Sociotechnical Misalignment in Industrial Air Quality: Bridging the Perception-Reality Gap Through Community Knowledge in Beaumont-Port Arthur, Texas

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PROBLEM STATEMENT

Beaumont and Port Arthur are two cities in Southeast Texas that host a high concentration of petrochemical refining and petroleum production facilities (Chambers et al., 2025). The presence of extensive petrochemical activity and crude oil refining spanning thousands of acres exposes adjacent "fenceline" communities (i.e., neighborhoods abutting industrial property) to air pollution (Li et al., 2024) and health risks (Gaffney et al., 2010). The region is also characterized by below-national-average incomes and a majority-minority population (Prochaska et al., 2014).

United States air quality monitoring networks are designed for compliance with the Clean Air Act (United States Environmental Protection Agency, 2024), as administered by the Environmental Protection Agency (EPA), rather than for neighborhood-scale assessment (Gardner-Frolick et al., 2025). For regulators and industry stakeholders, a central question is whether ambient concentrations of criteria pollutants meet the National Ambient Air Quality Standards (NAAQS) (Gardner-Frolick et al., 2025). For residents of fenceline communities, a central question is whether the air they breathe is safe and whether they have meaningful input into understanding the air quality around them, given the disparate scales and sensitivities relative to NAAQS. McCarron et al. (2022) further caution that air pollution policies disproportionately focus on outdoor environments, even though people spend most of their time indoors. This misalignment between outdoor and indoor pollution is a gap that compounds the misalignment between monitoring and community needs.

This compliance-oriented approach creates a sociotechnical misalignment. Residents report acute sensory exposures, odors, and visible emissions that may not correspond to regulatory exceedance events (Morris et al., 2004). The disconnect between lived experience and regulatory data can foster mistrust among corporations, regulators, and residents, undermining mitigation efforts (Bruno & Jepson, 2017). Visible emissions coupled with regulatory attainment can erode institutional trust (Couch & Coles, 2011). Mistrust can lower civic engagement, systemically reducing community pressure on regulatory bodies (Bruno & Jepson, 2017), while propagating mistrust toward adjacent media such as water and soil quality (Dory et al., 2017).

This study asks how community perceptions and spatial patterns of industrial air quality reveal sociotechnical misalignment. We explore policy solutions to bridge this gap. We integrate qualitative experiences with technical environmental data to validate community knowledge, mitigate resident concerns, and inform regulatory frameworks that could improve air quality management and social-justice outcomes (McCarron et al., 2022; Commodore et al., 2017).

RESEARCH METHOD

We used a mixed-methods, community-based participatory research (CBPR) framework and held three workshops ($N_{total} = 55$, $n = 13–22$ per workshop) with Habitat for Humanity in Beaumont, Texas, in late 2025 and early 2026. Workshop sampling represented residents from Beaumont and Port Arthur in Jefferson County. Each workshop was semi-structured, one hour long, and included Institutional Review Board (IRB)-approved questions. Sessions were recorded and transcribed with participant permission. We used Dedoose (Salmona et al., 2024) to conduct a hybrid inductive-deductive qualitative content analysis of the three workshop transcripts (Saldana, 2025). Parent categories were derived deductively from the literature (i.e., perceived sources, trust, information sources, health perceptions, and policy priorities), and child codes were developed inductively from workshop transcripts. Intercoder reliability, measured with Mezzich's Kappa (Eccleston et al., 2001), was 0.75, indicating substantial agreement (Landis & Koch, 1977). Participants completed an air quality perception-mapping exercise during the first workshop, in which they color-coded red for poor air quality, black for moderate, and blue for good. To digitize perceptions, we aggregated maps using a majority-rule criterion to produce a composite layer in ArcGIS Online (Esri, 2025). We mapped perception data over the EPA's Toxic Release Inventory (TRI) facility locations using overlay analysis (Bajjali, 2023).

FINDINGS & DISCUSSION

Community-identified poor air quality regions spatially contain the majority of federally inventoried TRI facilities in the mapped area. Industrial facilities were the most frequently coded perceived source of air pollution (n = 28, 8.2% of all codes). Air quality source perceptions had the highest frequency (33.7%, n = 115), followed by health perceptions (17.6%, n = 60), and information sources (15.0%, n = 51). Of 57 TRI facilities in Beaumont, 40 (70%) lie within the community-identified poor air quality region. Of Port Arthur's 34 TRI facilities, 28 (82%) fall within the community-identified poor air quality region. This convergence between participatory mapping and federally inventoried point sources offers spatial corroboration of community knowledge. The aggregate mistrust-to-trust ratio is 4:1 (40:10) from code application frequency in transcripts, with trust referring to overall confidence and assurance in a given institution. Residents mistrust the industry over twice as much as they mistrust regulators.

Technical instrumentation data and self-assessed sensory cues measure different parameters at disparate sensitivities. These findings suggest residents actively mitigate perceived risks through individual action when institutional responses are deemed insufficient or untrustworthy. We infer a negative feedback loop starting with the architectural exclusion of community input via regulatory priorities, in which policymaking records are based on air-monitoring-derived concentrations measured against NAAQS, compounded by the fact that resident observations are not considered regulatory evidence in policymaking. Trust erosion reduces public participation across many civic channels, including state implementation plan comment periods, permit hearings, and community town halls. Reduced civic engagement may weaken the political pressure that shapes air quality rulemaking.

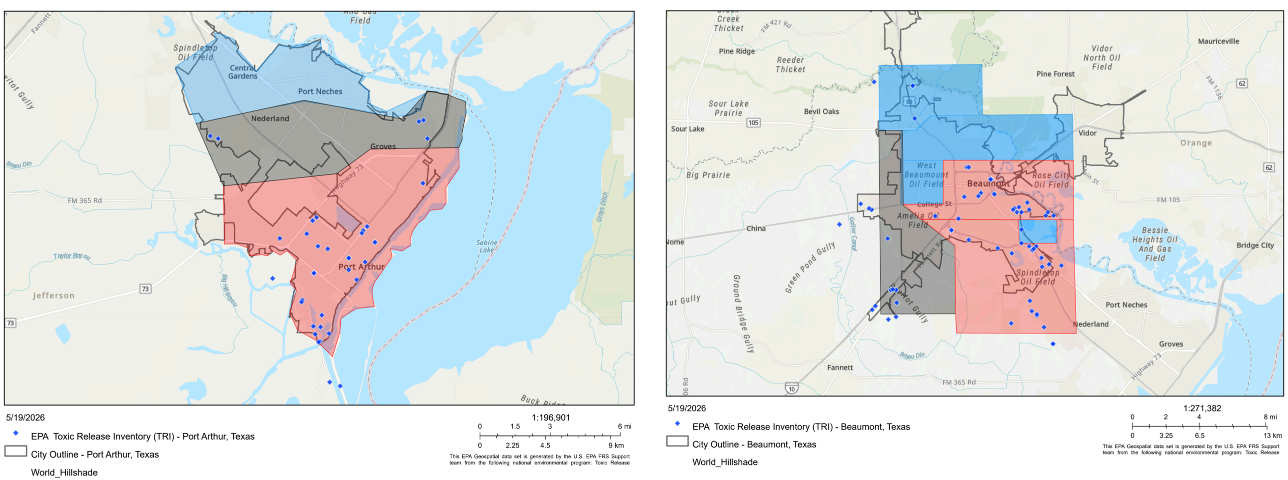

Figure 1. EPA Toxic Release Inventory (TRI) overlaid with community perception in Beaumont and Port Arthur.

Table 1. Frequency of child codes nested within each parent (root) code, applied to participant responses across three community workshops in the Beaumont-Port Arthur region.

Code Applied	Workshop 1	Workshop 2	Workshop 3	Total Count	% of Total
AIR QUALITY SOURCE PERCEPTIONS					
Industrial Facilities	11	7	10	28	8.2%
Flaring & Emissions	6	6	7	19	5.6%
Traffic & Vehicles	8	3	4	15	4.4%
Indoor Contaminants	6	6	9	21	6.2%
Weather & Humidity Factors	5	2	11	18	5.3%

Green Spaces	2	3	2	7	2.1%
Swamp & Marsh Burning	2	2	0	4	1.2%
Construction	1	2	0	3	0.9%
HEALTH PERCEPTIONS					
Respiratory	5	3	11	19	5.6%
Allergies & Sinus	3	1	4	8	2.3%
Cancer & Chronic Diseases	5	0	12	17	5.0%
Psychological & Emotional Impacts	1	3	12	16	4.7%
TRUST PERCEPTIONS					
Mistrust in Industry	3	8	13	24	7.0%
Positive Trust	6	3	1	10	2.9%
Mistrust in Regulators	2	3	6	11	3.2%
Mistrust in Monitoring Data	1	1	3	5	1.5%
INFORMATION SOURCES					
Self-Assessed Sensory Sources	11	5	15	31	9.1%
Government	2	10	1	13	3.8%
News	1	3	0	4	1.2%
Phone Apps	1	2	0	3	0.9%
POLICY PRIORITIES					
Community Involvement	5	8	4	17	5.0%
Stronger Enforcement	1	3	2	6	1.8%
More Industry Responsibility	1	3	2	6	1.8%
Air Quality Monitoring	2	1	4	7	2.1%
ADAPTIVE BEHAVIORS					
Air Purifiers & Filtration	4	8	5	17	5.0%
Staying Indoors	3	1	1	5	1.5%
Home Modifications	4	0	1	5	1.5%
Timing Outdoor Activities	2	0	0	2	0.6%

IMPLICATIONS

Environmental governance in fenceline communities could triangulate three data domains: community knowledge, empirical measurements, and spatial-demographic context. This iterative approach creates feedback loops in which each modality reshapes the questions posed to the others, ensuring policies remain responsive to quantitative measurements and community perceptions. A policy framework that incorporates resident concerns, regulatory aims, and governance realities could address the information deficit in community participation. Policy solutions could also address the communication gap between community residents and industrial operators, a fundamental structural deficit in participatory governance.

Based on direct resident concerns elicited through the three workshops, we propose policy interventions that could bridge knowledge gaps and misalignment between perception and environmental spatial data: timely notification of violations to elected officials, community engagement incentives through tax abatements at the state legislature level, revisions to new source review grandfather clause provisions, local hiring requirements to establish vested community interest, youth empowerment through junior councils, air purifier and sensor distribution programs, and consumer confidence reports analogous to EPA-mandated water quality reporting. These interventions address the identified trust gaps and protective behavior patterns while aligning with institutional and community objectives.

The same air quality monitoring architecture (Gardner-Frolick et al., 2025) and misalignment structures govern fenceline corridors nationally, including the Houston Ship Channel (Nicole, 2021), Louisiana's Cancer Alley (Smith et al., 2025), and the Chevron Refinery corridor (Sanchez et al., 2019). Future work could disentangle which determinants are sector-specific (e.g., point-source pollutants from industrial facilities versus nonpoint-source emissions from transportation and construction) and which generalize across sectors.

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