



GeoHumanities

ISSN: 2373-566X (Print) 2373-5678 (Online) Journal homepage: <https://www.tandfonline.com/loi/rgeo20>

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To cite this article: Helen Pritchard & Jennifer Gabrys (2016) From Citizen Sensing to Collective Monitoring: Working through the Perceptive and Affective Problematics of Environmental Pollution, *GeoHumanities*, 2:2, 354-371, DOI: [10.1080/2373566X.2016.1234355](https://doi.org/10.1080/2373566X.2016.1234355)

To link to this article: <https://doi.org/10.1080/2373566X.2016.1234355>



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Published online: 16 Nov 2016.



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From Citizen Sensing to Collective Monitoring: Working through the Perceptive and Affective Problematics of Environmental Pollution

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Citizen sensing, or the practice of monitoring environments through low-cost and do-it-yourself (DIY) digital technologies, is often structured as an individual pursuit. The very term *citizen* within citizen sensing suggests that the practice of sensing is the terrain of one political subject using a digital device to monitor her or his environment to take individual action. Yet in some circumstances, citizen sensing practices are reworking the sites and distributions of environmental monitoring toward other configurations that are more multiple and collective. What are the qualities and capacities of these collective modes of sensing, and how might they shift the assumed parameters—and effectiveness—of citizen sensing? We engage with Simondon’s writing to consider how a “perceptive problematic” generates collectives for feeling and responding to events (or an “affective problematic”), here through the ongoing event of air pollution. Further drawing on writing from Stengers, we discuss how the “work” of citizen sensing involves much more than developing new technologies, and instead points to the ways in which new practices, subjects, milieus, evidence, and politics are worked through as perceptive and affective commitments to making sense of and addressing the problem of pollution. **Key Words: Air pollution, citizen sensing, collectives, perceptive and affective problematics.**

Citizen sensing is a practice of monitoring environments that is in many ways structured as an individual pursuit. The very term *citizen* within citizen sensing suggests that the practice of sensing is the terrain of one political subject using a digital device to monitor her or his environment to take individual action. Yet in some circumstances, citizen sensing practices are reworking the sites and distributions of environmental monitoring toward other configurations that are more multiple and collective (cf. Gabrys 2016b). What are the qualities and capacities of these collective modes of sensing, and how might they shift the assumed parameters—and effectiveness—of citizen sensing? These are crucial questions that we examine here.

GeoHumanities, 2(2) 2016, 354–371 © Copyright 2016 The Author(s).

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Initial submission, April 2016; revised submission, August 2016; final acceptance, August 2016.

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In this article, we discuss the emerging practice of citizen sensing, or practices for monitoring environments through low-cost and do-it-yourself (DIY) digital technologies. As we have discussed in previous writings, citizen sensing can address everything “from air pollution to the migrations of animals,” where “sensors generate data on any number of environmental phenomena” (Gabrys 2016b). In the interdisciplinary literature on citizen sensing and participatory sensing, these practices are often situated as grassroots undertakings that can challenge the usual alignments of technoscience and governance (Campbell et al. 2006; DiSalvo et al. 2008). Citizen sensing technologies are then meant to provide a democratic corrective or challenge to the standard processes for monitoring environments, gathering data, and acting on those data.

Discussions about citizen science and citizen sensing often focus on the technologies, methods, and outcomes of monitoring practices. Although these are important areas of inquiry, we consider here how the *subjects*—including collective subjects—of monitoring are constituted to examine how environmental problems are felt, and to consider how political action might be constituted as a comparatively individual or collective pursuit (cf. Gabrys 2016c). Entities and environments are formed through monitoring, as are the distributions of perception and feeling. We engage with the writings of Simondon (1958, 1992, 2005) to consider both how individual and collective potential is transindividuated through perception and milieu (cf. Combes 2013, 26), and we extend this insight to demonstrate the technical relations—or technicity—that take hold and to what effect. By specifically focusing on air pollution as a “perceptive problematic” and “affective problematic,” a condition that Simondon (2005, 167; cited in Combes 2013, 31) articulated as a condition that coconstitutes entities and milieu, we consider how a feeling for air pollution generates individuals, collectives, and responses to this ongoing event.

In the context of this forum on “Border Topologies,” we locate this article as an inquiry into the movable borders that demarcate practices of citizen sensing. These practices, which might be differently delineated as individual or collective, are not only relational engagements across individuals and collectives, but also are relational articulations of the milieu within which entities operate. In other words, encounters with perceptive and affective problems cocreate the entities and environments that experience those conditions. This is a way of addressing a topology of political subjects, as well as a topology of political milieu, as processes of transindividuating individuals and collectives. As these entities and milieu form and are informed through practices of participation, we further consider how participation is always a more-than-individual project that constitutes new collectives and new collective relations. Border topologies in this sense are generative and multiply situated, as the very relations as well as the entities and milieu that are parsed are in formation and not preconstituted objects put into relation. Processes of feeling problems constitute individuals, collectives, and their ways of relating.

Along with this focus on how individuals and collectives are transindividuated, we then take up questions of how citizen sensing is not only or primarily a project of making knowledge, but is also a project of doing politics. Stengers has drawn attention to the ways in which science is constitutive of facts and collectives, and how this process is also generative of politics (Stengers 2000, 91; cf. Mackenzie 2005, 385). In other words, for Stengers, science is both the production of things of interest and community affairs that assemble in relation to these things (Stengers 2000, 162–63). As she (2000) observed, however, these productions and affairs are laborious processes, as it is not easy to make a “new scientific being exist” or to inaugurate the community that would recognize such beings (98). To use Stengers’s term, it takes “work” to undertake such scientific practices.

Of course, we can apply the term *work* to describe most endeavors. Yet in the context of this article on community air quality monitoring, we take Stengers's notion of work to imply something more intensive and transformative. Despite the marketing campaigns for an ever-expanding array of citizen sensing devices, the work of citizen sensing involves much more than developing new technologies, and instead points to the ways in which new practices, subjects, milieus, and politics are worked through as perceptive and affective commitments to making sense of and evidencing the problem of air pollution. The work of citizen sensing, as a form of citizen science, then further transforms Stengers's notion of the work of science by moving the experimental facts and collectives where scientific work is undertaken out of the laboratory of experts and into the world of citizens. This is not to adhere to a strict dichotomy between experts and citizens, because this is also a movable border, but citizen sensors and citizen scientists typically work outside of the spaces and practices in which scientific knowledge is validated. The field in which citizen scientific "facts" are tested out and able to take hold so that new ways of being together are realized is even more open to the pluralities and conflicts that Stengers identified to be part of the way in which the politics of science play out. With citizen science, contestations over authority, the legitimacy of actors, the intensity of scientific controversies, and the work undertaken to establish facts through experimental apparatuses and practices also runs up against the politics of evidence in terms of which communities of interest will be listened to and which will be ignored.

Approaching citizen sensing as a technoscientific practice that configures entities, milieus, and relations, we extend Stengers's articulation of work as the labor involved in taking risks, problematizing practices, and destabilizing alignments in ways that affect collective life through citizen-based attempts to generate evidence. Through engaging with practice-based research on citizen sensing, this article attends to the work that is involved in generating collective thinking, community-designed processes, and emergent common accounts. This work also extends to asking how citizen sensing can intervene within environmental politics to reinvent collective capacities for making claims about environmental problems such as air pollution.

We take up these topics through a discussion of practice-based participatory research into citizen sensing of air pollution. We mobilize the concepts of work and perceptive and affective problematics to expand on field work engagements with citizen-based monitoring practices at sites of energy extraction in Pennsylvania. We do this to engage with what is meant by and operationalized through citizen sensing, community monitoring, and collectives by looking at the concrete ways in which resources, infrastructures, and connections—as well as disconnections—are formed through citizen-based monitoring. We further engage with the difficulties experienced when moving across individual and collective practices of monitoring. Our intention in engaging with this material is to consider the "collective-in-becoming" (Combes 2013, 53), and to suggest that feeling through perceptive and affective problems constitutes the relational work of political praxis.

CITIZEN SENSING AND THE PROMISES OF PARTICIPATION

Many citizen sensing projects position themselves so that monitoring devices seem to have the power to explain and address pollution problems. Although Web site platforms such as Smart Citizen and the Air Quality Egg discuss monitoring as a proposal for local change or intervention, the technologies themselves are designed for a global user (Figures 1 and 2). This user is



FIGURE 1 Air Quality Egg. Photo by Citizen Sense (2013). (Color figure available online.)

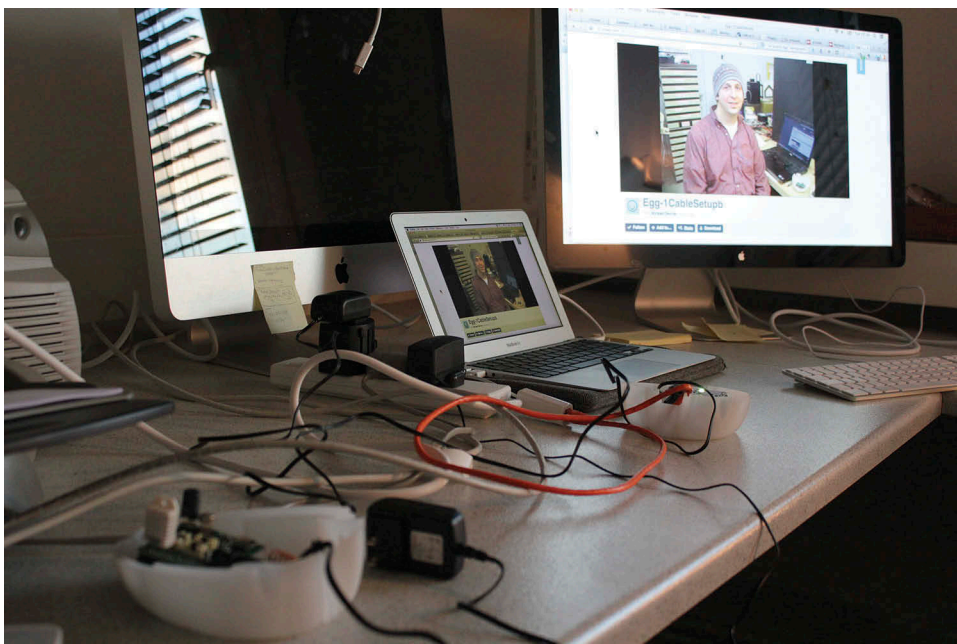


FIGURE 2 Air Quality Egg setup. Photo by Citizen Sense (2013). (Color figure available online.)

typically delineated as an individual person undertaking monitoring, who is likely to have more advanced technical knowledge when working with computational technologies. Other devices such as the Speck particulate matter (PM_{2.5}) air pollution monitors, which we discuss in more detail later on, are designed to be more accessible for users without advanced technical skills. Yet they are also designed to be used by individuals. A numerical display on the device shows air quality measurements, which an individual user can respond to, typically by making changes in her or his home, rather than monitoring of outdoor and more public spaces.

Accounts of DIY, participatory, and citizen sensing often suggest that these technologies and practices lead to a “democratization” of science (cf. Punie, Misuraca, and Osimo 2009). Such democratization is signaled through the use of *citizen* as a term to describe the type of sensing or monitoring underway. This is less an expression of the citizen as a member of a nation state, and more an articulation of a citizenly practice that translates across contexts and beyond specific units of belonging. The citizen is a global user-operator who can monitor air and report data about its quality, seemingly irrespective of context. Such technologies are meant to be generative of participatory processes that unfold through the use of comparatively low-tech and low-cost devices. By taking up low-cost and DIY environmental monitoring technologies, users are meant to realize newfound abilities to engage with problems such as air pollution, as well as acquire new capacities for acting on those problems. Inherent within these platforms are the assumptions that there might be the possibility of a consensual approach to environmental monitoring that transcends the political, while bypassing conflict and struggle. Most engagements with DIY environmental monitoring, participatory, and citizen sensing, however, do not engage with or account for the complexities of working across individual monitoring to collective monitoring experiments, or of the difficulties that arise when attempting to mobilize citizen-gathered data for political change.

The generalized promises of citizen sensing devices then contrast sharply with the challenging work that sustained citizen sensing might actually involve. These promises typically characterize the becoming-of-community as something that unfolds through merely purchasing a device, signing up to an online platform, and uploading data. Many citizen sensing projects claim that the devices and platforms themselves can “generate participatory processes” by “connecting data, people, and knowledge,” and further enabling the “collective construction of the city for its own inhabitants” (Smart Citizen n.d.). Citizen sensing is often further mobilized in ways that promise universal and stable configurations for collecting and communicating environmental data. As Gabrys (2014) discussed previously in the context of smart cities, citizen sensing often promises a relatively friction-free form of empowerment, where the devices and platforms of citizen sensing are meant to generate trouble-free forms of environmental engagement.

One of the ways in which environmental engagement is simplified is through the adding up of individual citizens into collectives. An overarching tendency we have noticed in our survey of citizen sensing technologies and practices is the connection between nodal sensing and nodal politics. Citizens are meant to operate as a node or data point, and the joined-up contribution of many individual citizen nodes is meant to produce collectives and collective data that are meaningful and actionable. Notions of network software design, big data, and crowdsourcing inform these relations. In many of the citizen sensing devices we tested, there appear to be considerable gaps between processes of collecting data and coming together as a community with the common resources needed to make that data actionable, or even to initially define the

problem of environmental pollution. Inherent within these configurations of citizen sensing is the implication that democratic modes of engagement can be readily accessed through these devices in ways that will automatically lead to community formations and involvement.

As citizen sensing becomes an increasingly established practice, often what is upheld as the transformational and democratic aspects of this mode of environmental citizenship can at times obscure the asymmetries of power that this monitoring practice and relationship to data and evidence can generate and reinforce (Suchman and Bishop 2000). By putting citizen sensing technologies to the test in a participatory research project on air pollution monitoring, we then interrogate these devices and claims to understand how collectives and sensing practices unfold.

PARTICIPATION AND THE RISKY WORK OF RELATION

Participation and public engagement are topics that have a long and rich research trajectory across multiple fields, including science and technology studies and feminist technoscience, geography, media studies, and creative practice. Whereas some of this literature focuses on collective politics or deliberative modes of democratic engagement (Wynne 2007; Felt and Fochler 2008), others attend to the new worlds and practices that come into being through reinventing participatory processes (cf. Lane et al. 2011; Chilvers and Kearnes 2015; Waterton and Tsouvalis 2015; Gabrys *forthcoming*). At the same time, participation and public engagement are not without a certain amount of work and tension. In their account of public engagement with local stakeholders affected by water pollution in the Lake District, Waterton, Norton, and Morris (2006) discussed the challenges that arose through collective attempts to develop inclusive approaches to “defining ‘the object of research’” (286). Here, undertaking a collective research project was at once destabilizing and generative of new encounters with “the problem” of water pollution (cf. Stengers 2011).

In a different way, Smith (1999) problematized participatory and feminist methodologies for undertaking community research by offering a nuanced account of the difficulties experienced as a researcher located both inside and outside of indigenous communities. Her critical account does not disregard the affirmative possibilities of community-based environmental science, but neither does it gloss over the work involved for researchers and practitioners. We regard these types of engagement as risky work (in a productive way), because just as they problematize community-based research approaches, they also seek to experiment with the collectives and collaborations that research might generate, and to realize new forms of collective potential through these alternative methods.

We build on this participatory research through developing further experiments with community monitoring in relation to air pollution sensing. We specifically address how collectives shifted, formed, and transformed in the process of working through the perceptive and affective problematic of air pollution. Part of this shifting of collectives involved challenging the usual practices for who might be authorized to monitor and account for air pollution. The work of citizen sensing can put into question the “testimony” of science (Stengers 2000, 102), while also redistributing its questions. Such redistribution involves shifting the actors who can undertake monitoring and gain authority about air pollution. The process of renegotiating and redefining expertise about air pollution through citizen sensing is just one aspect of how, as an apparently “amateur” form of science, this practice becomes political by challenging established accounts. As Stengers (2000) has noted, science implies “truth” in a way that “conserves its traditional

power to create unity, beyond divergent interests” (99). Part of the work of science is in the effort it takes to arrive at a stable agreement on a problem, situation, or thing. Citizen science and citizen sensing, however, mobilize very different alignments in the process of stabilizing and destabilizing problems such as pollution that upset the usual politics of expertise and evidence.

Citizen sensing can be very laborious for citizens and collectives (and we include ourselves within this description). Although we participated in this research as visiting academics who were not resident in the community, we became involved with practices of working through the problem of air pollution in a way that did not allow us to stand apart as disinterested observers. We engage with and address the tensions that arose around expertise in relation to community air quality monitoring not because they were somehow unusual or surprising, but rather because it was in the specific process of working through struggles over perception and expertise that particular collectives came into formation.

The work of citizen sensing and community engagement is not always straightforward. It can at times create feelings of frustration, exhaustion, and anxiety. To engage with feelings in relation to technology and participation, we mobilize Simondon’s (1992, 2005) writing on collective potential and perception, which provides a useful approach for thinking about perception and affect in relation to community engagement. For Simondon, perception and affect emerge through relations and modes of collective individuation, wherein individuals feel that they are “more-than-one,” while encountering perceptual problems. As Combes (2013) wrote:

The “perceptive problematic” is that of the existence of a multiplicity of perceptual worlds wherein it is always a matter of inventing a form inaugurating a compatibility between the milieu in which perception operates and the being that perceives; and this problematic concerns the individual as such. Why insist here that we are speaking of the individual *as such*? This is because the affective problematic is, inversely, the experience wherein a being will feel that it is not only individual. (31)

What Combes pointed to here is that the process of working out perceptual problems articulates and generates relations across individuals, collectives, and milieus, which themselves are entities that coemerge through this process. Ways of working through perceptual problems are shared and world-making processes. As Simondon (2005) wrote, “the ‘collective’ *for an individual being*, is the mixed and stable home in which emotions are perceptual points of view, and points of view are possible emotions” (261; cited in Combes, 2013, 34). Working through perceptual problems—including the problem of air pollution—requires the constitution of collective affect. Such constitution of collective affect is also a process for parsing individuals and milieus, or for forming subjects and environments, through coconstitutive (and noncausal) dynamics that *inaugurate a compatibility* of feeling across individuals and collectives, as Combes suggested earlier. This is not to say that such collective encounters are a linear achievement for solving perceptual and affective problems. Instead, they are the basis for ongoing encounters and negotiations, or in other words, the very basis for political life.

CITIZEN ACTION GROUPS AND COLLECTIVE MONITORING ON THE MARCELLUS SHALE

Turning now to consider how encounters with the perceptive and affective problematic of air pollution unfold through the use of environmental sensors, we discuss participatory research undertaken with a group of residents and community group in northeastern Pennsylvania

affected by hydraulic fracturing (Figure 3). As we have documented elsewhere (Gabrys and Pritchard 2015), fracking is an emerging industrial activity that has rapidly expanded over a relatively short space of time, and yet has been insufficiently regulated for environmental effects to air and water. We worked with residents in this area to learn more about the monitoring activities they were already engaged in, and it was through the range and depth of their monitoring practices that we initially came to be in conversation with residents in this area. After first learning more about their existing monitoring practices, we then worked with community members to cocreate a kit for monitoring air pollution (Figure 4). This kit was distributed to thirty participants, who used the kit over a time span of seven months. Participants gathered air pollution data that they hoped might provide more insight into whether air pollution was occurring, how it might be identified in relation to particular pollution sources, and whether air pollution patterns were shared across the region or specific to particular locations.

In our participatory research with residents, we worked with a number of community organizers, including a community action group that had emerged in the Marcellus Shale, Breathe Easy, located in Susquehanna County. During the pollution sensing project we worked closely with most of the members of Breathe Easy, as well as residents in the area who were not affiliated with the group. The Breathe Easy group, which had a core membership of eight to ten people, emerged after the community had become divided over protests and civil actions related to the water pollution in the local township of Dimock. As many participants explained to us, the pollution of the water in Dimock caused deep-seated disagreements between families, neighbors, and activist groups. The water pollution problem had also drawn many scientists and activists to the area, as the emerging collective attempted to understand the pollution and its relation to the fracking infrastructure.

Many of the members of Breathe Easy were contact persons for scientific research projects, taking on the role of collecting samples and arranging access to monitoring sites for scientists. In this highly sensitive context, the arranging of access and collecting of samples had also become emotional work. Feelings coevolved with the technologies of fracking and the practices of science across the collectives. Although many participants accounted for moments of empowerment when contributing to scientific research, for most, feelings of disappointment, desperation, and anger were prevalent. Breathe Easy had formed partly out of the energy from these feelings, as a way to retain some of the collective potential energized by these research projects. Here, the problems of understanding pollution in Susquehanna County were inseparable from lived experiences, and were constituted through people's differing relations to the fracking industry and its effects. Speaking out about the water pollution was an important event that led to the formation of Breathe Easy.

Wanting to move away from the conflicts that had arisen from the earlier collectivizing around water pollution, Rebecca Roter, the group's founder, instead engaged with air pollution stemming from fracking infrastructure. Air was "something everyone breathed," as Breathe Easy's mission statement articulated, and therefore was seen as something that could energize new and potentially less rancorous engagements. Unlike previous struggles members of the group had faced, the aim of Breathe Easy was not to take a polarizing position for or against fracking. Instead the group aimed to work with scientists, so that "the facts could speak for themselves." Although citizen science might have seemed to be a way to sidestep political struggles, instead, it generated new forms of political work in forming facts that could count as evidence.



FIGURE 3 Fracking on the Marcellus Shale. Photo by Citizen Sense (2014). (Color figure available online.)



FIGURE 4 Setting up the Speck for monitoring particulate matter ($PM_{2.5}$). Photo by Citizen Sense (2014). (Color figure available online.)

The Politics of Expertise

The notion of facts speaking for themselves is a well-established topic within science and technology studies, and the ways in which expertise is central to the formation of facts—and the alternate perspectives that citizen or “lay” knowledge can provide—has also been advanced as a critical point of consideration (Wynne 1996; Jasanoff 2004). The importance of gathering evidence through citizen sensing technologies became a recurring point of focus in our research on the Marcellus Shale. Residents were concerned with gathering “hard data” that regulators would take seriously. Yet at the same time we continually questioned what counted as hard data, and whether there were other forms of evidence that citizens could provide, or other ways of gathering evidence that could provide equally valuable and unique insights (cf. Gabrys 2016a).

Drawing on commitments to practice-based research, feminist technoscience, and participatory engagements with science (Corburn 2005; Reardon et al. 2015), our approach to the formation of the research was for practices of environmental monitoring and evidence gathering to be a collective undertaking. In the process of attending community meetings, however, community members expressed uncertainty about our approach to citizen sensing, as they anticipated that we would adopt the role of the expert.

Although the group, as well as other local residents concerned about air and water pollution, had a critical perspective of universities and the perceived distance of experts developed through their prior experiences, part of the focus of the group was to attract “more science” to attempt to address the problems they were experiencing. As researchers, we were neither legible to the group as scientists, nor as advocates of a type of citizen sensing that promised to “solve the problems of air pollution.” In part, this was because we were also located outside of the usual expert spaces for measuring air pollution. Instead, we were committed to working together with participants to develop practices that might contribute to enabling the community to develop accountability for air pollution in a much more open-ended and locally configured way. Yet this less linear process left us all at risk.

What we “offered” in terms of both expertise and research design was not necessarily or initially what the community group thought what was needed to improve air quality. We also recognized that despite the aim of the group to embrace more heterogeneous positions in relation to fracking (neither simply for or against), there were those who were interested to work with us who were excluded from the group because of personal conflicts with other participants, those who excluded themselves as they did not feel involved with the main community group Breathe Easy, and participants from differing groups who remained on the margins of the research as their aims did not align with the core group. Our response to this was to become exclusive as researchers neither to one particular group such as Breathe Easy nor to any one individual’s agenda.

As mentioned earlier, many residents were very experienced in working with academic research projects, and many had participated in multiple data collection projects for scientists, including gathering water samples and air samples, filling in diaries on health effects, and logging experiences on the effects of the natural gas infrastructure (cf. Macey et al. 2014). Simultaneously, many participants had become contact persons in the area for anyone who wanted to know more about natural gas and so were regularly running tours, giving press interviews, and attending conferences as panel members. Despite this depth of experience, monitoring expertise and understanding of natural gas infrastructure, during the first stage of the project there was an assertion from participants that a scientist should be leading the project. By “scientist,” the residents were not referring to our research project members, who were social

scientists and designers. Instead, propelled by their day-to-day experiences of pollution and the urgency of their situation, the participants would often suggest that the person to use equipment, design protocols, and “lead the group” should be a scientist, and preferably one based in a North American institution.

As well as disappointing the expectations of what counts as disciplinary expertise, our resistance to stepping in as experts during conference calls and workshops was also sometimes met with frustration. At an initial meeting, a participant asked what we wanted to do with the monitoring data, to which we replied this was a question for the whole group to discuss and decide. At first, this answer met with suspicion by some participants, as their prior experience with scientific monitoring indicated that we would have decided in advance how the collected data would be mobilized. Instead of perceiving the participatory process as opening up possibilities for what could be monitored and who could act on the monitoring data so that science and politics were already entangled (cf. Lane et al. 2011), our openness toward the outcomes was initially seen as lack of clarity and direction. As these tensions appeared it allowed us all to talk through the questions of how citizen sensing might be undertaken in ways that differed from the scientific research with which they had previously participated. In this respect, the approach of community-based citizen sensing was very different to most of the previous projects in which the citizens had been involved. In these earlier projects, environmental monitoring was typically seen as a collective effort only as far as crowdsourcing data samples and gaining property access to sites of interest near significant infrastructure such as wells or compressor stations.

Reworking Expertise and “Shitting” on Peer Review

Despite an intense and lively engagement about the citizen sensing to be undertaken, and the reciprocity that emerged throughout the project (Gabrys and Pritchard 2015), the perceived need by some participants for a scientist to be leading the project continued to be a recurring topic to address. This request was also often highly gendered. This dynamic was most pronounced in public settings, including e-mails to experts or in local press interviews. The struggle with gendered forms of expertise was an ongoing dynamic throughout the project. It also caused conflicts between the participants as some participants openly discussed what they described as the “misogyny” of other members of the group. Some participants tried to resolve the problem by bringing in (often male) scientists and technologists to give us advice on how to undertake the project with them. We engaged with the “experts” who were introduced to us, but we also continued to articulate our commitment to undertake the research through a collaborative approach so that the community would be involved in making decisions about monitoring practices and the data collected.

Throughout this process, a number of tensions were worked through as environmental monitoring was underway. During one particularly lively conversation, a heated debate arose between participants about whether the Speck devices and the PM_{2.5} air quality data they collected would be of any use. One participant repeatedly spoke of the need to engage in monitoring as “hard science” that would generate “hard data.” The harder the science and the harder the data, the more irrefutable the arguments that could be made to environmental regulators, one participant claimed. This same participant indicated that hard science was also the basis for generating solid peer-reviewed journal articles, which would be taken seriously by regulators. During this exchange, one participant who was less convinced of the hard science angle said to the other, “The industry

doesn't care about hard science, so why should we? They say 'We shit on peer review.'" This assertion at once highlighted how the fracking industry did not consider it to be a necessary process to work through peer review to demonstrate their legitimacy, and that the process of peer review itself was biased toward particular forms of expertise that excluded community undertakings, which inevitably would always be discredited in one way or another, especially by regulators. Indeed, because fracking generally is not subject to many typical environmental regulations that pertain to other industries, residents also repeatedly questioned the degree to which scientific expertise would even be able to address pollution problems.

In this back-and-forth negotiation, of which this conversation was just one instance among many, there was a continual grappling with how to undertake citizen sensing in ways that would produce viable and valid evidence that could make "real political change," while the same time doubting that evidence would even have such an effect. As residents were accustomed to having their concerns about environmental pollution dismissed, and their attempts to provide evidence discredited, they saw their environmental monitoring as one more effort that would likely be rejected, but that still required a concerted attempt to document environmental conditions, as they "had tried everything else."

The validation of monitoring practices and evidence was as much a worked-through feeling for how data should be gathered and presented, as it was the following or diversion from "instructions" for use. In the process of undertaking the air monitoring research, environmental scientists, regulators, and technologists often weighed in on the "correct" way of undertaking monitoring, and of indicating that if certain protocols were followed then valid data would be produced, but not otherwise—and that citizen sensing generally would not be able to follow or replicate these forms of legitimacy (Gabrys and Pritchard 2015). Yet as science and technology studies and feminist technoscience researchers have indicated, what counts as valid data within science often also requires a feeling for instruments and data (Myers 2015). In other words, this is not merely a matter of citizens having an emotional and "biased" (as in politically motivated) approach to monitoring, whereas scientists are exempt from these entanglements—although this continues to be a prevailing sentiment within spaces of scientific expertise (cf. "Rise of the citizen scientist" 2015). Instead, all forms of monitoring (and modeling) require affective and sensory engagement with instruments, as well as a commitment to working through the environments and collective infrastructures and politics for validating data.

At the same time, as these debates about data and the validity of citizen sensing resurfaced throughout the process of undertaking environmental monitoring, as researchers we began to consider the politics of expertise in another light. We realized that there was an uncertainty about the open-ended participatory processes we were attempting to work through because they were unfamiliar to residents. This uncertainty also created additional work, as attempting to realize alternative forms of political engagement meant there was a continual struggle to carve out a different yet effective approach. In other words, by not adopting an explicitly positivist relationship to the citizen-gathered data, a clear dynamic emerged where certain politics and modes of environmental citizenship, along with distinct types of science, were valued over others. There was an expectation that the devices, pollutants, and data gathered would be taken at face value, that hard evidence would be gathered, and that environmental regulation and policy would be changed for the better through this process. Along the way, though, citizens developed a feeling for the data they were gathering and its potential use exactly because they were often as involved with questions of how to make sense of the data as we were.

Whereas on one level we had an interest in questioning the assumptions and practices built into and materialized through these monitoring devices, we developed new alignments and modes of accountability to participants and to the data generated, whereby it became necessary to take seriously the practices of monitoring as they were typically configured and to work with these parameters, while also questioning them. What would it mean to stabilize monitoring practices to attempt to realize greater legitimacy for them and the claims made through citizen-gathered data, while also attending to the limitations of generating some forms of evidence and not others? This question cuts to the core of how perceptive and affective problematics inform the possibilities for political engagement.

FROM PERCEPTIVE PROBLEMATIC TO AFFECTIVE PROBLEMATIC

Within a week of collecting their Speck PM_{2.5} monitors, many participants had begun to run their own collective experiments and evaluations of the technology. Participants started to borrow devices from each other so that they could run comparative tests, partly because they were skeptical about whether or not the monitors were “accurate enough.” Skepticism of the devices was a particularly powerful perceptive and affective problematic in this situation, because it emerged in ways that structured an evaluation process for the project, with participants moderating each other’s claims about what the devices were capable of. In a sense, the community began to build their own sets of monitoring standards. This process also began to shift the perception of participation in science. One participant, Audrey, described how “previously science has been done to us but this time we are doing the science, we can make the decisions.”

Despite the initial frustrations with the participatory approach to the research, residents began to develop concrete ideas about how air quality data collected during the monitoring might be used. Some participants wanted to use the data to stop further expansion of the hydraulic fracturing industry, some participants wanted to use the data as a way to engage in dialogue with industry, and others wanted to use the data to request improvements to particular parts of infrastructure such as compressor stations. During the monitoring period, residents began taking their collected data to town hall meetings, preparing reports, and using the data for meetings and teleconferences with public health and environment officials.

In one particular county commission meeting, Audrey brought her preliminary PM_{2.5} data for discussion and as a form of evidence to argue that local government funds should be invested in undertaking further air quality monitoring, as there is an absence of air quality monitoring in the region. In the course of presenting the citizen sensing research with which she was involved and showing the data that she had gathered, she became embroiled in a debate with the county commissioner about the validity of the study. On the one hand, Audrey argued that well-respected universities and academics were leading the research project, as a way to demonstrate that the perceived necessary forms of expertise were in place to ensure the robustness of the study. Yet on the other hand, she also attempted to make a case for the validity of her own knowledge and data collection, as well as experience, in bringing forward a proposal to the commission.

The heated exchanges that unfolded as Audrey presented her material were very much part of a process of working through ways of taking account of citizen monitoring and environmental observations. They also extended to the ways in which citizens might be able to have a voice in

community forums, and to make proposals for how public funds should be invested. Other residents in attendance at the commission meeting began to voice their concerns over air quality in relation to fracking. They discussed the extent to which their own health or the health of their families—particularly children who might be at risk of developing lifelong asthma—mattered in relation to how the relevance of the community observations should be registered. There was, in effect, a collective working through the perceptive problem of air pollution. This process of collective working and feeling also gave rise to the demand to take citizen environmental monitoring seriously, and to allow for that monitoring to inform how residents lived and how they might exercise political agency in relation to their environments.

In another teleconference with environmental regulators and public health agencies, Rebecca (chairperson of Breathe Easy) and Meryl also talked through their preliminary findings from collecting PM_{2.5} data. They presented the regulators with their evidence and analysis of recurring spikes in the data, which suggested pollution events that should be looked at more closely, and they also requested that follow-up monitoring by state and federal regulators be undertaken. In the course of this conversation, and in exchanges in other contexts, regulators would suggest that the Speck PM_{2.5} monitors with which citizens gathered data were not measuring at a regulatory standard, that citizens were not following set protocols for taking their air samples, that deliberate bias could be introduced by citizens to the monitoring, and that monitoring should only be done indoors as outdoor monitoring introduced too many weather-related uncertainties into the data.

In their multiple encounters with regulators, residents then found themselves refining arguments, finding new ways to present data, and generally developing resilience in the process of developing their environmental monitoring practices that were often dismissed. They also began to articulate how their data were not the same as regulators' data, but provided equally important and valid insights as citizen-gathered data within a spatially dense community-monitoring network. Their protocols for data gathering were not entirely predefined, but instead developed in practice, as did their strategies for addressing how to interpret and communicate the data. Rather than return their study to an indoor air-monitoring project that would attend only to how they could manage their individual air in their own homes, they retained their commitment to addressing air inside and outside their homes, thereby continuing to focus their concern on the air as an atmospheric commons that affected everyone in the community. In effect, the engagement with the perceptive and affective problematic of air pollution was a process that articulated individuals, collectives, and their relations.

CONCLUSION: WORKING IN A TECHNICAL REGISTER TOWARD COLLECTIVE POTENTIAL

Through the process of undertaking participatory research in relation to citizen sensing, air pollution, and fracking, it became clear that the perceptive and affective problematic of air pollution also generated new forms of collective potential for addressing the problem of air pollution. The “border topologies” that were worked through, from the mobilization of data and evidence to the possibilities of transforming air pollution into a set of environmental practices, unfolded as relational engagements that articulated particular ways of developing feelings for environments and collective political projects. These are not borders as necessarily delineated

spatial arrangements, but rather are traversals made across experiences, practices, and political entities that—through these traversals—rework collective sensation, political subjects, and their potential.

The citizen sensing research that participants undertook was also not singular, and developed alongside other monitoring studies in which they were engaged. During the project these relations shifted and mutated, together with the feelings and attachments to this scene of transindividuation. New community formations emerged through new monitoring practices, stabilizing and underscoring the importance of ongoing and already existing monitoring practices. New relationships to researchers emerged, as well as new articulations for researchers of how to undertake participatory research. In other words, as researchers we were part of the collective process of research, and become involved in the perceptive and affective problematics and work from which science and politics jointly emerge.

As part of these “sensing practices,” as well as dealing with how devices for citizen sensing work in a technical register (Gabrys 2012, 2016c; Pritchard 2013; Gabrys and Pritchard *forthcoming*), we as researchers also become obligated to explore the possibilities of collective action that emerge with these technologies and to take seriously the commitments of the participants using the technologies. Citizen sensing as a practice for perceiving and documenting air pollution is, similar to scientific practice, dependent on collective infrastructures of expertise, validation, and feeling. Unlike science, though, these infrastructures are yet to be stabilized and are in ongoing processes of being made and remade, contested and confirmed. The claims of “open” and “participatory” technologies do not automatically grant citizen sensing projects the power to mobilize action in relation to pollution—or to realize new forms of collective potential. Beyond the hyperbole of global media marketing, social networking, and TED-talk-style promotional campaigns, citizen sensing is in many situations not yet fully established as a legitimate practice for making evidential claims.

As the preceding account of our participatory pollution sensing research has shown, the promises of citizen sensing as instantly “democratic” often obscure the work it takes to move across and through border topologies to make interventions into the sedimented “practices that we have a role in shaping and through which we are shaped” (Barad 2007, 390). These are practices that are contingent on social, material, economic, and environmental conditions. In community monitoring, forming collectives is not a matter of redistributing who can monitor in any simple way such as giving out devices to citizens, but rather involves the affective grappling and collective encounters with problems brought about by existing practices in the attempt to forge new political capacities.

As our research has shown, it is by engaging with perceptive and affective problematics that collective potential is released and politics are made—through the work of participation and engagement. Community monitoring generates scenes and relations in which articulations across “citizens” and “scientists,” as well as experiences and environments are being continuously configured. At the same time, natural gas extraction continues to shape communities and environments through processes of production and pollution. This work of responding to environmental problems and creating political capacities is not easy, but it is a crucial part of the potential for collective politics, and for the emergence of community bonds.

ACKNOWLEDGMENTS

Thanks are due to participating residents in Pennsylvania, including Frank Finan, Rebecca Roter, Meryl Solar, Vera Scroggins, Chuck and Janis Winschuh, Paul Karpich, Barbara Clifford, John Hotvedt, Barbara Scott, Audrey Gozdiskowski, and Alex Lotorto, along with anonymous participants, as well as previous Citizen Sense researchers, including Nerea Calvillo, Tom Keene, and Nick Shapiro, and consultants including Kelly Finan (illustration), Dr. Benjamin Barratt (atmospheric science), Lau Thiam Kok (data architecture), and Raphael Faeh (Web design). Thanks are also due to the Create Lab for loaning Speck devices for use in this study.

FUNDING

The research leading to these results has received funding from the European Research Council under the European Union's Seventh Framework Programme (FP/2007–2013)/ERC Grant Agreement No. 313347, "Citizen Sensing and Environmental Practice: Assessing Participatory Engagements with Environments through Sensor Technologies."

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