they will say I am showing off, or that I am doing something demonic. Sometimes it is better not to be the first."* (Female, Bundu FGD)

This statement illustrates the importance of observability and social proof in technology adoption, consistent with Rogers' (2003) diffusion theory.

3.4 Hypothesis Testing

Hypothesis One (H_{01}): There is no significant relationship between the level of awareness about bio-digesters and the willingness to adopt the technology.

Table 4: Chi-Square Test for Relationship between Awareness Level and Willingness to Adopt

Awareness Level	**Willing to Adopt n**	**Not Willing n**	**Total n**
High Awareness	22	6	28
Low/No Awareness	105	167	272
Total	**127**	**173**	**300**
χ^2 cal = 25.48, df = 1, χ^2 crit = 3.84, p < 0.05			

The chi-square analysis revealed a statistically significant relationship between awareness level and willingness to adopt bio-digester technology ($\chi^2 = 25.48$, df = 1, $p < 0.05$). The calculated chi-square value substantially exceeded the critical value of 3.84, leading to rejection of the null hypothesis. Among respondents classified as having high awareness (those answering "Yes" to at least two awareness items), 22 out of 28 (78.6%) expressed willingness to adopt. In contrast, among those with low or no awareness, only 105 out of 272 (38.6%) expressed willingness. This 40-percentage point difference demonstrates that awareness is not merely correlated with adoption intention but appears to be a powerful predictor of it. The odds ratio calculated from the contingency table indicated that respondents with high awareness were 5.8 times more likely to express adoption willingness than those with low awareness.

This quantitative finding resonated strongly with FGD narratives, where participants explicitly articulated the connection between knowledge and adoption readiness: *"If I see this thing working with my own eyes—if I see the gas burning, if I smell that there is no smell, if I talk to someone who has used it for years—then I will believe. Then I will find money to build it. But now, it is just words."* (Male, Bundu FGD). *"The problem is that we don't know. When you don't know something, you fear it. When you fear it, you reject it. So first, you must make us know."* (Female, Okrika FGD). These testimonies illuminate the psychological mechanism linking awareness to adoption: awareness reduces uncertainty, diminishes fear, and enables positive benefit perceptions to exert greater influence on decision-making.

4. Discussion

This study provides the first systematic investigation of awareness and perceptions regarding bio-digester toilet technology specifically among waterfront settlement residents in Nigeria's Niger Delta region. The findings reveal a sanitation technology awareness vacuum of profound proportions and a complex perceptual landscape characterized by simultaneous strong positive benefit recognition and equally strong negative emotional and cognitive responses.

4.1 Awareness Deficit as Foundational Barrier

The finding that 90.7% of respondents had never heard of bio-digester toilets, that knowledge of specific functions was below 5%, and that only 1.7% had ever observed a working system indicates that this technology exists completely outside the cognitive and experiential world of the target population. This level of unawareness exceeds even the low awareness rates reported in previous Nigerian studies. Adeyemi (2022) found that 78% of Ogun State farmers lacked awareness of biogas technology; the current study's 91% unawareness rate among waterfront residents suggests that urban poor populations are even more information-disadvantaged than rural agricultural communities regarding sanitation innovations.

This awareness deficit cannot be attributed to inherent characteristics of the technology itself but rather reflects systematic failures in information dissemination systems. The waterfront settlements, despite their proximity to Port Harcourt—a major city with universities, research institutions, and government agencies—have been effectively excluded from the knowledge networks through which information about beneficial technologies typically flows. This exclusion is multidimensional: mass media campaigns have not targeted these communities; extension services do not reach them; NGOs working on sanitation have focused on latrine construction rather than innovative technologies; and community leaders have not been engaged as knowledge brokers (Udom, 2023).

The significant relationship between awareness and adoption intention demonstrated through chi-square analysis ($\chi^2=25.48$, $p<0.05$) confirms that awareness is not merely a desirable precondition for adoption but appears to be a necessary condition. This finding aligns with Rogers' (2003) knowledge stage proposition and with empirical sanitation research in other contexts. Jenkins and Scott (2007), in their Ghanaian study, found that awareness of improved sanitation options was the strongest predictor of movement from the "no demand" to "latent demand" category. Similarly, O'Reilly and Louis (2014) documented that Indian households receiving information about toilet technologies through community health workers were significantly more likely to construct facilities.

The qualitative finding that some aware respondents initially disbelieved information received through informal channels is particularly significant. It suggests that for innovations that violate cultural expectations or seem "too good to be true," mere information transmission is insufficient. Credibility of both the message and messenger matters critically. This has important implications for intervention design: awareness campaigns must be accompanied by demonstration effects that provide sensory confirmation (sight, smell) of claimed benefits.

4.2 Perceptual Duality and Its Implications

Perhaps the most theoretically and practically significant finding of this study is the clear demonstration that waterfront residents simultaneously hold strongly favorable evaluations of bio-digester benefits and strongly unfavorable emotional and cognitive responses to the technology. This perceptual duality has not been previously documented in sanitation adoption research, which has typically characterized perceptions as either predominantly positive or predominantly negative (Chukwu, 2021; Adeyemi, 2022). The strong positive endorsement of relative advantage attributes—modernity, cleanliness, health protection, economic savings, and pride—indicates that once residents

understand what bio-digester toilets do, they immediately recognize the technology's superior value proposition compared to their current sanitation arrangements. This finding is theoretically important because it contradicts any characterization of waterfront residents as "resistant to change" or "culturally traditional" in ways that preclude technology adoption. The cognitive appraisal of benefits is clearly favorable.

However, this favorable appraisal is currently overshadowed by negative perceptions that are more emotionally immediate and viscerally powerful. The fear of explosion (mean=3.65) represents an intense, specific, and actionable concern. This fear is not irrational but grounded in legitimate community experiences with household energy accidents involving kerosene stoves, generators, and cooking gas cylinders. The fear is amplified by unfamiliarity: because respondents have never seen a biogas system, they have no mental model of how gas is safely contained and transported from digester to stove. Without this mental model, they default to catastrophic scenarios.

This finding resonates with psychological research on risk perception. Slovic (1987) demonstrated that laypeople's risk perceptions are influenced by factors beyond statistical probability, including dread, unfamiliarity, and lack of control. Bio-digester gas embodies all these dread characteristics: it is unfamiliar, its potential consequences are catastrophic (explosion, fire, death), and individuals perceive themselves as lacking control over its safe management. Effective risk communication must address not only factual safety records but also these psychological dimensions of perceived risk.

The disgust response to waste-derived biogas (mean=3.40) represents another potent emotional barrier. This finding aligns with Chukwu's (2021) documentation of cultural reservations regarding biogas in Plateau State and with the broader psychological literature on ideational disgust (Rozin & Fallon, 1987). Importantly, the current study found that disgust was not universal; some participants explicitly rejected this framing, distinguishing between the original waste and the transformed gas. This suggests that disgust is not an immutable cultural given but a cognitive frame that can be shifted through appropriate messaging that emphasizes the transformation process and the scientific equivalence of biogas regardless of feedstock.

Perceived technical complexity (mean=3.30) reflects respondents' accurate assessment of the gap between their current technical capabilities and the perceived demands of bio-digester management. This perception links directly to the Theory of Planned Behavior's perceived behavioral control construct (Ajzen, 1991). When individuals believe they lack the knowledge, skills, or resources to successfully operate a technology, adoption intention is suppressed regardless of favorable attitudes. This finding is consistent with Jenkins and Scott's (2007) observation that perceived difficulty of construction and maintenance constitutes a significant barrier to household sanitation investment.

Cultural and religious reservations (mean=2.95), while above the agreement threshold, were somewhat less intensely endorsed than fear, disgust, and complexity concerns. This finding is noteworthy and potentially encouraging. It suggests that while cultural compatibility is a genuine concern for many residents, it is not the overwhelming obstacle that some previous literature (Chukwu, 2021) might suggest. The variation in FGD responses regarding cultural acceptability indicates that these beliefs are not monolithic and may be amenable to change through appropriate social influence mechanisms, particularly endorsement by respected religious and traditional authorities.

Social norms regarding neighbor approval (mean=2.80), while the lowest-scoring negative perception, still exceeded the agreement threshold. This finding aligns with the subjective norm construct in the Theory of Planned Behavior (Ajzen, 1991) and with Rogers' (2003) observability attribute. Residents care about what their neighbors think; innovations perceived as strange or deviant face social penalties for early adopters. However, the moderate intensity of this concern also suggests that social norms could become powerful facilitators of adoption once a critical mass of adopters demonstrates the technology's normalcy and benefits.

4.3 Theoretical Integration

The findings of this study can be productively integrated within the Diffusion of Innovations framework. Rogers (2003) posited that adoption rate is determined by potential adopters' perceptions of five innovation attributes. This study measured these perceptions and found:

Relative Advantage: Strongly positive (mean=3.38). Residents clearly perceive bio-digesters as superior to pit latrines and open defecation on multiple dimensions.

Compatibility: Moderately problematic (mean scores: cultural/religious=2.95; social approval=2.80). The technology conflicts with some existing values and beliefs but not universally or insurmountably.

Complexity: Strongly negative (mean=3.30). Residents perceive the technology as too complicated for them to manage.

Trialability: Essentially zero. With no demonstration units accessible, residents cannot experiment with the technology on a limited basis.

Observability: Essentially zero. With almost no visible installations, residents cannot observe benefits in others' experience.

This profile—high relative advantage, moderate compatibility concerns, high complexity, zero trialability, zero observability—explains the current adoption impasse. The innovation is perceived as beneficial but also as complex, untriable, and unobservable. Under these conditions, Rogers' theory predicts slow adoption concentrated among a small, atypical innovator category, which accurately describes the current situation. The implication is that promotion strategies must address not only information deficits but specifically target the trialability and observability deficits through demonstration programs.

The Theory of Planned Behavior (Ajzen, 1991) provides complementary insight into the psychological pathway from perception to intention. The strong negative perceptions regarding fear, disgust, and complexity directly undermine perceived behavioral control. Even among respondents with favorable attitudes and positive subjective norms (which are currently weak due to low awareness), adoption intention is suppressed by the conviction that "I cannot do this successfully." The significant awareness-adoption relationship can be reinterpreted through this lens: awareness reduces uncertainty, which enhances perceived behavioral control, which increases adoption intention.

4.4 Comparison with International Contexts

The awareness and perception patterns documented in Port Harcourt's waterfront settlements differ markedly from those reported in countries with successful bio-digester dissemination programs. In India, the Sulabh International bio-digester program achieved widespread adoption through a strategy combining intensive awareness campaigns, visible demonstration of benefits, and institutional partnerships (Singh et al., 2022). Awareness in target communities reportedly exceeded 80% within program areas, and perceptions were shaped through direct sensory experience: community members visited functioning toilets, observed biogas cooking demonstrations, and inspected effluent used in garden irrigation.

In Kenya, biogas dissemination through the Africa Biogas Partnership Program similarly prioritized awareness creation and perception management. Research by Mutungwa et al. (2020) found that Kenyan households exposed to demonstration units showed significantly lower fear perceptions and higher adoption intention than those receiving only information. The Kenyan experience demonstrates that fear of explosion, while initially prevalent, can be substantially reduced through transparent safety education and visible evidence of safe operation over time.

In Rwanda, government integration of bio-digesters into national sanitation policy included substantial investment in public awareness campaigns using radio, community meetings, and school-based education (Singh et al., 2022). These multi-channel approaches recognized that awareness is not a single event but a process requiring repeated exposure through multiple trusted sources.

The contrast between these international experiences and the Nigerian situation underscores that the awareness deficit documented in this study is not inevitable but reflects policy and programmatic failures. The technology itself is not inherently too complex for poor communities to understand; Indian and Kenyan experiences demonstrate that with appropriate communication strategies, comprehension can be achieved. The fear of explosion is not insurmountable;

safety records can be communicated and demonstrated. Cultural reservations are not immutable; they can be addressed through engagement with religious and traditional leaders.

4.5 Implications for Intervention Design

The findings of this study carry specific, actionable implications for intervention design. First, the profound awareness deficit demands immediate, intensive, and sustained investment in community-based awareness campaigns. However, these campaigns must be designed differently from conventional health education approaches. They must move beyond one-way information transmission to incorporate demonstration, dialogue, and social learning. They must employ multiple channels—radio dramas, community theater, religious gatherings, market forums, school programs—to achieve message saturation and reinforcement.

Second, the perceptual duality finding suggests that awareness campaigns must simultaneously accomplish two distinct communication tasks: they must reinforce and elaborate the benefit case that residents already largely accept, and they must directly and credibly address the specific negative perceptions that currently dominate decision-making. Addressing fear of explosion requires transparent presentation of safety records, explanation of safety mechanisms (pressure relief valves, flexible gas bags), and most critically, opportunities for residents to observe functioning systems and speak with long-term users. Addressing disgust requires reframing narratives that emphasize the scientific transformation process and distinguish between feedstock and end product. Addressing perceived complexity requires demonstrating that day-to-day operation is simple and that maintenance support systems can be established locally.

Third, the significant awareness-adoption relationship provides empirical justification for investment in awareness as a necessary condition for adoption. However, it also indicates that awareness alone is insufficient; the 38.6% adoption willingness among low-awareness respondents suggests that even without specific bio-digester knowledge, many residents are predisposed toward improved sanitation solutions. The task is to channel this latent demand through the provision of credible, trustworthy information and demonstration.

5. Summary

This study concludes that the adoption bottleneck for bio-digester toilet technology in Port Harcourt's waterfront settlements begins at the most fundamental level—the level of awareness. With over 90% of residents completely unfamiliar with the technology and almost none having observed a functioning system, the innovation exists outside the cognitive universe of the target population. This awareness deficit represents not merely an information gap but a fundamental failure of the technology dissemination system and a form of exclusion of urban poor communities from knowledge networks through which beneficial innovations typically spread.

The study further concludes that waterfront residents, once informed about bio-digester technology, demonstrate sophisticated and balanced cognitive processing. They simultaneously recognize and strongly endorse the technology's substantial advantages over their current sanitation arrangements while also expressing powerful negative emotional and cognitive responses regarding safety, disgust, complexity, and cultural compatibility. This perceptual duality indicates that residents are not irrational or change-resistant but are rationally weighing perceived benefits against perceived risks and costs within their specific context of limited resources, prior negative experiences with household energy technologies, and cultural frameworks regarding purity and pollution.

The significant relationship between awareness and adoption intention, combined with the specific negative perceptions identified, provides clear direction for intervention. Awareness is necessary but insufficient; it must be accompanied by credible demonstration that addresses fear through visible evidence, reframes disgust through scientific explanation, reduces perceived complexity through skills training, and addresses cultural concerns through respected community and religious leaders.

The waterfront communities of Port Harcourt are not resistant to bio-digester technology. They are, however, rationally cautious about adopting an unfamiliar, seemingly complex innovation that appears to carry significant risks and requires substantial upfront investment. Their cautiousness is not a barrier to be overcome but a reasonable orientation to be respected and addressed through appropriate communication, demonstration, and support systems. With such systems in place, the substantial latent demand for improved sanitation that this study has documented can be channeled into adoption behavior that will improve health, protect the environment, and enhance dignity for some of Port Harcourt's most vulnerable residents.

6. Recommendations

Based on the findings regarding awareness deficits and perceptual barriers, the following recommendations are specifically directed at addressing awareness and perception-related obstacles to bio-digester adoption:

- **Design and Implement Multi-Channel Community Awareness Campaigns:** The Rivers State Ministry of Environment, in partnership with local government authorities and sanitation-focused NGOs, should develop comprehensive awareness campaigns utilizing local languages (Ikwerre, Ijo) and culturally appropriate communication formats including radio jingles, community theater performances, town hall meetings, and religious congregation announcements. Campaign content must address both the benefits of bio-digester technology and, crucially, the specific negative perceptions identified in this study. Fear of explosion must be addressed directly with factual safety information and testimonials from long-term users.
- **Establish Visible Demonstration Units in Each Waterfront Community:** Government and development partners should fund construction of 3-5 public bio-digester toilet facilities with attached biogas cooking stations in each waterfront settlement. These demonstration sites should be strategically located in high-traffic areas (markets, community centers, health clinics) to maximize observability. Community members must be able to see the toilet, smell the absence of odor, observe the biogas flame, and inspect the effluent. Trained community health workers should conduct regular guided tours and answer questions.
- **Develop Targeted Messaging to Address Specific Negative Perceptions:** Communication materials should directly and separately address each identified negative perception. For explosion fear: include safety statistics, diagrams showing safety valves, and testimonials from users. For disgust: frame biogas as a transformed product, scientifically identical to natural gas, and emphasize the environmental benefits of waste recycling. For perceived complexity: demonstrate simple daily operation and announce plans for local technician training.
- **Engage Community and Religious Leaders as Perception Influencers:** Government and NGO programs should first educate and secure endorsement from community chiefs, council of elders, and church/mosque leaders. These trusted authorities should be featured in awareness campaigns and invited to officially inaugurate demonstration facilities. Their public endorsement can substantially reduce cultural resistance and shape positive subjective norms regarding adoption.
- **Integrate Bio-digester Education into School Curricula:** The Rivers State Ministry of Education should incorporate age-appropriate content on sustainable sanitation and bio-digester technology into primary and secondary school science curricula. Children can serve as agents of household attitude change and will constitute the next generation of informed sanitation consumers.

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