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Community Awareness, Risk Perception, and Water-Source Vulnerability: Evidence from Residents Living near Retail Fuel Stations in Gwagwalada Central, Abuja, Nigeria

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ABSTRACT

Retail fuel stations are spreading into the residential and commercial areas of fast-growing Nigerian towns, yet research on petroleum contamination has concentrated on the Niger Delta, and the community-level risks of small, chronic retail spills in secondary towns of the Federal Capital Territory remain poorly documented. This study assessed hazard awareness, risk perception, self-reported exposure and water-source vulnerability among residents living near retail fuel stations in Gwagwalada Central, Abuja. A cross-sectional survey was administered face to face to 305 adult residents (77.6% of the 393 targeted) selected by stratified systematic random sampling within 300 m of stations, in English. Awareness was measured with three objectively scored factual items, and perceived risk with a five-point Likert battery. Associations were examined with chi-square tests. Borehole or well water was the main domestic source for 63.6% of respondents, a plausible pathway for benzene, toluene, ethylbenzene and xylene (BTEX) migration. Although 63.9% knew that fuel spills can contaminate groundwater, only 30.2% knew that benzene is found in petrol and 34.8% that long-term exposure can cause cancer; only 39.3% answered at least two of three items correctly. Perceived risk was highest for fire or explosion (mean 4.51 of 5) and drinking-water contamination (4.36), while agreement that residents are well informed was lowest (2.16). Awareness was not significantly associated with education ($p = .192$) or distance ($p = .954$), but only 19.3% had ever received safety information. Residents feel acutely exposed to a hazard whose chemical basis they largely cannot name, and the deficit reflects access to information rather than education or proximity. Benzene-focused risk communication and water-quality testing for households near stations are recommended.

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INTRODUCTION

Motor vehicle ownership has risen quickly in cities across the developing world, and retail fuel stations have spread just as fast into residential neighborhoods, markets and other crowded places. The qualities that make petroleum products commercially valuable, namely energy density, volatility and chemical potency, also mean that a small operational failure can endanger the people and surroundings nearest a station (US EPA, 2021). In the Federal Capital Territory (FCT), Abuja, rapid and largely

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unplanned urban growth has placed many stations close to homes, open markets, schools and the shallow hand-dug wells and unprotected boreholes on which part of the population relies for domestic water (FCTA, 2022).

Stations store large volumes of petrol, diesel and kerosene in underground tanks that become vulnerable to corrosion, overfilling and poor containment management (US EPA, 2021). When fuel escapes, nearby residents face two kinds of risk. The first develops slowly: the soluble aromatic fraction known as BTEX (benzene, toluene, ethylbenzene and xylene) moves through soil into shallow groundwater and can reach wells and boreholes (Abdullahi et al., 2022). Nigerian studies have reported benzene in shallow groundwater near stations at several multiples of the WHO guideline value of 0.010 mg/L (Adekoya et al., 2021; WHO, 2022). The second risk is sudden: flammable vapors accumulate in drains and low-lying spaces near homes, and fires at stations have been recorded in FCT area councils (NEMA, 2023). The health case for concern is well established. The International Agency for Research on Cancer classifies benzene as a Group 1 human carcinogen (IARC, 2023), and sustained low-level BTEX exposure has been linked to neurological, reproductive and developmental effects (ATSDR, 2024).

Whether residents can protect themselves from such hazards depends partly on what they know and how they perceive the risk. Nigerian research on petroleum contamination has focused largely on large upstream spills in the Niger Delta (Achebe et al., 2021), leaving diffuse, chronic risks from the retail sector in secondary towns comparatively under-examined. Where community studies exist, they point to low awareness. Olajide and Akinlabi (2021) reported that a minority of residents living near fuel stations in Ibadan could name the health risks of hydrocarbon exposure, and Okafor et al. (2023) argued that the concentration of hazardous facilities in lower-income settlements is a structural equity concern. Low awareness matters because it weakens self-protective behavior, delays the reporting of symptoms and spills, and reduces community pressure on regulators.

This study draws on the Social Amplification of Risk Framework (SARF), which holds that perceived risk is shaped by cognitive, social and institutional factors and need not track objectively assessed hazard (Pidgeon et al., 2003). Under this lens, low trust in regulators can amplify perceived risk, whereas habituation to a familiar hazard can suppress it. Water-source vulnerability supplies the exposure context: households that depend on shallow groundwater sit on the pathway through which a tank release would reach them. The resulting conceptual framework is shown in Fig. 1.

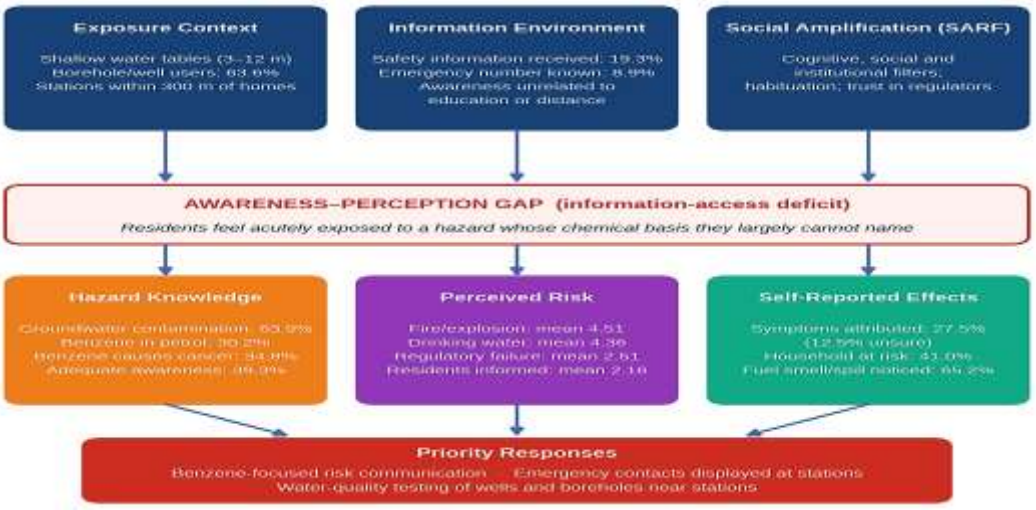


Figure 1. Conceptual framework: exposure context, information access and social amplification of risk as

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drivers of the awareness–perception gap among residents near retail fuel stations in Gwagwalada Central (values from the present survey, n = 305).

The aim of this paper is to assess community awareness, risk perception and water-source vulnerability among residents living near retail fuel stations in Gwagwalada Central, Abuja. It addresses four questions. (i) How much do residents know about the hazards of fuel spills, and of benzene in particular? (ii) How do residents perceive the risks, and how many report symptoms they attribute to nearby stations? (iii) Is hazard knowledge associated with education, distance to the nearest station, or access to safety information? (iv) How many households depend on water sources vulnerable to shallow-groundwater contamination? The findings are perceptions and self-reports, not measured contamination, and they are intended to guide risk communication and to prioritize laboratory follow-up.

MATERIALS AND METHODS

Study Area

The study was conducted in Gwagwalada Central, about 40 km southwest of the Abuja Central Business District along the Abuja–Abaji Expressway, in Gwagwalada Area Council, FCT. The area has a tropical wet-and-dry climate, with rain from roughly April to October and a mean annual rainfall near 1,300 mm (NiMet, 2023). The resident population was estimated to exceed 300,000 (NPC, 2021). Land use is a dense mix of residential, commercial, institutional and informal housing, with active open-air markets (FCTA, 2022). The geology is dominated by Precambrian basement complex rocks overlain by sandy to sandy-loam soils, with seasonal water tables at roughly 3–12 m below the surface (Ezekwe et al., 2022), and many households in informal areas use shallow hand-dug wells or unprotected boreholes.

Study Design and Sampling

The community survey formed one component of a cross-sectional, convergent mixed-methods study (Creswell and Creswell, 2023) that also included a station compliance audit, an operator questionnaire, a regulatory-official questionnaire and GIS analysis; only the resident survey is analysed here. Eligible respondents were adults aged 18 or older who had lived within 300 m of a retail fuel station for at least six months and whose household water was sourced within the household. People unable to give informed consent and current fuel station employees were excluded.

The sampling frame was approximately 20,000 households within the 300 m buffer of at least one station, estimated from the area council population, an average household size of 5–6 persons (NPC, 2021) and assumptions about the proportion of households in the commercial core and within the buffer. The Taro Yamane formula (Kothari and Garg, 2021) at a 5% margin of error gave a target of 393 respondents, distributed across three distance strata (0–100 m, 101–200 m and 201–300 m). Within each stratum, households were selected by systematic random sampling from a random start with a fixed interval. Where no household listing existed, the right-hand-rule traverse served as an equivalent randomisation procedure (Bennett et al., 1991). Community leaders eased access but did not choose respondents. One adult per household was selected systematically (Clark et al., 2022). In total, 305 valid questionnaires were obtained (77.6% of target).

Questionnaire

The questionnaire had five sections: (A) socio-demographic characteristics, including primary water source and self-reported distance to the nearest station; (B) hazard awareness; (C) perceived risk; (D) safety concerns and self-reported exposure; and (E) emergency preparedness. Awareness was measured with three factual items scored 0 or 1 (fuel spills can contaminate groundwater; benzene is found in petrol; long-term benzene exposure can cause cancer). They were summed into an Awareness Index (range 0–3), and “adequate awareness” was defined as at least two correct answers.

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Perceived risk was measured with eight statements rated on a five-point Likert scale (1 = strongly disagree, 5 = strongly agree). Self-reported exposure covered headaches, dizziness, skin irritation, nausea or breathing difficulty that the respondent attributed to station activity, and whether the household felt at risk. The instrument was written in English, translated into Hausa by a professional translator, and back-translated by a second translator.

Data Collection and Analysis

Four trained research assistants administered the questionnaire door to door over six weeks, using tablets or smartphones running an offline-capable electronic form, with paper forms as a backup. Data were analysed in IBM SPSS Statistics version 26 (IBM Corp., 2021). Descriptive statistics (frequencies, percentages, means) were computed for all items. Pearson chi-square tests examined associations between adequate awareness and education and distance band, and between distance band and household risk perception, at a significance level of 0.05. The eight Likert items were treated as separate single-item measures and not combined into a scale.

Ethics

The study followed the ethical standards for postgraduate research at Abubakar Tafawa Balewa University, Bauchi, and the principles of the Declaration of Helsinki (World Medical Association, 2013). Permission was sought from the Gwagwalada Area Council administrative authority before fieldwork. Each participant received a written information sheet and gave written informed consent. Responses were anonymised, no personal identifiers were recorded, and data were stored on password-protected devices.

RESULTS AND DISCUSSION

Respondents and Domestic Water Sources

Of the 305 respondents, 155 (50.8%) were male and 150 (49.2%) females. The sample skewed young and relatively well educated (Table 1): 69.2% were aged 18–35, and 59.0% held tertiary or postgraduate qualifications. By self-report, 50.5% lived within 100 m of the nearest station. Borehole water was the main drinking and domestic source for 144 respondents (47.2%) and wells for 50 (16.4%), so 194 respondents (63.6%) depended on a source with a plausible shallow-groundwater pathway to BTEX migration (Fig. 2). Only 15 respondents (4.9%) had piped supply.

Table 1. Characteristics of respondents (n = 305).

Characteristic	Category	N	%
Sex	Male	155	50.8
	Female	150	49.2
Age	18–25 years	101	33.1
	26–35 years	110	36.1
	56 years and above	23	7.5
Education	Primary or none	24	7.9
	Secondary	101	33.1
	Tertiary	164	53.8
	Postgraduate	16	5.2
Distance to nearest station	Less than 50 m	67	22.0
	50–100 m	87	28.5
	100–500 m	112	36.7
	More than 500 m	39	12.8
Main water source	Borehole	144	47.2
	Well	50	16.4
	Sachet or bottled	96	31.5
	Pipe-borne	15	4.9

Source: field survey. Age bands between 36 and 55 years are omitted for brevity.

The dependence of roughly two-thirds of respondents on groundwater is the central vulnerability finding. It matters because the shallow, seasonal water tables of the basement-complex setting (Ezekwe et al., 2022) leave little vertical buffer between a leaking tank and a hand-dug well. Residents also reported sensory evidence consistent with this concern: 199 (65.2%) had noticed fuel smell, an oil spill or contaminated drainage near a station, 89 (29.2%) had noticed discolored or foul-smelling water in

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their area, and 141 (46.2%) said the nearest station had affected their environment. These are perceptions and do not confirm contamination. In the companion spatial analysis of the same study, 14 of 32 audited stations lay within 100 m of a residence (minimum 45 m) and 20 of 32 within 150 m of a well or borehole (Motunrayo et al., in preparation), which suggests the receptors are physically close.

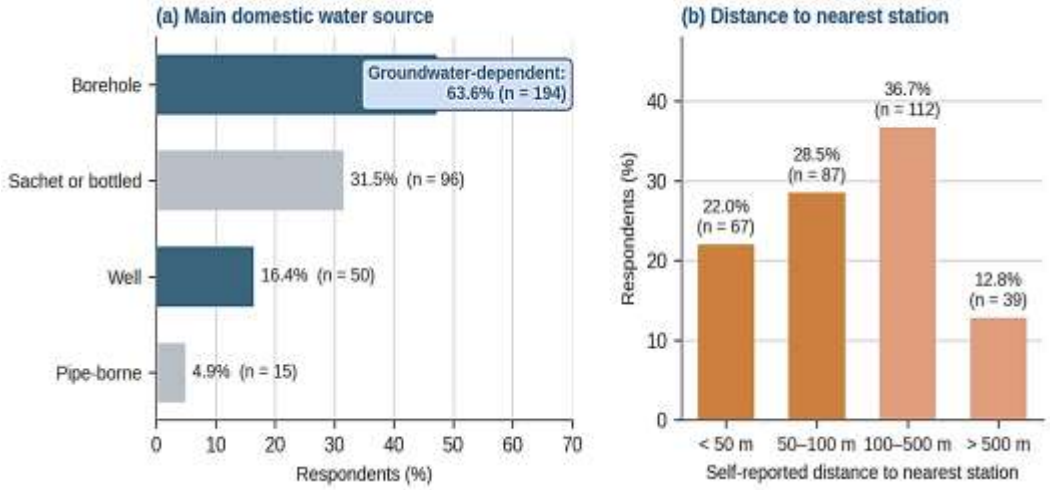


Figure 2. Domestic water sources and proximity: (a) main domestic water source, with borehole and well users (navy) forming the groundwater-dependent group; (b) self-reported distance to the nearest station (n = 305).

Hazard Knowledge: General Awareness Runs Ahead of Chemical-Specific Knowledge

The mean Awareness Index was 1.29 of 3 (43.0%), and only 120 of 305 respondents (39.3%) reached the adequate-awareness threshold. Knowledge was uneven across items (Table 2, Fig. 3a). Nearly two-thirds knew that spills can contaminate groundwater, but fewer than a third knew that benzene is present in petrol, and "I don't know" was the commonest answer on both benzene items.

Table 2. Responses to the hazard-knowledge items (n = 305).

Item	Correct, N (%)	"I don't know", N (%)
Fuel spills can contaminate groundwater	195 (63.9)	not reported
Benzene is found in petrol	92 (30.2)	189 (62.0)
Long-term benzene exposure can cause cancer	106 (34.8)	180 (59.0)

Source: field survey. Mean Awareness Index = 1.29 of 3; at least two items correct: 120 (39.3%).

This pattern suggests that residents recognize spills as a problem in principle but do not know why benzene in particular is dangerous, even though benzene is an established human carcinogen (IARC, 2023). It is consistent with, though higher than, the low awareness reported near stations in Ibadan (Olajide and Akinlabi, 2021). The gap has practical consequences. A household that does not link petrol with benzene has little reason to test or treat well water, to keep children away from forecourt drains, or to report a persistent fuel odor.

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Figure 3. Hazard knowledge and information access: (a) responses to the three hazard-knowledge items (the "I don't know" share was not reported for the groundwater item); (b) adequate awareness, receipt of safety information and knowledge of an emergency contact number (n = 305).

Awareness Reflects Information Access, not Education or Distance

Adequate awareness was not significantly associated with educational attainment, $\chi^2(3, N = 305) = 4.73$, $p = .192$, or with self-reported distance to the nearest station, $\chi^2(3, N = 305) = 0.33$, $p = .954$ (Table 3). By contrast, access to information was very limited: only 59 respondents (19.3%) had ever received safety information about fuel station risks, mainly through radio or television (30 respondents) or social media (29), and only 27 (8.9%) knew an emergency contact number for station incidents (Fig. 3b). The awareness deficit therefore appears to be a failure of information supply and not a by-product of low schooling, which is notable in a sample in which 59.0% held tertiary or postgraduate qualifications. Living next to a station, too, does not teach residents about benzene.

Table 3. Chi-square tests of association (N = 305).

Association	χ^2	df	p
Education and adequate awareness	4.73	3	.192
Distance band and adequate awareness	0.33	3	.954
Distance band and household risk perception	5.71	6	.457

Source: field survey.

The null distance results should be read with care. Respondents were sampled within 300 m of a station, yet 39 (12.8%) reported living more than 500 m away, and distance was collected in broad self-reported bands. Misclassification of this kind would tend to weaken any true distance gradient, so the findings show no detectable association, not proof that distance is irrelevant.

Perceived Risk: Fire and Water Are Feared, Enforcement Failure Is not

Perceived risk was high for the most visible and immediate hazards (Table 4, Fig. 4). Respondents agreed most strongly that proximity to stations raises fire or explosion danger (mean 4.51) and that spills threaten drinking-water quality (mean 4.36), and 78.4% agreed that operations pose a significant health risk. Agreement was weaker on pollution contribution (2.60), regulatory failure (2.51) and inadequate emergency response (2.41), and lowest of all on the statement that residents are well informed (2.16; 72.1% disagreed). Residents therefore feel acutely exposed to a hazard whose chemical basis they largely cannot name.

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Table 4. Perceived-risk statements (five-point scale; n = 305).

Statement	Mean	Agree, N (%)	Neutral, N	Disagree, N (%)
Proximity increases fire/explosion danger	4.51	278 (91.1)	14	13 (4.3)
Spills/leaks threaten drinking-water quality	4.36	281 (92.1)	11	13 (4.3)
Operations pose a significant health risk	4.06	239 (78.4)	34	32 (10.5)
Operations have harmed environmental quality	3.73	205 (67.2)	55	45 (14.8)
Operations contribute to air and land pollution	2.60	64 (21.0)	93	148 (48.5)
Regulators fail to monitor/enforce effectively	2.51	62 (20.3)	76	167 (54.8)
Emergency response protocols are inadequate	2.41	52 (17.0)	71	182 (59.7)
Residents are well informed about risks	2.16	31 (10.2)	54	220 (72.1)

Source: field survey.

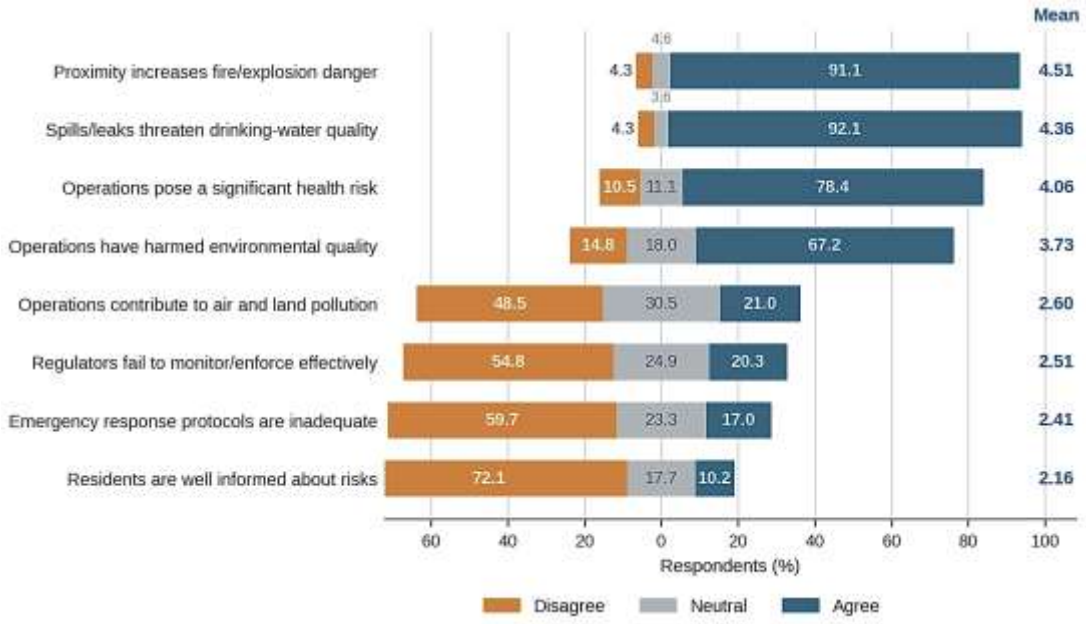


Figure 4. Perceived-risk statements: percentage of respondents who disagreed, were neutral or agreed, ordered by mean agreement (mean at right; five-point scale; n = 305). Neutral shares were calculated from the reported counts.

Through the SARF lens, the pattern is partly as expected and partly not. The strong fear of fire and water contamination fits a hazard that residents can smell and see, and the low rating of resident information matches the objective knowledge results. Yet only 20.3% agreed that regulators fail to monitor and enforce, even though this is the sort of distrust the framework predicts would amplify risk. Possible explanations include habituation, limited visibility of enforcement activity, or ambiguity in the item wording, and the data cannot separate them. The apparent inconsistency between 67.2% agreeing that operations harmed environmental quality and 21.0% agreeing that they contribute to air and land pollution points the same way: the eight statements behave as largely independent opinions, which is why they are reported individually and not summed to a scale. Future

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work should pilot a shorter, conceptually narrower battery.

Self-Reported Symptoms and Household Risk

Eighty-four respondents (27.5%) reported that they or a household member had experienced headaches, dizziness, skin irritation, nausea or breathing difficulty that they attributed to station activity, and a further 38 (12.5%) were unsure, so about two in five suspected a health effect (Fig. 5). Asked whether their household was at risk because of nearby stations, 125 (41.0%) said yes, 88 (28.9%) said somewhat and 92 (30.2%) said no. Household risk perception did not differ significantly by distance band, $\chi^2(6, N = 305) = 5.71$, $p = .457$ (Table 3). Households more than 500 m away were about as likely to feel at risk as those within 50 m. This suggests that perceived household risk is shaped less by exact proximity than by an area-wide narrative of hazard, consistent with the widespread sensory evidence reported above, although this interpretation is untested and the distance measure is imprecise. The symptoms are non-specific and attributed by the respondents themselves, so they indicate concern, not a measured health effect.

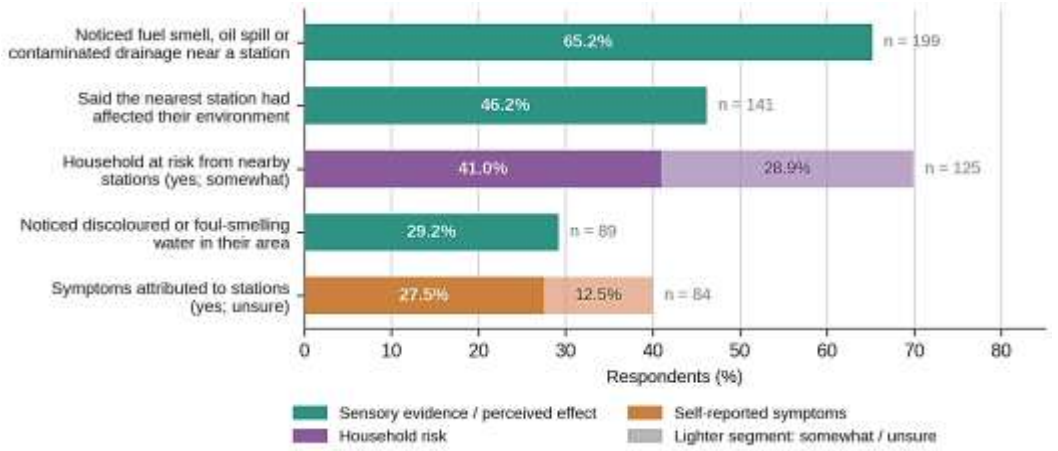


Figure 5. Sensory evidence, perceived effects, household risk perception and self-reported symptoms (% of respondents; n = 305). Lighter segments show "somewhat" (household risk) and "unsure" (symptoms) responses.

Implications for Risk Communication and Water Protection

The results point to three priorities. First, because awareness tracked information access and not education or distance, communication should aim for reach, using radio, community meetings and forecourt signage, and should not assume formal schooling. Second, because general awareness of contamination already exceeds chemical-specific knowledge, messages should name benzene and explain its health effects and its presence in petrol. Third, the fact that 63.6% of households use boreholes or wells, together with the small share who know an emergency number (8.9%), argues for mandatory display of an emergency contact at stations and for water-quality testing of wells and boreholes near stations, starting where stations cluster. The precautionary logic is that waiting for laboratory confirmation before acting on a likely hazard is itself a public-health risk (Okafor et al., 2023), but testing would also show whether the perceived risks match measured contamination.

Limitations

The study is cross-sectional and cannot capture seasonal variation in water tables or spills. The achieved sample (77.6% of target) skewed towards younger and better-educated adults and was collected largely on digital devices, so the results may not generalize to older or less

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connected residents. Distance was self-reported in broad bands, and some respondents reported distances beyond the sampling buffer. The Awareness Index rests on three items and should be regarded as a knowledge screen and not a validated scale, and the Likert items are single-item measures. No water or soil samples were analyzed, so contamination is inferred from exposure context and perceptions. Self-reported symptoms may be affected by recall and attribution bias.

CONCLUSIONS

Residents of Gwagwalada Central who live near retail fuel stations depend heavily on groundwater (63.6% use boreholes or wells), fear fire and drinking-water contamination, and largely lack chemical-specific knowledge of the hazard: only 39.3% showed adequate awareness and fewer than 35% knew that benzene is in petrol or can cause cancer. Awareness did not differ by education or distance, but only 19.3% had received any safety information, which points to an information-access gap that is cheap to address. Benzene-focused risk communication through radio, community meetings and forecourt signage, visible emergency contact numbers at stations, and priority water-quality testing for well and borehole households near stations are recommended, followed by laboratory studies to test whether perceived and measured risks agree.

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