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Repairing the Anthropocene

Toward Civic Validity for Environmental Data Justice

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Abstract

If the Anthropocene is an epoch of extraction causing ecological harm and risks that sever relations between bodies and land, it can also be an epoch of repair and reconnection. Recent scholarship in studies of science, technology, and society (STS) and environmental data justice (EDJ) has challenged many forms of extraction, from oil and gas extraction to data mining, as they perpetuate systems of oppression that produce environmental injustice. This paper positions regulatory systems as mechanisms of extraction, primarily through what Kirsty Howey and Timothy Neale (2022) call "divisible governance," which fragments the environment by soil, air, water, time by days or years, bodies by organ systems, and isolates compounds while manipulating time. This paper positions EDJ as a framework geared towards repairing these divisions epistemically through community and civic sciences. Drawing from three ethnographic scenes of air monitoring collaborations among STS scholars, residents living near oil and gas extraction in Karnes, Texas, scientists, and community organizers, the paper shows how incorporating diverse tools and community-driven methods to monitor health-harming toxicants such as hydrogen sulfide (H_2S), volatile organic compounds (VOCs), and black carbon, can help to surface community experiences. These reflections offer a vision of "civic validity," which includes standards for science and future community-based air monitoring and research that aims to improve ecological health and livelihoods.

Keywords: environmental data justice; civic science; extraction; divisible governance; environmental health

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Civic Air Monitoring Across Landscapes of Extraction

The Eagle Ford shale play is a sedimentary rock formation containing underground oil and shale gas deposits that stretch approximately 650 kilometers across southeast Texas (Speight 2020). As of 2021, it supplies more than 4,721 active oil and gas wells in Karnes County, a rural region more than an hour's drive southeast of the City of San Antonio (Texas Railroad Commission 2023).

Until the 2010 US Shale Revolution, a period fueled by government loopholes and research funding in hydraulic fracturing to benefit industry growth, the Eagle Ford shale was less conducive to oil and gas extraction than other Texas counties.[1] Colloquially known as "fracking," hydraulic fracturing pumps fluids, including water and anthropogenically produced hazardous compounds called toxicants, into horizontally drilled wells to crack the bedrock and release previously hard-to-reach oil and natural gas (Vera 2022). This surge has benefited some of Karnes' 14,836 residents, who have noticed the growth of local businesses and public necessities like a new hospital and school (U.S. Census 2022; Vera 2022). Yet, this economic resurgence comes at the expense of ecological and public health, as oil and gas activity emissions are ultimately harmful.

Bordering Mexico, Texas has a sizeable Latine demographic, a gender-neutral term referring to people with Latin American heritage, such as myself. This includes 58% of Karnes residents counted in the U.S. Census plus undocumented immigrants living in the area (U.S. Census 2022).[2] This group experiences widespread environmental injustice, which is environmental harm disproportionately directed towards marginalized or oppressed groups such as Black, Indigenous, People of Color (BIPOC), and lower-income communities (Pellow 2017). In the Eagle Ford region, for example, Jill Johnston et al. (2020) found that nighttime flaring, which burns excess oil and gas, usually occurs closer to Latine homes than white non-Latines. Malfunctioning flares produce black carbon, a small solid suspended in the air called particulate matter that attaches to volatile organic compounds (VOCs), which are toxicants such as carcinogenic benzene that readily evaporate in the air (Vera 2022).

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[1] Fracking operations do not report the chemicals they inject into the ground to the US Environmental Protection Agency. This 2005 Energy Policy Act loophole was created by Dick Cheney, former Vice President (2001-2012) and CEO of Halliburton, an oil/gas service company (Wylie et al. 2017). US Department of Energy also contributed $137 million to fracking research from 1978 to 1992 (Merrill 2012).

[2] Latino is masculine, Latina feminine, and Latine is gender neutral. As Latine is an ethnicity, racial identities vary. For example, I am of mixed American (European settler) and Latin American (European settler, Indigenous, Afro-Caribbean) ancestry.

I first traveled to Karnes in July 2015, as I was beginning my PhD in Sociology at Northeastern University with STS scholar Sara Wylie's research group, which we eventually named the Wylie Environmental Data Justice (WEDJ) lab. Despite my previous activism to ban fracking in New York State, I had never witnessed fracking or its tangible impacts. This reality came to light while driving through an area in Karnes where, two months prior, Encana Corporation had lost control of the pressure in a fracking well. This resulted in a “blowout,” which released natural gas, oil, and other toxicants, killed vegetation and livestock, and sent five families to a motel. At the same time, the company prevented them from returning home for several weeks (Vera 2022). It is the occurrence of such acute disasters, along with chronic emissions, which has made residents living near oil and gas extraction seek data with which to understand and communicate their “exposure experiences” (Adams et al. 2011).

In Karnes, the agencies that collect and disseminate toxicant data include the Texas Commission on Environmental Quality (TCEQ) and the US Environmental Protection Agency (EPA). The Texas Railroad Commission, led by three elected commissioners, is the main overseer of extractive activities and the primary authority on the operations of oil and gas facilities (Vera 2022). These agencies' decisions about permit renewals or penalties for facility violations directly affect communities. However, although the agencies are tasked with protecting the environment, undue industry influence—what is known as regulatory capture—means that it is the adversely affected public that is burdened with proving harm, which is made difficult by many barriers to obtaining the required environmental data (Richter, Cordner, and Brown 2021). Regulatory capture can result in “undone science,” where research is actively discouraged or obfuscated by powerful economic and state actors who thereby avoid accountability (Frickel et al. 2010). Among the “done” science that informs environmental regulations and oversight, much is "top-down," exclusively oriented to institutional expertise that often leaves out community concerns.

In response to these gaps and hurdles, many communities, activists, and scholars have begun working together on collecting and analyzing environmental data relating to toxicant levels and health effects. Because these "bottom-up" community science collaborations involve communities designing and leading studies, they pose challenges to "top-down" research (Dosemagen and Gehrke 2017). Many community science projects include a dimension of civic science, which "questions the state of things, rather than a science that simply serves the state" (Fortun and Fortun 2005, 50). They also emphasize participatory production of knowledge and information sharing in the civic sphere. In this paper, I build on these ideas to consider how civic science can become better equipped to question the state and its systems on environmental matters. This follows sociologist David Pellow's (2017, 27) call for "a deeper grasp of the entrenched and embedded character of social inequality- reinforced by the power of the state - in society and therefore a reckoning with the need for transformative...approaches to realize environmental justice."

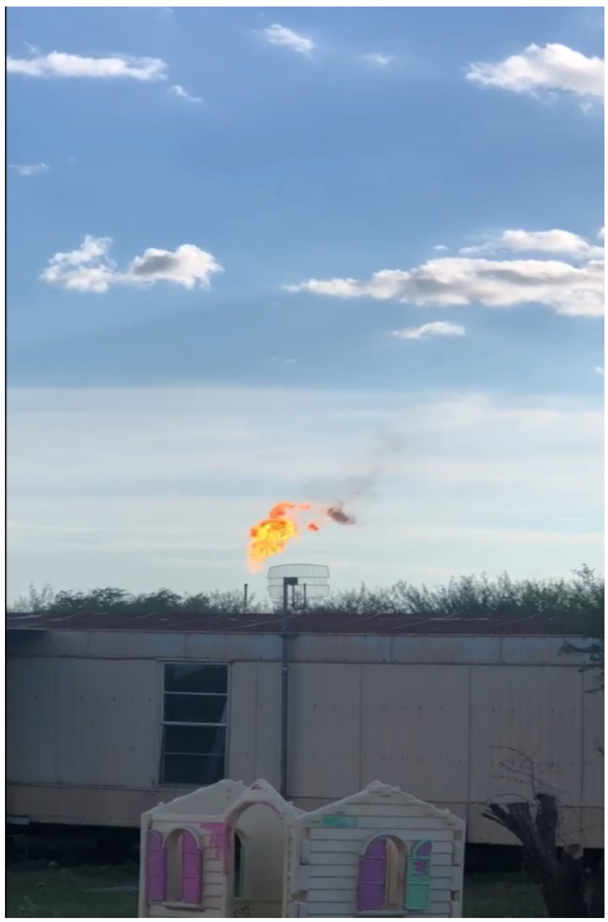

Figure 1. A flare trailing black smoke behind KARE member Mrs. Lópezes' backyard (Photograph courtesy from Mrs. López)

The primary aim of my first trip to Karnes with WEDJ Lab was to develop a Do-It-Yourself civic science tool using photo paper to measure and visualize hydrogen sulfide (H_2S). Hydrogen sulfide is a gas, recognizable for its smell of rotten eggs, which damages neurological and respiratory systems, and causes death or unconsciousness at high levels (Wylie et al. 2017). I was joined by Sharon Wilson, the senior community organizer for Texas at a national non-profit organization called Earthworks, which had connected us to residents. We planned to deploy the tool on "fencelines," which are the boundaries between private or public property and industrial facilities. Deborah Thomas, the Executive Director of Wyoming-based non-profit organization ShaleTest, led this campaign because of her experience with the tool and VOC monitoring. During the trip, we met Priscilla Villa, who was then interviewing residents living near facilities about health symptoms associated with oil and gas-related compounds for her master's thesis in Applied Anthropology. Those symptoms are wide-ranging and include chronic bronchitis, dizziness, nosebleeds, rashes, and neurological and gastrointestinal symptoms. Eventually, Villa became an organizer with Earthworks, and we reported our collective results, which included findings of relatively high VOC concentrations outside an immigrant detention facility, in a white paper called "Hazards in the Air" (Villa et al. 2017). Residents formed the group Karnes Area Residents for the Environment (KARE) to monitor air and organize for political attention and more robust regulatory oversight after we presented these results at a Town Hall meeting.

Over a six-year period, these concerns and collaborations became the topic of my doctoral research. During this time, I spent four months in Karnes, where I worked on community-level air monitoring campaigns with KARE, activists and scientists, and established close relationships with co-researchers, visited homes, and conducted numerous formal and informal interviews. I also joined the Environmental Data and Governance Initiative (EDGI), a collaborative network of academics, scientists, and technologists archiving and monitoring federal environmental data at risk of obfuscation or deletion by the climate change-denying Trump administration then in charge (Vera, Walker, et al. 2019). Among other things, I co-led a working group that used Environmental Data Justice (EDJ) as a framework for engaging community and civic science critiques of state-based data practices and emphasizing community access to data and involvement in its production, storage, stewardship, and dissemination (Dillon et al. 2019). Thus, EDJ was developed to respond to how the state and industry construct and perpetuate intersecting systems of oppression that produce environmental injustice (Vera, Walker, et al. 2019).

This framework guided my approach toward air monitoring collaborations in Karnes, and in this paper, I seek to solidify these connections. I begin with an overview of EDJ as an emerging framework rooted in feminist STS, civic and community science, and critiques of authoritative institutional notions of validity that produce environmental data injustices harming fenceline communities. This outline transitions into three ethnographic scenes, each reflecting on civic and community-engaged air monitoring projects in Karnes—and one additional campaign in Saskatchewan, Canada. I end by synthesizing these experiences to envision "civically valid" standards for environmental science and EDJ that surface exposure experiences to materially improve the lives of residents experiencing environmental injustice.

Why Fenceline Communities Need Valid Environmental Data

Our air monitoring campaigns gave rise to much discussion about how to capture high concentrations to validate community experiences without jeopardizing our health. What caused this dilemma? TCEQ had installed a statewide network of state-of-the-art air monitor trailers to measure oil and gas production-related toxicants, such as H_2S, VOCs, and particulate matter. Although this enormous undertaking had been celebrated by environmental activists and the broader public, the data was soon used to dismiss community concerns (Vera 2022). For instance, based on an analysis comparing toxicant measurements to respective thresholds, levels under which the state considers concentrations safe (Texas Commission on Environmental Quality 2013), a TCEQ technical specialist discussing Eagle Ford in a YouTube video tour of the Floresville monitor 25 miles north of Karnes concluded that "shale play activity does not significantly impact air quality or pose a threat to human health." As later evidenced by disasters like the Encana blowout and thoroughly documented links between fracking and health harms (Villa et al. 2017), this was not accurate.

The limits of the TCEQ monitor became apparent to me at the aforementioned Town Hall meeting, where we showed how the health symptoms reported in 18 resident interviews aligned with the documented health effects from toxicants (Villa et al. 2017). Residents noted that the monitor in the town center could not fully capture exposure miles away and closer to oil and gas facilities, as the air tends to "whip around" with northwesterly winds meeting southeast winds from the Gulf of Mexico on hilly terrain. One consequence of this discrepancy was that TCEQ rejected the odor log—a complaint form that residents can submit when they smell foul odors—submitted by KARE member Mrs. Sharp, because the wind direction differed from TCEQ's own records. Moreover, TCEQ agents often arrive to investigate sites after more than a day has passed, which often means that the issue has passed (Vera 2022). Even so, Texas recently passed Senate

Bill 471, which relieves TCEQ of the obligation to investigate repetitive facility complaints or repeated complaints from individuals if previous submissions within a given period appear "unsubstantiated" (Springer 2023). By elevating prior "substantiation" as a criterion for action, this assumes that TCEQ investigation records more accurately reflect industry activity than residents' exposure experiences. The systematic dismissal of those experiences led a Karnes resident to reflect that he wants "peace of mind" from knowing what is in the air at his home and that he is "tired of being a guinea pig."

Figure 2. TCEQ monitor in Karnes County (Photo taken by TCEQ personnel

How did the TCEQ monitor network turn from an apparent achievement on behalf of fenceline residents and environmental activists into a tool for dismissing their concerns? To address this question, it is helpful to frame these monitors as components of an "experimental system," which the historian Hans-Jörg Rheinberger (1997, 238) defines as the "local, technical, instrumental, institutional, social, and epistemic aspects" of experimental activity. This includes components inherent to the TCEQ monitor, such as how it works through gas chromatography/mass spectrometry (GC/MS), the toxicants it measures, the regulatory thresholds used to contextualize these measurements, institutions such as TCEQ and the company Orsat that sells and maintains the monitors, the people analyzing data, established research norms and protocols, industry actors influencing legislation, Eagle Ford Shale geology, and other components charted in *Figure 3*. These elements may overlap in some categories as they inform one another as well as the outcomes of monitoring.

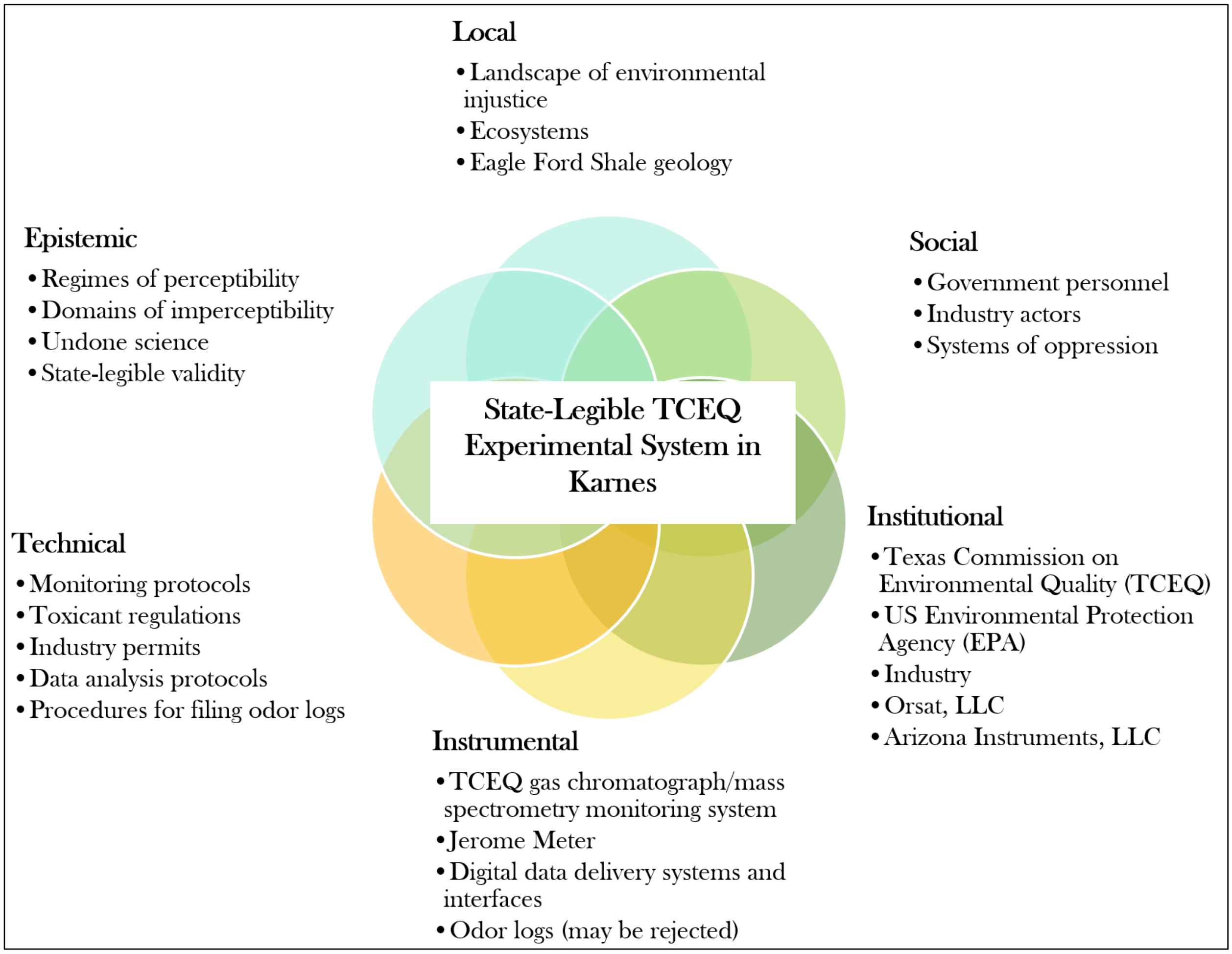

Figure 3. Key components of the TCEQ monitor experimental system

The TCEQ's experimental system contains protocols and regulations emblematic of a "permission to pollute system," where state agencies permit individual facilities to release toxicants under respective thresholds (Liboiron 2021). Such regulatory systems burden communities with proof of harm instead of requiring industries to prove safety.[3] Yet, this is often a facade, as many compounds have no safe concentration or are not regulated at all. For instance, even though

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[3] Ideally, government policies would implement a precautionary principle, which Kriebel et al. (2001: 871) list as having four central components in environmental science: "taking preventive action in the face of uncertainty; shifting the burden of proof to the proponents of an activity; exploring a wide range of alternatives to possibly harmful actions; and increasing public participation in decision making.

Karnes air monitoring has detected benzene, which a 1948 American Petroleum Institute report deemed unsafe at any level, TCEQ sets a threshold for benzene at 180 parts per billion (ppb)[4] over one hour and 1.4 ppb over one year (Villa et al. 2017). In their discussion of regulations in the Northern Territory of Australia, Kirsty Howey and Timothy Neale (2022: 1084) characterize such thresholds, which vary across multiple agencies and predefined timespans, as emblematic of "divisible governance" that involves the "fragmentation of environmental risks between temporal and jurisdictional categories." Permitting facilities to pollute toxicants as isolated entities over predefined measures of time also fragments the temporalities of chemical aggregation and the realities of mixing from multiple pollution sources (Vera 2022).

As communities and researchers struggle to piece scientific understandings of chemicals and their health effects together, they often face challenges to the legitimacy of their data. This is apparent when seeking procedural justice through state mechanisms, such as redress in a courtroom and more robust regulatory oversight, where it is difficult but necessary to have the resources and expertise to prove harm (Ottinger 2013). In Karnes, for example, one lawsuit against a company failed because the courts require data from at least two epidemiological studies confirming a two-fold risk from environmental emissions to prove causation (Cranor 2017). Echoing historian James Scott (1998), I refer to such data as "state-legible," a notion that captures how the state organizes diverse, interrelated elements into standardized, simplified components—such as chemical thresholds—to maintain its authority. In this sense, state legibility is a function of divisible governance.

State-legible data must be "valid," which "signifies consistency within a system or between systems." Such validity is sought, for example, by using common tools and replicable methods across institutions. However, consistency is different from "the reliability of the system in representing natural phenomena" (Oreskes, Shrader-Frechette, and Belitz 1994, 642). For instance, the TCEQ air monitor locations are chosen according to EPA protocols, and they use regulatory standard technologies to provide precise, quantitative measurements. When TCEQ analyses concluded that Eagle Ford Shale extraction posed little health risk and rendered Mrs. Sharp's odor logs invalid, they used scientifically valid data to dismiss and quell community concerns instead of taking them seriously. These practices construct what STS scholar Murphy

[4] One part per billion is equivalent to one drop of water in an Olympic-sized swimming pool.

(Métis) (2006) calls a "regime of perceptibility;" but by rendering a single way of understanding exposure valid, they also turn civic experimental systems into "domains of imperceptibility" that are not state-legible.

Dominant notions of validity lead to instances where, as Howey and Neale (2022: 5) write, "state and non-state actors superficially appear to protect the environment while actually deferring, forestalling, or eliminating their accountability for the consequences of extractivism." Even if individual agents aim to protect health and the environment, limited resources, legislation such as Texas Senate Bill 471 and threshold-centered analyses, which take the epistemic superiority of TCEQ for granted, produce harm through inaction. More accountable civic practices would involve state and industry air monitoring with community oversight. This would include working with residents to choose locations and design assessments while keeping the data open and accessible. To move beyond harm towards practices that make the imperceptible perceptible, I propose civic validity based on EDJ as norms, values, beliefs, and definitions for legitimacy and validity in science that challenges extractive logic and uplifts exposure experiences.

Environmental Data Justice as a Feminist STS Challenge to Extraction

Extractive processes like fracking require data, or its suppression, to relinquish liability. The effect is to prolong and justify colonial arrangements and the commodification of land through extraction. State systems for environmental data and notions of validity accomplish this partly through divisible governance, which separates the environment by soil, air, water, time by days or years, bodies by organ systems, and isolates compounds while segmenting time. Here, I argue that underlying this form of governance is extractive logic, which I and other EDGI members defined as "the logic of pulling relations out from bodies and lands into data directed towards other ends" in our work on environmental data justice (Vera, Walker et al. 2019, 1013). As discussed above, this has resulted in regimes of perceptibility dismissive of exposure experiences and perpetuating pollution and interlocking systems of oppression. This raises the question of how environmental data justice (EDJ) can challenge this extractive logic.

In one of the first articles conceptualizing EDJ, EDGI members Dillon et al. (2019) particularly drew from feminist STS as a theoretical basis for EDJ that recognizes how incorporating different types of standpoints and situated knowledges into environmental data practices can form a more comprehensive understanding of environmental problems. This work is based on DataRescue events in 2016 and 2017 where we, as EDGI members, along with academic and community partners, archived and tracked at-risk environmental data at risk of being obfuscated by the Trump administration across the US and Canada. Here, we integrated diverse knowledges and expertise through civic engagement. For instance, I could contribute without being a software programmer using my knowledge of environmental policy to help identify essential datasets. Reflecting on this work from a feminist perspective, we found ourselves working within the tensions of our struggle to save regulatory environmental data despite its aforementioned role in supporting extraction (Vera, Walker et al. 2019)

As STS scholarship has documented, community and civic air monitoring projects conducted by activists and scholars have similarly integrated feminist methodologies to co-produce knowledge about exposure experiences and support democratic participation (Vera 2022). While community science ideally anchors research in residents' questions and needs from project inception to conclusion (Dosemagen and Gehrke 2017), civic science emphasizes "how scientists themselves understand, strategize, and take responsibility for their situatedness in social context" while doing science for the public good (Fortun and Fortun 2005, 44). Sara Wylie et al. (2014) conceptualized “civic technoscience” as material interventions into the politics and practices of science, for instance, by making new tools like the H_2S photo paper tool, which will be introduced shortly. EDJ echoes this call for alternative data practices as it seeks to move beyond what critical race and Indigenous studies scholar Eve Tuck (Unangax̂) refers to as "damage-centered research" (Tuck 2005) that only seeks to prove harm.

Community air monitoring projects have wrestled with the tensions of seeking justice within and outside state systems. The Western New York Clean Air Coalition, an organization with which I am familiar in Buffalo, NY, for example, spent years monitoring the air and building relationships with state agencies to eventually shut down a polluting facility producing coke (a fuel derived from coal) Using federal enforcement data and an EPA-approved bucket sampling method, they found high levels of toxicants such as benzene.[5] Regulators questioned the study’s validity, and the community felt they could not trust the state agents. Yet, these tensions eventually transformed into a collaboration with state personnel and led to the funding of a year-long, scientifically valid,

[5] The community group Global Community Monitor partly developed this bucket sampling method. It used low-cost buckets lined in Tedlar plastic to grab air and analyze it for toxicants related to oil and gas processing in Louisiana (Shapiro et al. 2023).

and state-legible, study with real-time air monitors (Shapiro et al. 2023). In 2009, nine years after the initial bucket sampling, federal law enforcement agents arrested the plant manager for violating federal law, and the facility closed in 2018, almost a decade later. However, it took decades to resolve these urgent issues and they caused lifelong harm.

Given the limits of procedural justice, researchers have begun to explore how experimental systems can generate meaningful data outside state legibility. When I entered Northeastern University, another PhD student, Jacob Matz, was doing civic air monitoring with communities near oil and gas extraction sites. He worked with the Southwest Pennsylvania Environmental Health Project in Pennsylvania, measuring particulate matter with a Speck monitor that is not EPA-approved, and which community researchers found to be "a black box that needed to be opened to understand its efficacy" (Matz, Wylie, and Kriesky 2017, 481). Eventually, the Speck helped the community to make sense of their exposure experiences and even to garner media attention. Jennifer Gabrys and Helen Pritchard (2022) have conceptualized research that is not necessarily state-legible but still meaningful to fenceline residents as "just good enough data." Among the diverse purposes served by "just good enough data" are developing personal understandings of exposure and the environment, determining whether emissions are present, building collective efficacy (Vera 2022), gaining media attention (Malivel 2019), or making preliminary research for state investigations (Shapiro et al. 2023).

Given shared purposes and principles, civic science, as a political intervention seeks to move beyond the limits of state-legible data. By promoting bottom-up and democratic participation in research to improve livelihoods, community science can support communities and researchers seeking environmental data justice.

Civic Experimental Systems for Environmental Data Justice

The Karnes air monitoring campaigns discussed below contain elements of civic and community science that embody "transformative approaches to realize environmental justice" albeit not perfectly or completely. The following scenes reflect on the successes and complications in building academic-community-activist partnerships, seeking state accountability, designing and conducting air monitoring studies, and using or developing tools. *Figure 4* provides an overview of the actors and locations comprising these experimental systems and a map of Karnes and the oil and gas wells across the Eagle Ford Shale.

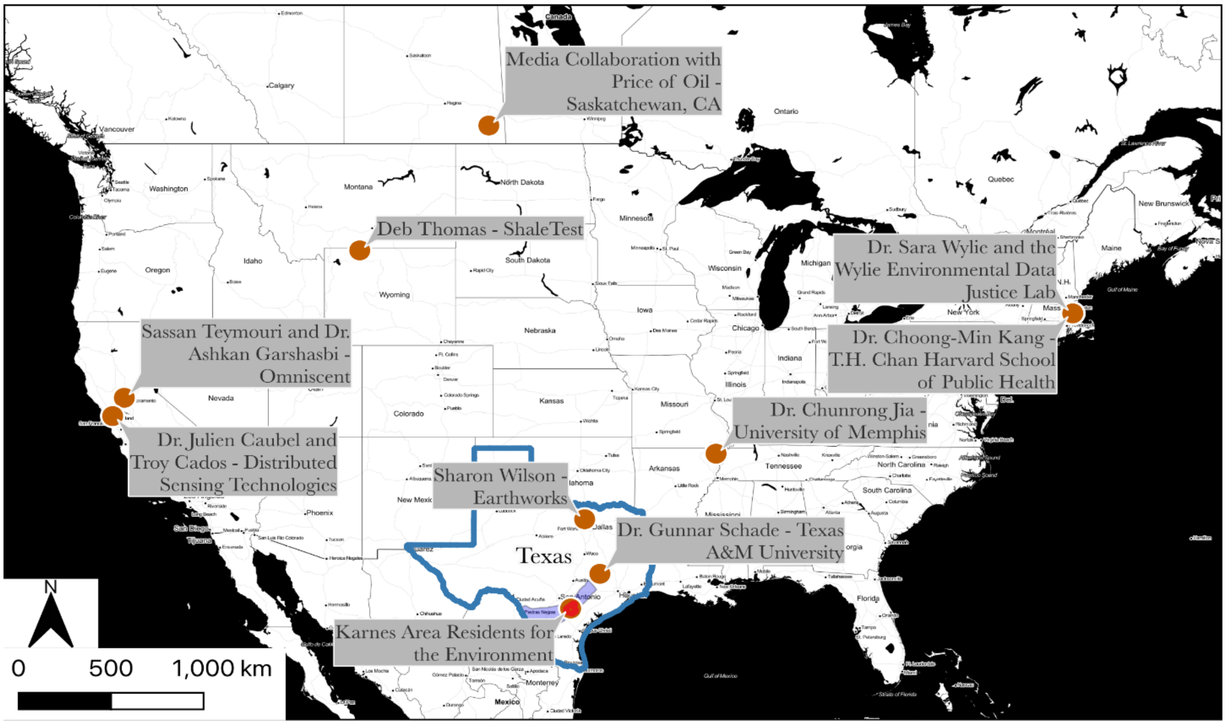
Re-Appropriating Tools to Challenge Extraction

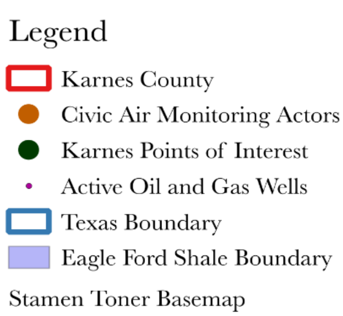
The TCEQ's history of dismissing complaints does not prevent Sharon Wilson from training community members to submit them. She has noticed more state oversight when residents regularly register complaints and coordinate to submit them simultaneously. Wilson files complaints while traveling across Texas to record facility leaks with Earthworks' $100,000 FLIR Optical Gas Imaging camera (*Figure 5*), which captures usually invisible infrared waves emitted by hydrocarbon gases, including methane, a greenhouse gas contributing to climate change, and VOCs (Villa et al. 2017). Wilson was in the front passenger seat pointing out drilling and processing sites, saltwater disposal wells, and stinky frac ponds that Karnes residents had asked us to investigate. At each site, Wilson stretched her arms out through the passenger window and scanned the environment for leaks that looked like textured grey and black clouds on the screen (*Figure 6*). As these videos only capture one scene in time, Wilson repeatedly visits facilities to capture consistent fugitive emissions and shed light on chronic exposure.

The constant buzzing sound of the FLIR signaled that this was not a regular camera but a delicate, powerful piece of equipment. As a military and industry-standard tool for detecting oil and gas leaks and ensuring that facilities meet environmental regulations, the FLIR was developed by Teledyne, a company whose mission is to make technologies to "enhance perception and awareness" for the military and oil and gas industry (Teledyne FLIR 2022). Wilson supports communities living near these facilities without the resources to purchase FLIR technology or access its costly training and certification. After the trips, she posts FLIR videos to Earthworks' channel on YouTube to allow viewers to make sense of the images themselves and confirm whether a facility is leaking hydrocarbons. The videos often end with a slide that says, "seeing is believing" (*Figure 7*). She has stressed to me the importance of these videos as part of "the court of public opinion," which can build legitimacy in the civic sphere.

During the air monitoring campaign in Karnes, Wilson recounted how in March 2014, she recorded a significant release (*Figure 6*) and immediately filed a series of complaints to TCEQ. The same week, Gunnar Schade, an atmospheric scientist at Texas A&M University, found that

Relevant Actors, Places, and Tools in Air Monitoring Scenes





The top map displays the collaborators across North America who were involved in Karnes air monitoring or the development of the photo paper tool used in Karnes. The extent of the Eagle Ford Shale is in light blue.

The bottom map shows Karnes County, the location of the US Immigration and Customs Enforcement Detention Facility, nearest city and TCEQ office, and locations of the TCEQ air monitors discussed in this paper. This is laid over the boundaries of the Eagle Ford Shale and active oil and gas wells (data from FracTracker 2021).

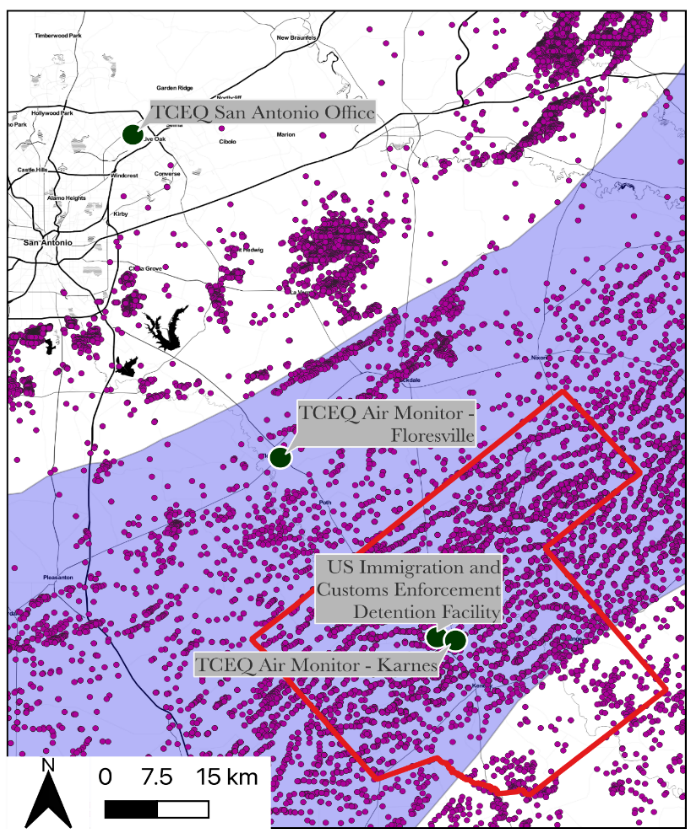


Figure 4. Maps of actors, tools, and places across narratives

Figure 5. A picture of Sharon Wilson and her FLIR camera that she posted on her blog, TXSharon's Blue Daze

the Floresville TCEQ monitor reported high levels of VOCs. This was the same monitor the aforementioned TCEQ technical specialist had used to conclude in a video tour that the risk of oil and gas activities was minimal on the Eagle Ford Shale Play. But, this time, the monitor was used differently. While TCEQ considered its data representative of air across the Eagle Ford and came to their conclusion by comparing the data to thresholds, Schade characterized the concentrations of toxicants in a particular plume moving across the monitor's path. Schade's approach accounts for hyperlocal variations, while TCEQ characterized a large region using limited data.

Schade sought to contextualize the data by asking environmental activists if they knew who had filed a complaint to TCEQ about the plume he had found. This contact list included Wilson, and it became evident that the FLIR images and TCEQ monitor data that informed Schade's air dispersion model complemented one another, effectively building together two forms of situated knowledge. They enabled identification of the source of the hydrocarbon emissions at the same facility (Schade and Roest 2016).

Given the high purchase and maintenance costs of the TCEQ monitor and FLIR and their certification requirements, civic validity in general should not be envisioned as dependent on such

Figure 6. Screenshot of FLIR video of the large release at Marathon Sugarhorn in March 2014. The grey clouds are hydrocarbons (methane and VOCs) rising above the pad site structures, including two flares (the bright white dots) and tanks (Taken by Sharon Wilson)

Figure 7. A screenshot of the Earthworks logo with the words, “seeing is believing” that appears at that appears at the end of the YouTube FLIR videos.

sophisticated technologies. Yet, we see the emergence of civic validity in how Wilson and Schade reappropriated the tools from institutions working within extractive logics and used them to surface community exposure experiences. This created forms of legibility beyond the state in both public and academic settings. Since the material aspects of the tools and their forms of usage can both either challenge or support extractive systems, this first scene, therefore, reveals the muddiness of civic validity with arenas of environmental data justice.

Do-It-Yourself Photopaper and the Quest for Scientific Validity

The prevalence of expensive and difficult-to-use monitors has led KARE to work with WEDJ Lab to develop alternative air monitoring tools and methods.

Past industry lobbying and regulatory capture have prevented EPA from requiring facilities to report chronic H_2S emissions. This also prevents residents from knowing more about their own exposures since agency tools and monitoring protocols are geared towards acute releases (Wylie et al. 2017). Rendering these political critiques into material interventions, WEDJ Lab developed the photo paper tool to visualize chronic H_2S exposure over one to three weeks (Vera, Malivel, et al. 2019).[6] At approximately $1 per canister compared to the $15,000 industry and regulatory standard Jerome H_2S Meter (*Figure 8*), the photo paper contains a layer of light-sensitive silver gelatin that darkens with H_2S exposure, from bright white to tan to brown-black (*Figure 6*). We collaborated with KARE and communities across Washington state, Wyoming and Montana, and Saskatchewan to co-design studies, for instance, choosing sample locations that investigate particularly odorous areas and deploying then picking up samples. Then, the samples were mailed to WEDJ Lab for processing in a darkroom.

Once the samples were no longer light-sensitive, WEDJ Lab visualized H_2S by overlaying scans of the samples on Google Maps or other software, or by placing them on printed maps. In this way, we were able to visualize baseline concentrations or dispersed emissions from a single source, such as a well or discharge canal.

[6] Initially, the volcanologist Claire Horwell developed it to map chronic community exposure to H_2S from a volcanic lake in New Zealand (Horwell et al. 2005). Then, members of the Public Lab for Open Science and Technology began deploying the photo paper near concentrated animal feeding operations and oil and gas development (Wylie et al. 2017).

Figure 8. Jerome meter and its digital readout (Photo taken by author)

The results thereby made visible, were easily interpretable, visually compelling, and rich with meaning. In subsequent work, we sought to further leverage the ‘charisma’ of the photo paper to establish the validity of this civic science method (Pine and Liboiron 2015; Wylie et al. 2017).[7] Since the paper's gelatin layer also contained sulfur from H_2S exposure, the tool operated as an “indexical design,” which simultaneously represented and contained traces of the measured object (Offenhuber and Telhan 2015; Wylie et al. 2017). This unique aspect of its design allowed us at WEDJ Lab to collaborate with Harvard scientist Choong-Min Kang, who used X-ray fluorescence (XRF) technology to analyze the masses of sulfur and silver embedded within the photo paper to establish a method for estimating H_2S quantitatively. We collocated the paper at a sewage treatment plant with known ambient H_2S alongside the Jerome and other tools, validating the photo paper through quality assurance and control protocols such as including blank and duplicate samples. Then, we began developing a colorimetric scale (*Figure 9*) with scans of photo paper samples in correspondence with estimated H_2S for users without XRF access. The publication of

[7] With funding from the JPB Foundation provided through the T.H. Chan Harvard School of Public Health.

our results in the journal *Atmospheric Environment* (Vera, Malivel, et al. 2019), was a significant step in validating the tool in the academy and on fencelines.

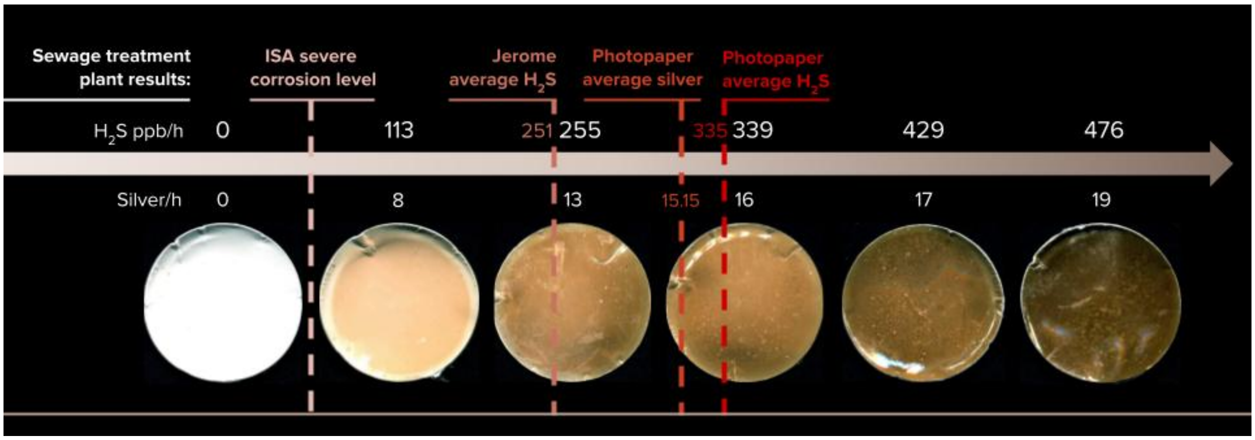


Figure 9. Current version of the colorimetric scale of the photopaper based on sewage treatment plant results, created by Garance Malivel, the author, and other members of the Wylie EDJ Lab

Despite these successes, the photo paper alone would be insufficient to bring justice through the state no matter how dark. It did, however, push us to think hard about what validation requires both within regulatory frameworks and outside in 'the court of public opinion.' Unlike the Jerome, FLIR, and TCEQ monitors, users could adapt the design to their needs and preferences. For instance, we created how-to guides and changed the design from rectangular photo paper strips in small black film canisters to circles secured in asbestos samplers, preventing the paper from falling out in the field and making it easier to load into the XRF machine (Wylie et al. 2017). While garnering media attention, the tool also provided informal education among community users, and it helped to mobilize residents and build partnerships. In Saskatchewan, Canada, we collaborated with a media team called "The Price of Oil" that connected us to fenceline residents, and we worked with them to address their H_2S concerns (Malivel 2019). After reports showed visible results, the company owning a well on one property swiftly improved its technologies (Malivel 2019). WEDJ Lab member Garance Malivel (2019: 6), who helped a family identify H_2S near a well on their ranch, subsequently characterized the data as "operative data," significant for "mak[ing] visible hazardous exposure and the mechanisms of risk production" while "lay[ing] the ground for meaningful community engagement"–Much like Wilson's FLIR work, the public dissemination of visually compelling data helped to validate exposure experiences and build partnerships.

Even though WEDJ Lab was developing this tool as a civic technoscience project to challenge the status quo of regulatory science, we still recognized the importance of scientific validation for improving livelihoods. This tool was inexpensive, flexible, and easy to use, and for that reason effective in building collective advocacy. By promoting civic engagement and supporting livelihoods outside state-legible systems, aspects of the tool including data indexicality, charisma, and operativity embodied civic validity. As a concept inspired by feminist technoscience, then, civic validity activates multiple ways of understanding air and exposure in support of fenceline livelihoods and experiences that also need to be legible to state institutions.

Finding Scientific Significance Outside Threshold-Based Logics

For my own dissertation fieldwork, KARE and I deployed automated thermal desorption (ATD) tubes, which are stainless-steel tubes that absorb air to measure integrated concentrations of VOCs over one to three weeks. These tubes were developed with both community science and scientific validity in mind by environmental health scientist Chunrong Jia. By using the EPA method TO-15 to derive VOC concentrations from the absorbent material inside the tubes, they made it possible to capture fenceline exposures over week-long periods (*Figure 10*).

Figure 10. ATD tube deployed at a resident's home (Photograph taken by author)

Like the TCEQ monitoring system, method TO-15 uses automated gas chromatography technology to collect data (Jia and Fu 2017). We also collocated one set of tubes with a digital weather station and, through a small startup company called Omniscent, a monitor that measures benzene, toluene, and xylene in real time (*Figure 11*). However, the COVID pandemic began in the middle of this study, and I had to leave Texas. As a testament to their developing expertise in air monitoring, residents carried on the sampling and successfully completed the study without me.

Figure 11. The Omniscent monitor with specks of brown-black solid material hypothesized to be black carbon (Photograph taken by author)

Despite the pandemic lockdown, we received the results from Jia's lab within weeks. To our dismay, the VOC concentrations seemed inconclusive and insignificant when compared to thresholds. Yet, Omniscent engineers Sassan Teymouri and Ashkan Garshasbi reported similarly low VOC levels with a tone of excitement. They had noticed sticky, black solid material on the intake tube leading into the instrument filter. The machine would have been ruined if the filter had not been installed. I was reminded of how Mrs. López and I had noticed a black-brown sticky substance—"gunk," as we called it—which covered the monitor and back of their home facing the facility. At the time, I had wiped the spots off somewhat nervous about damage (*Figure 12*). But since our focus was on VOCs, we had moved on. Now, the Omniscent engineers had materialized the connection by suggesting this was black carbon.

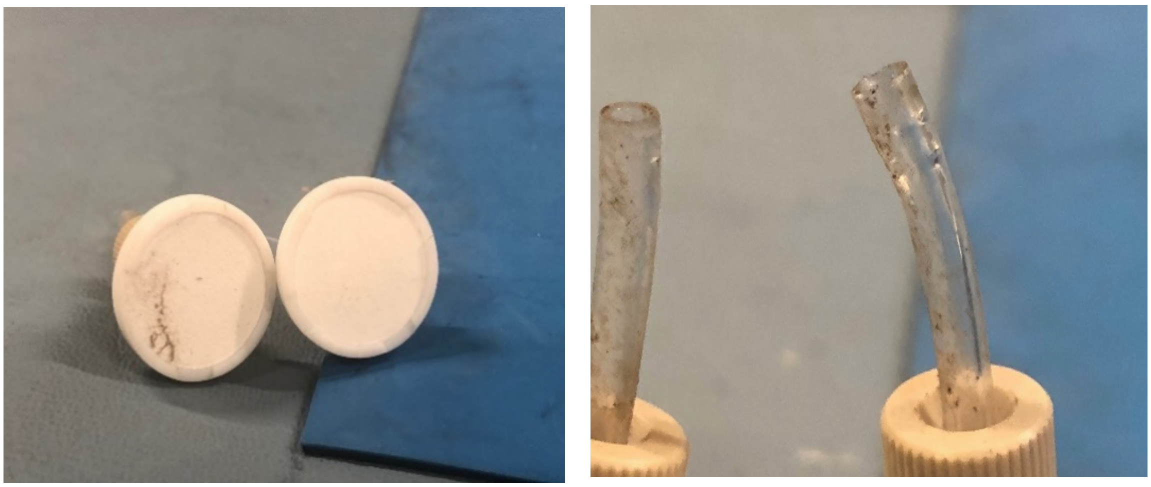


Figure 12. Black carbon on filter and tubes leading into Omniscent monitor (Photograph courtesy of Omniscent)

After this news, I thought about Mrs. Sharp's description of flares at nighttime as "a birthday cake with too many candles all the time." Although EPA regulations only allow "smoking flares" for five minutes in a two-hour period, the Lópezes can often see smoking for extended lengths of time with their own eyes, only 200 meters away (See *Figure 1* above). The particles were black carbon. I immediately searched for black carbon monitors and community-based studies and came across the names of Julien Caubel and Troy Cados, scientists who ran a startup called Distributed Sensing Technologies. They enthusiastically offered a loan, and, with Mrs. López, we collectively designed a testing plan. For the initial experiment, Mrs. López placed the monitor outside and brought it inside during times of extreme sun and heat or heavy rain. When Caubel and Cados reported to us, they were amazed by such high levels of black carbon concentrations in a rural environment. As *Figure 15* shows, the black carbon concentrations ranged from 0 to 64.539 $\mu g/m^3$ (a unit of mass per volume), with the highest levels when the wind came from the facility's direction.[8] We conducted further tests in the winter of 2021 when the dominant wind direction

8 For comparison, a study in Manhattan subway stations measured black carbon concentrations ranging from 5 to 23 $\mu g/m^3$ underground and street-level concentrations upwards of 3 $\mu g/m^3$ (Vilcassim et al. 2014).

differed. These results were much lower than in the summer (*Figure 14*), and similar patterns both outside and inside where the concentrations were lower.

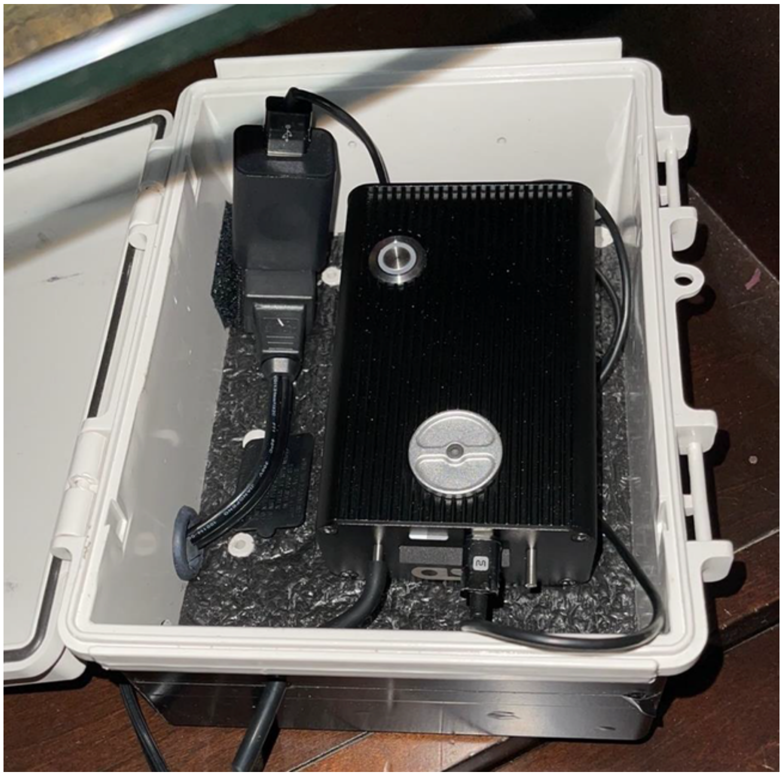


Figure 13. The black carbon monitor, courtesy of Mrs. López

In contrast with TCEQ investigators, who pack up and leave after receiving low results of a single pollutant, continued assessment of different pollutants led to the identification of significant sources of resident health problems. In turn, this highlights why it is so important to allow residents' knowledges and intuitions to guide research beyond the monitoring of regulated pollutants. Black carbon remains within a domain of imperceptibility from the point of view of state institutions, but engineers such as Caubel and Cados are working to make the toxicant data accessible to fenceline residents through dashboards, cost-effective and scientifically valid monitors, and by building relationships with communities so they can know more about their exposure experiences. However, the question of whether we should want to advocate for regulatory thresholds that imply "safe" levels of exposure remains.

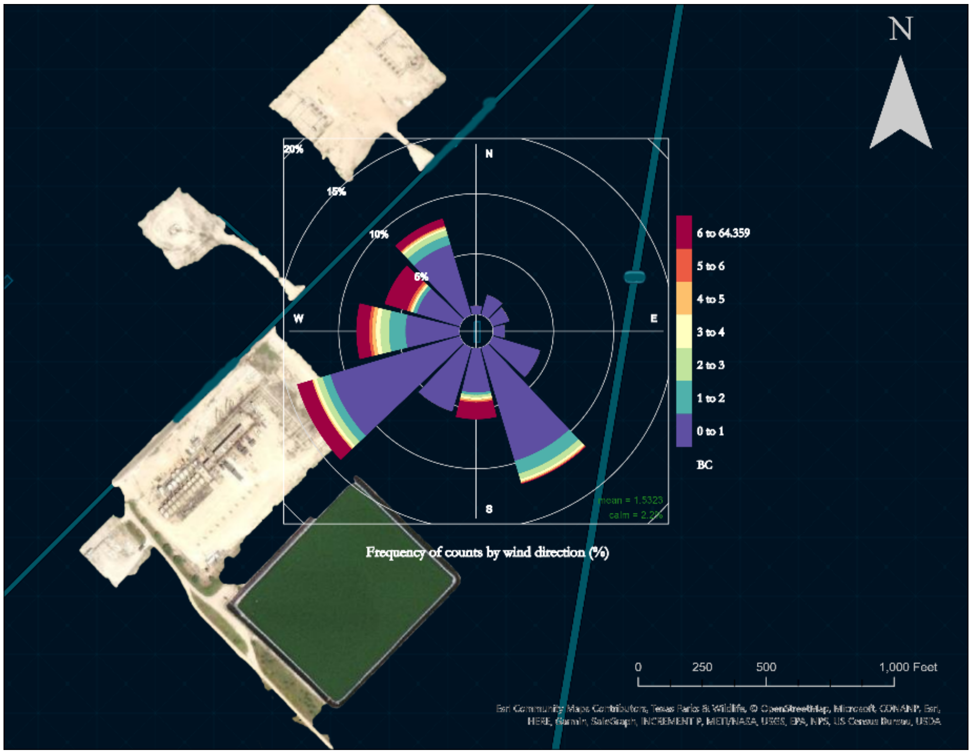


Figure 14. Black carbon monitoring results in summer 2020 (map created by author)

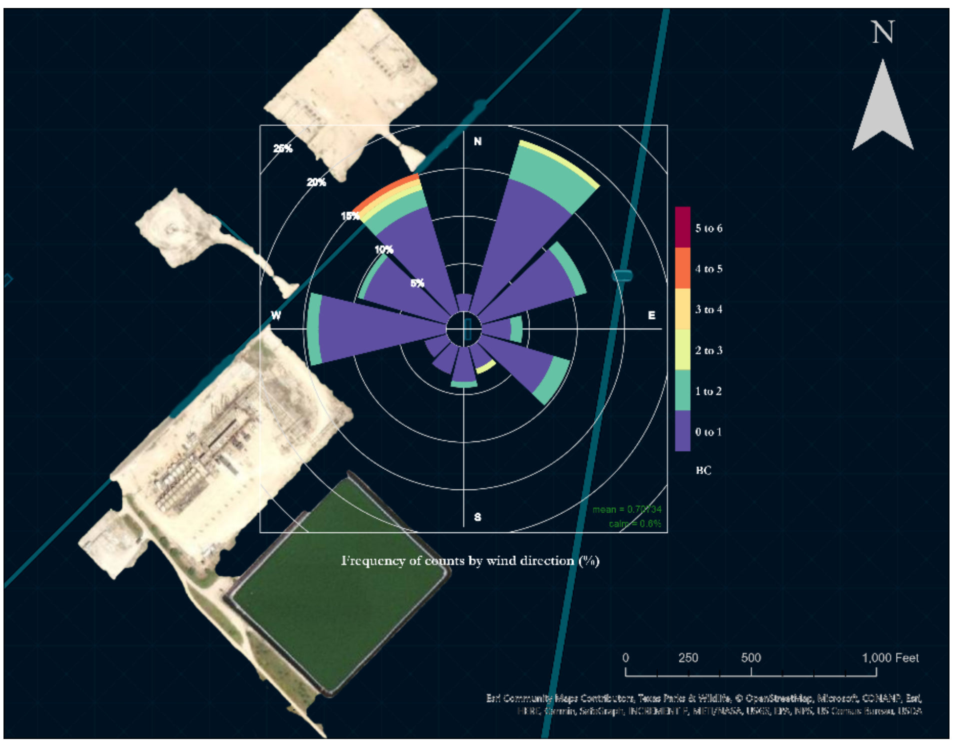


Figure 15. Black carbon monitoring results in winter 2021 (map created by author)

Civic Validity: 'Seeing' is Believing

By producing experimental systems operating with an extractive logic, divisible governance fragments time, social relationships, and peoples', including scientists, residents, and politicians', understanding of the environment. Additionally, extraction manipulates time since drilling operations retrieve oil and gas that formed over millions of years in a matter of days.

As we have seen, TCEQ experimental systems based on these temporal divisions favor extraction by rendering exposure experiences imperceptible. Meanwhile, the confinement of regulatory science to lists of compounds influenced by industry lobbyists has prevented the discovery of pressing problems such as black carbon. In such ways, the pathways for redress through state-legible experimental systems carry a history of diminishing and invisibilizing community concerns through data gaps and a lack of comprehensive, inclusive science.

In response to these issues and reflecting my own research experiences, I position civic validity as a way to map the connections (Howey and Neale 2022) that divisible governance fragments.

In Karnes, relations converging across land, humans, and technologies emerged from alternative experimental systems built by a network of engineers, scholar-activists, and community members. While the air monitoring scenes with KARE and others did not happen exactly as planned and did not win a lawsuit or prevent a facility from operating, they contain many valuable elements that make perceptible emissions from oil and gas extraction that are usually obscured by prevailing institutional hierarchies of expertise.

With reference to these experiences, I seek here to conceptualize civically valid science as providing tools with which to reconnect these fragments and surface previously imperceptible exposure experiences outside and within regulatory systems.

Figure 16, which shows the components of a civically valid experimental system, includes TCEQ's experimental system while seeking to diminish, but not erase, the harm it produces. In light of the framework for environmental data justice outlined in this paper, I suggest that the kind of civic science required to inform valid future fenceline monitoring and research must at least include: 1) Visibility, 2) Access, 3) Context, and 4) Community-led inquiry.

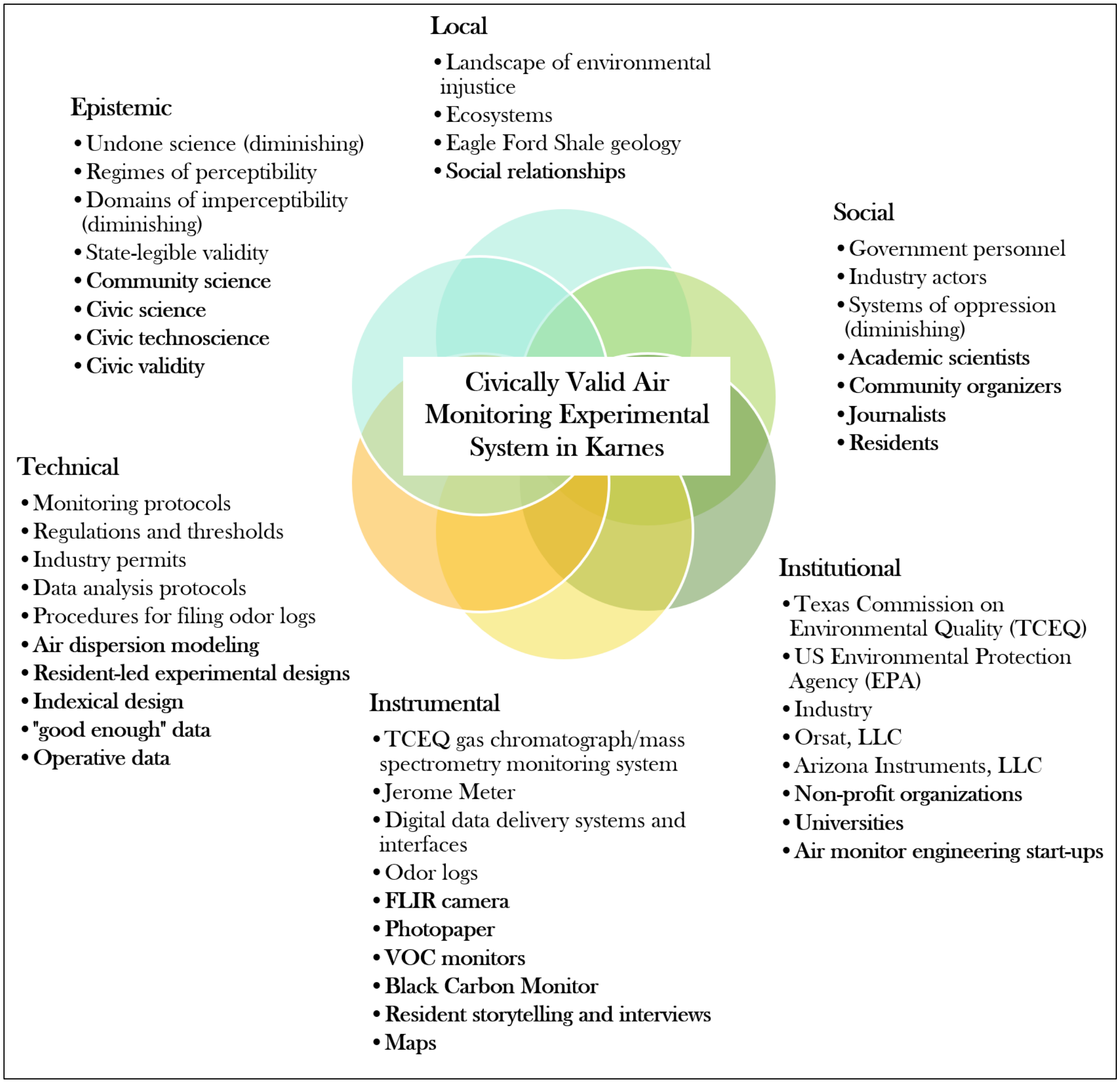


Figure 16. New experimental system for civically valid monitoring. Bolded terms are the components added to the TCEQ experimental system

As environmental data justice attends to how systems of oppression render specific data and experiences imperceptible or perceptible in the interest of extraction, *visibility* is crucial. Practices for visibility include surfacing systematically the dismissed exposure experiences of residents who want to be heard and respecting the confidentiality of those who do not. Data visualization and media publicity have proven effective means of making exposure visible. For instance, Wilson used the FLIR videos to generate public support on social media, informing official complaints to TCEQ and supporting a scientific study. Omniscent and Distributed Sensing Technologies also utilized digital dashboards to make data more accessible and visible in real-time to users, and much of the air monitoring data could be incorporated into interpretable maps. Mapping was essential for interpreting the photo paper, a tool that embodies the data visualization elements of indexical design and charisma.

Not all efforts to produce and disseminate data successfully deliver information to the public. This calls attention to the fact that *access* is also very important. Residents have had trouble accessing TCEQ data through its complicated digital interface, and access can also be understood as limited whenever data is visualized without context. Moreover, some tools are inaccessible because they are expensive and difficult to operate. As we have seen, DIY alternatives like the photo paper, how-to guides, and outreach efforts among scientists and academics can enhance access to knowledge and data about environmental exposure among affected communities.

Central to civic validity is the critique of scientific authority and top-down regulatory experimental systems that assume a clear-cut epistemic authority where abstract scientific knowledge is elevated above local knowledge and experiences. *Context* matters. Our experiments with integrating different knowledges and tools to guide the air monitoring leverage feminist principles of valuing diverse types of expertise, and of incorporating various standpoints for a more comprehensive view of exposure experiences. This means that contextualizing data with relevant standpoints such as the hidden political background of compounds or thresholds, data provenance, or contestations, is central to environmental data justice. It provides civic science with tactics to counter the harms that exclusively state-legible regimes of perceptibility produce.

In the case of the TCEQ monitor, for example, instantaneous measurements can be helpful with the caveat that they do not represent all exposures in an area. This contextualization might prevent regulators from dismissing fenceline monitoring data of toxicant concentrations below thresholds in regions heavily populated by polluting facilities.

Combining scientific and local knowledge led to findings from lines of *community-led inquiry* that would not have happened if the focus had been exclusively on scientific validation. For instance, Wilson's public reports to TCEQ, made as a lay citizen, expanded Schade's analysis and guided his inquiry, which led to indisputable identification of the plume's source. The Lópezes and Omniscent engineers collaboratively inquired into black carbon. Unlike TCEQ research which often begins too late and stops too early, these lines of inquiry were civically valid because they took fenceline experiences seriously for long enough to find the harmful toxicants.

Across these four values, civic validity wrestles with the tensions between proving harm in a way that is good enough to convince communities and that may become legible to a system of regulation guided by an extractive logic where permission to pollute is systematically granted. Since civic validity seeks ecological health and community well-being, it does not necessarily exclude threshold-based analyses. Industry and regulatory-standard tools have indeed brought a degree of scientific validity to the studies, which, considering the context, can be components in civic validation if the science that has been 'undone' (Frickel et al. 2010) starts being done in a manner that legitimizes community experiences with toxicant exposure. For instance, the photo paper and ATD tubes can represent chronic exposure, and the real-time monitors from Omniscent and Distributed Sensing Technologies can take instantaneous measurements on a regular basis over long time periods. Pathways toward community goals can include such analyses, but it is vital that this is only a beginning.

Conclusion

In this paper, I have positioned civic validity broadly as a challenge to extraction and its data practices, which perpetuate oppressive systems of environmental data injustices. Environmental studies and STS scholars can play significant roles in building relations by refusing research approaches that favor extraction. We can work with forms of civic validation in mind as we plan and conduct our studies. For researchers working with communities, further standards and norms that comprise civic validity can emerge based on the experiences of other fenceline residents who respond to extraction through knowledge and data-making. It is worth considering to which extent standards of civic validity can apply across case studies and which components are specific to each community, culture, place, tools, methodologies, and goals. As emphasized by the environmental justice framework, civically valid standards should ideally be sufficiently flexible and adaptable to work for community needs among the unique landscapes and places harmed by extraction. Broader questions relate to how civic validity would be in systems less based on 'permission to pollute' than in the US and Canada. How might it be adapted, for example, for systems that interpret the precautionary principle as requiring proof of safety rather than harm? Or outside of settler colonial sovereignty?

How might scientists in the academy and regulatory spheres go about seeking civic validity? Working from within, such researchers may actively seek to incorporate community knowledge, and they may recognize and legitimate these forms of knowledge as providing guidance contextualizing and informing their work. Schade's work, for example, exemplifies an openness to let community voices and public complaints guide scientific research. In cases where incorporating community knowledge or needs is not as relevant, such as chemistry experiments exploring toxicants' molecular makeup, the methods and findings can and should still be made publicly available. Civic validity can emerge by making state-legible forms of science such as exposure science and epidemiology more transparent as a situated form of knowledge in the public sphere through accessible, contextualized videos or articles. This could encourage civic participation in regulatory decision-making while acknowledging that state-legible science is valuable but not the only or necessarily most effective way to understand exposure experiences.

The Anthropocene is an epoch of extraction, but I envision it also as an epoch where relations can be built and repaired. Civically valid science offers one kind of mechanism through which these reconnections happen. Civic validity can challenge but not necessarily reverse the time manipulation that regulatory systems and extraction impose by incorporating multiple tools and methods. By imagining alternative systems for science that challenge extractive practices even when we can't avoid them, it becomes possible to draw closer to environmental data justice for fencelike communities and others.

References

Adams, Crystal, Phil Brown, Rachel Morello-Frosch, Julia Green Brody, Ruthann Rudel, Ami Zota, Sarah Dunagan, Jessica Tovar, and and Sharyle Patton. 2011. "Disentangling the Exposure Experience: The Roles of Community Context and Report-Back of Environmental Exposure Data." *Journal of Health and Social Behavior* 52 (2): 180–96. doi:10.1177/0022146510395593.

Clinton, Marshall. 1948. "API Toxicological Review: Benzene." New York, NY: American Petroleum Institute Department of Safety.

Cranor, Carl. 2017. "How Demands for Ideal Science Undermine the Public's Health." In *Tragic Failures: How and Why We Are Harmed by Toxic Chemicals*, edited by Carl Cranor, 0. Oxford, UK: Oxford University Press. doi:10.1093/acprof:oso/9780190635756.003.0005.

Dillon, Lindsey, Rebecca Lave, Becky Mansfield, Sara Wylie, Nicholas Shapiro, Anita Say Chan, and M. Murphy 2019. Situating data in a Trumpian era: The environmental data and governance initiative. Annals of the American Association of Geographers, 109(2), pp.545-555.

Dosemagen, Shannon, and Gretchen Gehrke. 2017. "Civic Technology and Community Science: A New Model for Public Participation in Environmental Decisions| Tecnologia Cívica e Ciência Comunitária: Um Novo Modelo de Participação Pública Em Decisões Ambientais." *Liinc Em Revista* 13 (1). Instituto Brasileiro de Informação em Ciência e Tecnologia.

Fortun, Kim, and Mike Fortun. 2005. "Scientific Imaginaries and Ethical Plateaus in Contemporary U.S. Toxicology." *American Anthropologist* 107 (1): 43–54.

Frickel, Scott, Sahra Gibbon, Jeff Howard, Joanna Kempner, Gwen Ottinger, and David J. Hess. 2010. "Undone Science: Charting Social Movement and Civil Society Challenges to Research Agenda Setting." *Science, Technology, & Human Values* 35 (4): 444–73. doi:10.1177/0162243909345836.

Gabrys, Jennifer, and Helen Pritchard. 2022. "Environmental Sensing Infrastructures and Just Good Enough Data." In *The Nature of Data: Infrastructures, Environments, Politics*, edited by Jenny Goldstein and Eric Nost. Lincoln, Nebraska: University of Nebraska Press.

Haraway, Donna. 1988. "Situated Knowledges: The Science Question in Feminism and the Privilege of Partial Perspective." *Feminist Studies* 14 (3): 575–99.

Harding, Sandra G. 1986. *The Science Question in Feminism*. Ithaca, NY: Cornell University Press.

Horwell, Claire J., John E. Patterson, J. A. Gamble, and A. G. Allen. 2005. "Monitoring and Mapping of Hydrogen Sulphide Emissions Across an Active Geothermal Field: Rotorua, New Zealand." *Journal of Volcanology and Geothermal Research* 139 (3): 259–69. doi:10.1016/j.jvolgeores.2004.08.010.

Howey, Kirsty, and Timothy Neale. 2022. "Divisible Governance: Making Gas-Fired Futures during Climate Collapse in Northern Australia." *Science, Technology, & Human Values*, January. doi:10.1177/01622439211072573.

Jia, Chunrong, and Xianqiang Fu. 2017. "Diffusive Uptake Rates of Volatile Organic Compounds on Standard ATD Tubes for Environmental and Workplace Applications." *Environments* 4 (4). http://www.mdpi.com/2076-3298/4/4/87.

Johnston, Jill E., Khang Chau, Meredith Franklin, and Lara Cushing. 2020. "Environmental Justice Dimensions of Oil and Gas Flaring in South Texas: Disproportionate Exposure among Hispanic Communities." *Environmental Science & Technology* 54 (10): 6289–98. doi:10.1021/acs.est.0c00410.

Liboiron, Max. 2021. *Pollution Is Colonialism*. Durham, NC: Duke University Press.

Malivel, Garance. 2019. "Addressing Community Exposure to Hydrogen Sulfide in the Saskatchewan Oilpatch: Interdisciplinary Investigations as a Lever to Expose Industrial Risk." Master's Thesis, Toronto, ON: York University.

Matz, Jacob Robert, Sara Wylie, and Jill Kriesky. 2017. "Participatory Air Monitoring in the Midst of Uncertainty: Residents' Experiences with the Speck Sensor." *Engaging Science, Technology, and Society* 3 (September): 464–98.

Merrill, Thomas W. 2012. "Four Questions about Fracking." *Case Western Reserve Law Review* 63: 971.

Murphy, M. 2006. *Sick Building Syndrome and the Problem of Uncertainty: Environmental Politics, Technoscience, and Women Workers*. Durham, NC: Duke University Press.

Offenhuber, Dietmar, and Orkan Telhan. 2015. "Indexical Visualization - the Data-Less Information Display." *Ubiquitous Computing, Complexity and Culture*, 288.

Oreskes, Naomi, Kristin Shrader-Frechette, and Kenneth Belitz. 1994. "Verification, Validation, and Confirmation of Numerical Models in the Earth Sciences." *Science* 263 (5147): 641–46. doi:10.1126/science.263.5147.641.

Ottinger, Gwen. 2013. "Changing Knowledge, Local Knowledge, and Knowledge Gaps: STS Insights into Procedural Justice." *Science, Technology, & Human Values* 38 (2). Sage Publications, Inc.: 250–70.

Pellow, David. 2017. *What Is Critical Environmental Justice?* Hoboken, NJ: John Wiley & Sons.

Pine, Kathleen H., and Max Liboiron. 2015. "The Politics of Measurement and Action." In *Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems*. Seoul Republic of Korea: ACM. https://dl.acm.org/doi/10.1145/2702123.2702298.

Rheinberger, Hans-Jörg. 1997. *Toward a History of Epistemic Things: Synthesizing Proteins in the Test Tube*. Palo Alto, CA: Stanford University Press.

Richter, Lauren, Alissa Cordner, and Phil Brown. 2021. "Producing Ignorance through Regulatory Structure: The Case of per-and Polyfluoroalkyl Substances (PFAS)." *Sociological Perspectives* 64 (4). CA: Los Angeles, CA: 631–56.

Schade, Gunnar W., and Geoffrey Roest. 2016. "Analysis of Non-Methane Hydrocarbon Data from a Monitoring Station Affected by Oil and Gas Development in the Eagle Ford Shale, Texas." *Elementa: Science of the Anthropocene* 4 (March). http://www.elementascience.org/articles/10.12952/journal.elementa.000096.

Scott, James C. 1998. *Seeing like a State: How Certain Schemes to Improve the Human Condition Have Failed*. Yale Agrarian Studies. New Haven, CT: Yale University Press.

Shapiro, Nicholas, Jackie James, Liz Barry, Shaun Crawford, Jennifer Pusatier, Adele Henderson, Timothy Logsdon, Joyce Hogenkamp, and Tom Gentile. 2023. "Refining Relationships: How an Unlikely Community–Scientist Partnership Led to a Historic Environmental Justice Victory." *Environmental Justice* 16 (2). Mary Ann Liebert, Inc., publishers 140 Huguenot Street, 3rd Floor New …: 151–61.

Speight, James. 2020. "Chapter Three: Reservoirs and Reservoir Fluids." In *Shale Oil and Gas Production Processes*, edited by James Speight, 139–220. Gulf Professional Publishing. doi:10.1016/B978-0-12-813315-6.00003-8.

Springer, Drew. 2023. *Texas Senate Bill 471*. https://legiscan.com/TX/text/SB471/id/2794064.

Suchman, Mark. 1995. "Managing Legitimacy: Strategic and Institutional Approaches," 41.

TCEQ. 2023. "TCEQ Region Directory." *Texas Commission on Environmental Quality*. March 13. https://www.tceq.texas.gov/agency/directory/region.

Teledyne FLIR. 2022. "Thermal Imaging, Night Vision and Infrared Camera Systems." https://www.flir.com/.

Texas Commission on Environmental Quality, dir. 2013. *Tour the TCEQ's New Auto-GC Monitor in Floresville, Texas*. https://www.youtube.com/watch?v=yyj56HNkgTc.

Texas Railroad Commission. 2023. "Well Distribution by County." https://www.rrc.texas.gov/oil-and-gas/research-and-statistics/well-information/well-distribution-by-county/.

U.S. Census. 2022. "U.S. Census Bureau QuickFacts: Karnes County, Texas." https://www.census.gov/quickfacts/fact/table/karnescountytexas/PST045222.

Vera, Lourdes. 2022. “Environmental Data Justice in Action: Civically Valid Air Monitoring Near Oil and Gas Extraction in the Eagle Ford Shale Play.” PhD Thesis, Northeastern University.

Vera, Lourdes, Garance Malivel, Drew Michanowicz, Choong-Min Kang, and Sara Wylie. 2019a. “Photopaper as a Tool for Community-Level Monitoring of Industrially Produced Hydrogen Sulfide and Corrosion.” *Atmospheric Environment* X (5).

Vera, Lourdes, Dawn Walker, M. Murphy, Becky Mansfield, Ladan Mohamed Siad, Jessica Ogden, and EDGI. 2019b. “When Data Justice and Environmental Justice Meet: Formulating a Response to Extractive Logic through Environmental Data Justice.” *Information, Communication & Society* 22 (7): 1012–28.

Vilcassim, MJ Ruzmyn, George D. Thurston, Richard E. Peltier, and Terry Gordon. 2014. “Black Carbon and Particulate Matter (PM2. 5) Concentrations in New York City’s Subway Stations.” *Environmental Science & Technology* 48 (24).

Villa, Priscilla, Lourdes Vera, Sara Wylie, and Sharon Wilson. 2017. “Hazards in the Air: Relating Reported Illnesses to Air Pollutants Detected Near Oil and Gas Operations in and around Karnes County, Texas.” https://www.earthworksaction.org/library/detail/hazards_in_the_air#.WXKpP4pJnow

Wylie, Sara, Elisabeth Wilder, Lourdes Vera, Deborah Thomas, and Megan McLaughlin. 2017. “Materializing Exposure: Developing an Indexical Method to Visualize Health Hazards Related to Fossil Fuel Extraction.” *Engaging Science, Technology, and Society* 3 (September): 426–63.