Special Issue: Inquiring into Technoscience in India

Peopling Technoscience: Locating the Sciences and Publics of Air Pollution in Delhi

ROHIT NEGI and PRERNA SRIGYAN

INDIAN ACADEMY OF SCIENCES

DIALOGUE
Science, Scientists, and Society

Table of Contents

1 **Introduction**

2 **The Technoscientific Atmosphere**

2.1 *Producing and representing air pollution science*

2.2 *Making an Indian air pollution technoscience*

3 **Technoscience and Its Publics**

3.1 *Citizen science in millennial Delhi*

4 **Localising Air**

5 **The People's Air**

6 **Conclusions**

Acknowldgement

References

Special Issue: Inquiring into Technoscience in India

Peopling Technoscience: Locating the Sciences and Publics of Air Pollution in Delhi

ROHIT NEGI and PRERNA SRIGYAN

School of Global Affairs, Ambedkar University Delhi, Shivaji Marg, Karampura, Delhi 110015

Email. rohit@aud.ac.in; psrigyan@uci.edu

Corresponding Editor: Dhruv Raina

Abstract. Delhi's toxic air, especially in the last decade, has invited a technoscientific scramble to understand, interpret, and provide fixes. The process takes place at a particular historical conjuncture marked by heightened scientism, the dominance of the market, and the splintering of scientific knowledge and practices. Technoscientific interest in air is then varied, and produces competing perspectives and policy interventions, further complicated by the state's persistent denialism on the one hand, and a push towards a national scientific project on the other. Yet, the issue is framed in a manner that papers over tensions and sutures within the technosciences, and privileges analysis and action that are abstracted from the lived experiences of the urban majority. In this article, we trace the emergence of the technosciences of air in Delhi and locate 'the people' in it, before moving to a more localised and situated understanding of air to argue that residents know air pollution in ways that differ from the technosciences, but are critical to appreciate and engage with, if alliances and effective actions are to be forged. We point towards greater emphasis on health to bring together technoscientific and popular praxis around air pollution.

Keywords: Air Pollution; Technoscience; Delhi; Urban Political Ecology; Science and Technology Studies

"We've run out of clean water and air…[we must] stop feeling helpless, be a part of change - listen to experts, see micro and macro solutions. Become armed and impactful, this is our Delhi, it is our responsibility!"
-Member, Help Delhi Breathe Alliance

"…Delhi now needs an 'Air Quality Manager' with a clearly defined mandate and powers…[air quality action] doesn't look like an economically or politically difficult proposition. Who can complete this picture, though, and take it to the masses? Perhaps, a visionary leader and statesman."

- Bolia and Khare 2018

1 Introduction

In April 2016, a consultation on air pollution took place in central Delhi. Such events are common in the city, given its pollution problem and widespread public concern. The goal of this meeting, however, was somewhat unique. It aimed to open a conversation between scientific and technical experts from the state, academic institutions, and non-governmental organizations with journalists and decision-makers, that is, with the interested but non-technical crowd. At this event, a representative of the ruling political party had reiterated the Delhi government's desire to engage with experts to find solutions. Later that day, a senior journalist would chide academic scientists for being cooped up in their laboratories and not being 'out there'—on the TV and at public events—more. Indeed, while a few scientists are regularly seen and heard, the loudest voices in the debate continue to be those of activists, lawyers, and certain self-trained experts/entrepreneurs. They speak of the air quality, the legal and regulatory environment, and of the technical measures that the state should implement. However, by reproducing the epistemology of the technosciences, even in the relative absence of actual scientists, these voices ensure a technoscientific hegemony in the discourse on air pollution.

It is in this backdrop that our paper considers the career of the sciences and technologies (or the technosciences) of air pollution in Delhi and their fraught relations with 'the people.' By the latter, we mean both the people as they appear in the technoscientific discourse, and as actual urban agents who inhabit specific localities and breathe in the air. The opening quotes introduce two possible trajectories of this link: the former suggests linking technical understanding with individual and collective action, while the latter, from an article by IIT-Delhi faculty, draws contrast between improvements in air quality in Chinese cities and Delhi's worsening air to make the case for an air quality tsar. While the loci of action are different in the two statements—collectives and the state—they share a common epistemological location of faith in expert knowledge. Moreover, as the latter quote reveals, this discourse produces a particular subject who is the recipient of expertise-driven actions but is largely unrepresented in the debate. Our premise is that these processes prepare the contours of the debate such that, first, the conversation is channeled towards increasingly narrow, sophisticated and asocial analyses, and second, it moves towards progressively larger spatial scales, largely neglecting everyday experiences and ideas of those who inhabit zones of heightened toxicity. To develop our argument, in the following sections, we track the emergence of the air pollution technosciences and then locate 'the people' in it, before moving

to a more localised and lived understanding of air to argue that residents understand air in ways that differ from the technosciences, but are critical to understand and engage with, if alliances and effective actions are to be forged. In this paper, we show the disjunctures within the technosciences and in its relations with the broader publics, making the case for greater engagement with localised toxicity and health.

2 The Technoscientific Atmosphere

When scientists and policy researchers working on air pollution enter into public discussions in Delhi, one stubborn question is repeatedly put forth: What causes it? Their answer is almost always a variation on 'it's complex.' Experts communicate the complexity by stating, for instance, that the question requires a 'long view' (Guttikunda 2016) with multi-scale, multi-sectoral, inter-state, and transnational collaborations (Dubash and Guttikunda 2018; Negi and Srigyan 2021). Indeed, as an array of collaborations between atmospheric scientists, computer scientists and engineers, epidemiologists, physicists, public health, and policy researchers are underway (discussed below) to further probe this complexity, we see an opportunity to use insights from Science and Technology Studies (STS), Anthropology, Geography, and Sociology (Jasanaoff 1987; Bickerstaff 2004; Cupples 2009; Ottinger 2010; Kimura and Kinchy 2016) to think through the epistemology and spatiality of the technoscientific apparatus on Delhi's air pollution.

Delhi's air has consistently ranked as the world's worst, responsible for thousands of deaths every year, reducing healthy years from people's lives. To enter into discussions on Delhi's air, one must learn scientific vocabularies, which are obviously out of reach to the urban majority. At the same time, navigating these spaces leads to the realisation that there are multiple tensions between epistemic cultures. Not only are there different epistemic locations from where air is viewed but results from new studies are often opposed to existing ones, and there is sharp division of opinion on the efficacy of monitoring devices and algorithms. As Timothy Choy (Choy 2010) notes, knowing more about air doesn't necessarily produce clearer understanding, but "yields a sensation of incomplete knowledge, a vertiginous sense that there is always something in excess of the explanation" (ibid, p.4). Our analysis finds that two contestations, in particular, are critical at the present conjuncture. First, when scientific communities measure air through different monitoring strategies, contradictory scalar representations are produced which entail competing policy interventions. Second, when air pollution science is challenged by the state to deliver ever more granular data specific to Indian contexts and bodies, we observe that transnational circulations of scientific research and citational networks do not translate neatly into expertise that the state may listen to. Despite these tensions, the argument that technoscientific knowledge is necessary to guide action stays strong.

2.1 *Producing and representing air pollution science*

To Julie Cupples (Cupples 2009), much of scientific air pollution research is a purifying endeavor, a desire for pristine nature and productive bodies. Any mixture of pollutants, environments, and bodies, that is, air pollution, is matter out of place. To discipline it, then, air pollution science parses atmospheric relations into components using appropriate monitoring and then connects those components to bodies using exposure monitoring and exposure-health linkages. Atmospheric scientists and epidemiologists exert ordering power onto a messy reality, often unsuccessfully. While attempts to order something as complex as air pollution will of course produce messiness, scholarship attentive to informational and data practices (reviewed in Garnett 2016) has shown how scientists are acutely aware of what counts as valid knowledge. Moreover, STS scholarship shows that the meaning of 'true, good, real data' (Garnett 2017) is dynamic and fraught with contestations at multiple points. Monitoring strategies become markers of such technoscientific practice around air because choosing *where* to capture, measure, and represent air has serious implications on which policies are prioritized, and, more importantly, on *who* becomes visible in technoscientific conversations.

In the Ministry of Health & Family Welfare document (Ministry of Health 2015) entitled 'Report of the Steering Committee on Air Pollution and Health Related Issues', an 'environmental health pathway' represents the conceptual linkages between polluting sources at one end, and health effects at another: Source —> Emissions —> Concentration —> Exposure —> Dose—> Health Effects. Each of these points is a potential risk indicator and developing each linkage is considered ideal for comprehensive risk assessment. However, developing each of them is a massive scientific endeavor, requiring time, funding, and institutional contexts that incentivize collaboration. Emission control is a frequently argued-for intervention, but emissions inventory requires sophisticated equipment, measurements, and training, and must be repeated to account for spatial and temporal variations. Scientists must choose what linkages would best represent a health risk, and their choices shape how concerns and interventions are prioritised.

Concentrations measured by ambient monitoring are traditionally used as risk indicators, directly affected by emissions but closer to health impacts in the pathway above. Ideal monitoring data for policy is believed to be ambient, on-ground, long-term averages, sufficiently nuanced to account for spatial and temporal variations, and measured from stationary, regulatory-grade monitors. Monitors in turn should be placed away from polluting sources like industries, emission hotspots, or traffic junctions, which detract from the representativeness of a geographical area. Each monitor represents an airshed of approximately 15 square kilometers (Guttikunda 2018). Such ambient data are considered the benchmark against which other monitoring methods have to be calibrated and validated. Ambient monitoring makes possible source-apportionment studies (knowing where pollution comes from or linking sources and emissions) and emission inventories (how much pollution is released annually or linking emissions and concentrations); the basic steps in developing a

technoscientific knowledge of air pollution. Four comprehensive source-apportionment studies exist for Delhi (Dubash and Guttikunda 2018), among them the highly cited and mobile IIT Kanpur report after which dust control became a top policy priority (Sharma and Dikshit 2016). These apportionment studies tell us what sectors and sources pollute the most, how much, and when. They agree that the air in the winters is worse. All point to the high contribution of power plants, vehicular emissions, biomass/waste burning (including stubble), construction activities, diesel generator sets; only varying by degrees in their estimations.

Another monitoring strategy—less expensive but not as popular—is preferred by the MoH&FW report Ministry of Health 2015. This involves exposure monitoring, measuring "where people are" instead of "where people hardly ever are, such as 24-hours per day on top of post offices or other buildings, or conversely, around streets" (ibid, p. 35). Wearable sensors help monitor the daily activities of a cohort, and non-wearable sensors monitor their micro-environments. A combination of personal and micro-environment monitoring with survey data can be used to estimate population-level exposures, attentive to household, socioeconomic, and geographic variations. Exposure monitoring thus captures differentiated and situated bodies and microenvironments, unlike ambient monitoring, which assumes that the entire air-shed experiences homogenous air quality.

Ambient and exposure monitoring reveal very different source landscapes and represent distinct sites of intervention. This separation is reproduced in the organization of air pollution science within different scientific and institutional cultures (though there is overlap). Atmospheric scientists and physicists are more concerned with links between sources and concentrations. Epidemiologists, public health, and medical researchers focus on links between exposures and health effects. The MoH&FW report also separates its author-experts into two working groups—Ambient Air Pollution (AAP) and Household Air Pollution (HAP). Much of the data for AAP come from India's ambient monitoring network, concentrated in urban areas. Most information for HAP comes from individual studies (exposure monitoring, household-level surveys to population estimates). How do scientists then put these different data streams together? The widely cited Lancet study (India State-Level Disease Burden Initiative Air Pollution Collaborators 2018) estimating state-wise disease burden due to air pollution in India kept monitoring strategies separate, resulting in independent estimates for PM2.5 exposure due to ambient particulate matter and household fuel use.

For Delhi, even though ambient monitoring data is available from 37 locations, the sheer geographical size and complexity of the city and the larger National Capital Region (NCR) make it impossible for scientists to rely on monitoring data alone. It is through remote sensing and modelling that the region and wider spaces are brought into conversations on Delhi's air. NASA's satellite data are mapped on to India to show both regional (severity and intensity of seasonal stubble burning from neighboring states of Haryana and Punjab) and transboundary (dust storms from the Middle East flowing onto India's land-locked Indo-Gangetic Plains) atmospheric relationships, emphasizing the need for governance at those scales (Negi 2018). Delhi is a dominant and haunting presence in these atmospheric relations, with scientists explicitly acknowledging in the various seminars and lectures we attended over three years,

that Delhi's air can never be pristine because of its geography and climate, and that it was wishful thinking to expect consistent blue skies in the near future. As much as scientists estimate anthropogenic sources of pollution, Delhi's climate and geography also shape how much pollution control is possible.

This shows that, Contra Cupples (Cupples 2009), scientists do not necessarily engage in purifying endeavors to separate nature from culture; in fact, they embrace messiness, debating, and negotiating over putting together different kind of data. But when challenged by the state to produce data specifically for Indian contexts and bodies, these contradictory scalar representations—personal microenvironments through exposure monitoring, local air-sheds by ambient monitoring and modelling, regional and transboundary atmospheric relations through remote sensing and modelling—cleave further in the second tension, where certain scientific knowledges and infrastructures are privileged over others.

2.2 *Making an Indian air pollution technoscience*

Vast scientific, technical, and policy infrastructures are being mobilized and assembled contemporarily to understand why Delhi's air is so polluted, and what researchers, policymakers, and non-experts can do about it. These collaborations, which look to produce, analyze, and rally colossal amounts of data, include the 'Atmospheric Pollution and Human Health in an Indian Megacity' programme, jointly funded by UK research agencies and the Indian government. Enrolling 42 organizations with research teams led by over a hundred scientists, this mega-project will, over four years, tell policymakers what pollutes, how much it pollutes, where it pollutes, and who it pollutes. Other projects—some India-wide (Gordon 2018), some focused on different Indian cities (Guttikunda et al. 2019; Centre for Environment and Energy Development 2017)—are also underway to identify pollution, model associated health effects, and propose appropriate policies.

This increased technoscientific attention to Delhi's air in recent years is in part a response to the national government's often stated position that not only is there insufficient evidence for mortality associated with air pollution, but also that existing publications that extrapolate from empirical research on non-Indian populations living in non-Indian environments do not adequately capture the specificities of the Indian scenario, that is, the "ecological and environmental impacts, social infrastructure, cultural ethos, and characteristics of the Indian economy" (Sundaray and Bharadwaj 2019: 51). The state in turn calls for 'indigenous studies' linking pollution and health. While this has been considered some mix of obstinacy and denialism by advocates, scientists have taken it up as a challenge, generating two kinds of responses. First, scientists identify what they consider gaps in research (Pant et al. 2016), listing short-term and long-term research priorities (Gordon 2018) which projects like those mentioned above, for example, try to accomplish. Second, scientists challenge the government's position, arguing that there *is* enough evidence of serious acute and chronic health effects not only to guide long-term policy, but to initiate actions 'mission mode' (Balakrishnan and Ghosh 2018).

Atmospheric scientist Sarath Guttikunda, for instance, has published primers on air pollution monitoring, source apportionments, and air quality management that are freely available on 'Urbanemissions.info' so bureaucrats, policymakers, urban planners, activists, and other actors may learn technoscientific vocabularies and tools. Pallavi Pant, an environmental health scientist, maintains an extensive database of air pollution research and journalism on her blog 'Air Quality in India', where she also interviews scholars, activists, and entrepreneurs working on the topic. In March 2019, one of us attended a public workshop at IIT Delhi which taught how to process, analyze, and visualize air pollution data. The Centre for Policy Research in Delhi hosted ten seminars on different aspects of air pollution to sustain year-long conversations, instead of peaking only during winter, when air quality gets significantly worse. Over three years, we have participated in at least twenty events (seminars, workshops, conferences, exhibitions) in Delhi that aimed to communicate scientific and policy research on air pollution to non-experts and for public understanding. These events asked invited experts: What is the nature of the problem? What is at stake? Who could be held accountable?

It is not that the Delhi's technoscientific apparatus is absent from spaces of authority. In 1998, the Indian government, under direction from the Supreme Court, formed the Environment Pollution (Prevention and Control) Authority for the National Capital Region. EPCA advised the Supreme Court on a variety of matters from technology adoption to parking policy while its membership comprised of representatives from central, state, and municipal governments, alongside well-known advocates, scientists, and technical experts. Since its conception until its disbanding in October 2020, it had the same Chairperson, and one member from the Centre for Science & Environment Centre for Science and Environment 2001 (CSE), a prominent environmental advocacy group. In 2018, EPCA prepared a Graded Response Action Plan (GRAP) tagged to the National Air Quality Index that initiated a set of actions (closing power plants, declaring school holidays) based on air quality thresholds. In October 2020, the government promulgated the setting up of a new Commission on Air Quality Management in the NCR and adjoining areas, thereby suspending the EPCA and other such bodies, while further centralising policy discussions and interventions.

The National Clean Air Programme (NCAP) finalized in January 2019 partially heeds the government's demands for 'authentic' Indian data and indigenous studies. The NCAP privileges monitoring data, proposing an extensive urban and rural monitoring network. The role of MoH&FW is restricted to management of household air pollution, suggesting that the 'pathways-tension' discussed above will persist in governance. It will maintain medical databases and registries away from public scrutiny, to be shared with the public *via* the media very carefully and only by environmental health experts. The latter therefore find themselves institutionally accountable for not only producing actionable knowledge, but also making calls on what is to be disseminated.

While the preceding discussion points to contestations within technoscientific knowledge and policy on Delhi's air, the larger scientization of politics (Kimura and Kinchy 2016)—that is, framing environmental problems as one of insufficient data and technological fixes—remains ubiquitous. The next section reflects on how this technoscientific apparatus is mobilized by

activists, advocates, and entrepreneurs—so-called non-experts, to take the form of citizen science. When this framing is written into a policy document like NCAP, it assumes that sufficient data and emission reduction technologies will reduce air pollution in a sustained manner. It also assumes that all we need are fixed targets for emission reductions. As scientific collaborations figure out what it means to have India-specific data, they would carefully choose appropriate populations, scale, and methodology because the NCAP is cautious about how that data would be interpreted and communicated to the public, especially by the media. Further, the NCAP demands staggering coordinational capacity between regulatory agencies, government institutions, and scientific research collaborations. India's regulatory agencies—the Central Pollution Control Board (CPCB) which coordinates activities of the Delhi Pollution Control Committee (DPCC) and other State Pollution Control Boards (SPCBs)—are severely under-funded and under-staffed, responding to not only air pollution, but water quality monitoring and regulating, noise pollution, and waste management (Sharma and Nagpure 2019). An audit of the CPCB (IIM Lucknow 2010: 85) further discloses the 'feelings of internal stakeholders', as CPCB not possessing enough traction to get things done, lack of coordination between CPCB and SPCBs, and lack of rewards and recognition, among others.

If we acknowledge that knowing and governing air pollution in Delhi requires making difficult scientific and regulatory choices, it becomes transformed from a purely technoscientific issue to a stubborn political one. When scientific and advocacy communities do acknowledge air pollution as political, they recommend generating greater awareness about air pollution and increasing people's participations in science through citizen science efforts. What ruptures (Ottinger and Cohen 2011) emerge when business-as-usual is disrupted by the entry of social agents, and what possibilities open up when unstable and uncertain connections form between data, knowledge, and action? To answer these questions, we read the place of the 'public' in technoscientific conversations to ask: What knowledges are attributed to them? How is their agency (or lack thereof) conceived, and where are they situated in the proposed interventions?

3 Technoscience and Its Publics

As we show above, with the persistence of air pollution and the state's response to it, scientists and policy researchers realise that they need to build bridges with constituencies beyond the scientific community to put pressure on the state to act decisively. We find that there are two means by which this is proposed: first, to understand how people comprehend and articulate air pollution, and second, to increase public participation in science *qua* citizen science. In this section, we examine both the approaches and who the publics of these technosciences are. We begin with perception studies that claim to assess people's attitudes and move to how key scientific and policy documents talk about people. We then evaluate the possibilities and dilemmas of citizen science efforts for air pollution advocacy. We argue that

these two means are built on similar assumptions that need to be evaluated for their relevance to addressing Delhi's air pollution.

Public opinion surveys in the 1950s and 1960s found that communities stressed by toxic infrastructures articulated a sense of invulnerability (Bickerstaff 2004), which was interpreted by experts as evidence of ignorance to be countered more effective scientific communication *via* translation into popular vocabularies. This is the foundation of the rhetoric that frames understanding technoscientific knowledge as essential to transforming behaviour. The perception studies and public opinions surveys in Delhi that we read (World Bank 2004; Saksena 2011; Mehta and D'Souza 2019; URJA 2019) follow in this tradition of 'risk perception', making the case for effective communication, without acknowledging that people do not necessarily assimilate air quality knowledges passively but encounter them alongside situated and experiential knowledges (Bush et al. 2001; Bickerstaff 2004; Bickerstaff and Simmons 2009;Cupples 2009).

Indications of how technosciences situate people can not only be gleaned through perception studies and public opinion surveys but also through analyzing important products of such research. To the authors of the influential IIT Kanpur report (Sharma and Dikshit 2016), actual people of *any* kind are completely invisible, not even showing up in the section of Delhi's demography, which lists the city's physical geography, population, size, key industries, literacy, and number of languages. When farmers make an entry, they appear as agents who indulge in problematic actions that ought to be banned outright. The report notes that "farmers prefer burning straw in the field, which is quick, easy and economical, rather than incorporating it for soil enrichment or harvesting it for any other use" (ibid, p. 278).

If Delhi's key source apportionment study ignores people, its public health assessments are appreciably more considerate, implying to us that health-focused conversations of Delhi's air, as opposed to conversations around monitoring, are more attuned to popular experiences. The MoH&FW report (Ministry of Health 2015) mentions that the urban poor are doubly burdened by ambient and household air pollution. Instead of outlawing certain practices, the report proposes affordable distribution of gas and electricity. Similarly, it does not blame rural households for not adopting improved cook-stoves (even though that is decades'-long intervention), offering alternative explanations for non-adoption. A report from the Public Health Foundation of India (2017) mentions explicitly that though air pollution is thought to affect all equally, it is a class-issue: "urban upper-middle classes were better equipped in knowledge and resources to seek solutions to poor air quality, in comparison to urban poor classes" (ibid, p. 40). It cites a social science study (Ramaswami et al. 2016) which surveyed three Delhi neighborhoods with different socioeconomic profiles, and interviewed waste handlers, showing that they were quite aware of health risks, but it was low on their priorities.

3.1 *Citizen science in millennial Delhi*

Citizen science efforts are valued because they blur expert-lay boundaries, police polluters, increase scientific literacy, broaden awareness, and may drive local-level policy changes where communities have a voice (Kimura and Kinchy 2016). These are instances when scientists, scientific institutions, and technical practitioners interact with environmental advocates and activists, leading to an uneasy enmeshment of science, technology, policy, and activism. The volume *Technoscience & Environmental Justice* (Ottinger and Cohen 2011) offers several case studies of such intersections. The collective insight is that while citizen science efforts are constrained by institutional limitations (Hoffmann 2011; Johnson and Ranco 2011; Liévanos et al. 2011), participants often become data-savvy and readily adopt technoscientific vocabularies to document gaps and disparities in risk assessments while advocating more just interventions (Powell and Powell 2011). In this process, experts develop a sense of community dynamics and environmental politics. We respond here to Kinchy and Kimura's (Kimura and Kinchy 2016) call for contextualizing citizen science, by asking how might we understand the actual citizen science processes related to Delhi's air pollution? One of our insights is that the increasingly decentralised architectures to monitor air may result in highly individualised ways of responding to pollution, while also blurring the lines between citizen science and entrepreneurship.

Air pollution data gathered by regulatory agencies are officially disseminated through web-based portals and mobile apps. These efforts though face many problems, from gaps in data collection to visualizations and interfaces that are far from user-friendly. In this scenario, many experts versed in air pollution and data sciences have led efforts to build user-friendly visualizations and interfaces. Advocates, and even ordinary citizen, may also purchase one of the many sensor-based monitors on the market, continually sensing their breathing zones—bedrooms, kitchens, cars, and officers—to guide decisions from exercising outdoors to the use of air purifiers. These monitors also form alternative infrastructure, wherein, the data crowdsourced through them may contest government data, especially amidst suspicions of data manipulation during peak pollution episodes, such as Diwali or the annual winter smog. While the scientists we spoke to often did not trust the authenticity and precision of low-cost monitoring devices as they get affected by high temperatures, pollution levels and humidity characteristic of Indian conditions, they do acknowledge that if properly calibrated and validated against ground-level concentrations, low-cost monitoring could 'empower communities' and fill spatial gaps in ambient monitoring networks (Public Health Foundation of India 2017; Roychowdhury et al. 2016). In a workshop on low-cost monitoring in August 2018, a representative from the environment ministry shared that the government had initiated projects for the certification of low-cost sensors (Choudhary 2019) adding that it was not necessary to have 100% accurate data, but 'data [one] can work with' (Air Quality in India 2018).

The rising acceptance of low-cost monitoring drives an expanding market. They are attached to air purifiers, capturing and extracting particulate matter simultaneously. At this

conjuncture, we notice a new group of air pollution advocates we call 'air entrepreneurs' or simply, 'airpreneurs'. They develop and market products that combine the promise of expertise with the possibility of ready, individual, action. Airpreneurs are motivated by personal struggles with breathing. Their stories share a common narrative: an experience of moving or 'returning' to Delhi from outside India, their own or their family's dramatically worsening health, and a desire to intervene by making available gadgets to measure and purify air (Negi and Srigyan 2021). They see themselves as warriors who fight toxic air (Almeida 2017), drawing a clear distinction between their action-orientation with the state's perceived inaction.

When one of us asked a prominent airpreneur about the efficacy of individualised solutions, he stated that there was nothing wrong with fulfilling a real demand and if demand was consistently high, it would lead to such technologies becoming more affordable with time. While this may indeed come to be, airpreneurs do profit from a health emergency, making it difficult to differentiate long-term concern from opportunism even when well-intentioned. Sections of the real estate and hospitality sectors in Delhi also benefit from the increased commodification of air. Godrej Air apartments in Gurgaon, for instance, are centrally air purified and priced at Rs. 10 lakhs more than non-purified apartments in the same neighborhood (Sirur 2018). Several luxury hotels and cinema theatres have been renovated to host large-capacity air purifiers (Singh 2017).

Both perception studies and citizen science can be fueled by the shared assumption that data by themselves produce knowledge and transform behavior. This idea is based on a 'deficit model' that proceeds from assuming a lack of understanding on part of the non-expert public and sets up knowledge transfer as the solution (Bickerstaff 2004; Cupples 2009; Dalborne and Galusky 2011). As we have shown above, aside from health research, people are not prominently visible in dominant technoscientific regimes that shape interventions around Delhi's air, or even citizen science engagements that purportedly aim to democratize science. Our interviews with scientists further elucidate that even though they are aware that people relate to air differently, few efforts have been made to incorporate these relations in risk communication or health advisories. Experiential and historical knowledges are hardly ever engaged with. In sum, air pollution science and advocacy in Delhi are fenced by the two dilemmas we have outlined thus far: scientization of environmental policy that obscures problems of coordinational capacity; and the dominance of the data deficit model that assumes that transfer of knowledge from experts to non-experts produces unmediated action. We end this section with a third reason for concern. These means of framing pollution can fracture possibilities of public mobilization by creating bubbles of sanitised air only accessible to a few. What alternatives do we propose? In the next section, we return to scalar representations of air and suggest a spatial shift that could be made use of to sense and articulate air differently.

4 Localising Air

Inherited technical and conceptual approaches tend to work with what may be called a fixed understanding of spatiality where the solution is located at the same scale as the problem. However, as critical geography has shown (cf. Neumann 2009), scale is socially constructed. Our reading of the geography of the technoscientific discourse on air pollution shows that the debate has been scaled to fold in increasingly larger territories to understand urban air. Atmospheric scientists, for instance, emphasize the regional dimension of air, and draw on satellite imagery to show the vast swathes of the sub-continent—especially the Indo-Gangetic Plains—enveloped by smog. Among institutions, Greenpeace India has repeatedly argued against the predominant focus on Delhi, terming their campaign, 'Clean Air *Nation*'[emphasis added]. During the 2017 smog episode in Delhi in fact there were repeated mentions of the transnational nature of air: the smoke from the burning of crop residue in Punjab put people in neighbouring Pakistan at risk. A report by an influential public institution (System of Air Quality and Weather Forecasting And Research (SAFAR) at the Indian Institute of Tropical Meteorology) argued that at least part of the smog could be explained by dust storms originating in the Middle-East which had travelled all the way to India (Beig and Parkhi 2017). There is of course the long association of studies of toxicity and health, as has been discussed previously. What is less researched is the neighbourhood *scale* in studies of air, even though that is an important scale for understanding other environmental concerns like water and waste. The neighborhood scale, especially considering what may be termed 'highly stressed communities', opens up questions around the ways the urban economy, social hierarchies and government of space produce localities of detritus, which are often consequent to pollution abatement mechanisms, and might be a productive entry point for the sciences willing to bring the people into their inquiries.

Among others, we consider the peri-urban interface of Delhi as a highly stressed zone where diverse land-uses, populations, and multiple governance blind spots where the urban/rural and administrative borders intersect. Cities' unwanted matter typically is pushed towards peri-urban spaces, resulting in what Govind Gopakumar calls 'degenerated peripheralization' Gopakumar 2009. Historically, urban frontiers in Delhi have absorbed activities considered 'out of place' in the modern metropolis: relocated urban poor, slaughterhouses, landfills, and hazardous industries (Sharan 2014). More recently, these zones are also sites of real estate speculation and accumulation. An influential report on Delhi's air commissioned by the Delhi government, for instance, locates all five of its pollution hotspots on the city's peripheries (Sharma and Dikshit 2016). These include Okhla-Badarpur and parts of NW Delhi, where we conducted fieldwork with assistance from researchers over the summer in 2017 and 2018, which included transects, interviews, and photo voices.

Okhla is at the path-dependent confluence of multiple sources of air pollution. The first of these is a container depot at the confluence of road and rail networks that connect Delhi to the rest of the country (and the world). The facility has been part of the larger debate on air due to

the pollution impacts of the over ten thousand diesel trucks that make their way to the depot each night. It has been suggested that the depot be moved outside the city, to newer urban peripheries. At the northeastern edge of the depot lies one of Delhi's three municipal landfills, officially closed but accepting refuse, nonetheless. To the people living in the area, the landfill is the biggest cause of concern. The local MLA or the member of the Delhi legislative assembly, resides in the neighbouring urban village (Tekhand) and showed us multiple letters addressed to the municipality, complaining of the nuisance and pollution caused by the landfill. Ultimately, he says, even his voice has gone unheard. The second source of pollution is the Badarpur power plant. Dated technology, imported from USSR, Czechoslovakia and USA through the 1970s, means that a lot of coal remains uncombusted, making it the country's most polluting power plant. Speaking of everyday relations with toxicity, a Badarpur resident says that "most of us suffer bouts of coughing in the morning and black sputum comes out. I feel guilty for letting my children grow up [here]. Even relatives stopped visiting us" (quoted in Goswami 2017). A former worker in the power plant narrates how the public sector corporation gave free jaggery for its workers, since it is considered helpful for lung function in vernacular health systems.

The third source of toxicity is a waste-to-energy plant that opened in 2011. According to residents of adjacent neighborhoods, the plant operates through the night without adhering to emission norms. They point to the layer of soot that deposits over their homes each night as evidence. The situation is terribly alarming. As a local resident put it: "Here, even the stray dogs are seen coughing" (Tayebulla 2016). Residents of one middle-class neighborhood (Sukhdev Vihar) mobilised and petitioned the city's politicians and administrators, campaigned *via* the media, and even went to court. For a while they were joined by residents of neighboring subaltern settlement, though protest fatigue and the exigencies of everyday life later pulled them away. Still, the protests brought into question the feasibility and desirability of technological interventions like Waste-to-Energy, which are often seen as panacea to the problem of municipal solid waste. In 2017, however, the apex court for environmental concerns gave green signal to the company and residents have had to accept their fate.

In their efforts to see air pollution as a generalized concern, the technosciences have largely missed the scale below the city. To be sure, the political valency of 'shared air' is high—the point being that even the well-off cannot be immune—and air indeed is an object that cannot be fully sealed and neatly packaged like water. However, in our view, such a stance must be accompanied with *care* for highly stressed zones, where people confront added risk. In the following section, we look at how those who inhabit these zones make sense of their immediate environments.

5 The People's Air

As noted above, there is a widespread sense in the technoscientific community that the masses lack credible knowledge, but in our fieldwork in NW Delhi and Okhla we observed that

awareness or lack thereof is not so much the point, as what kind of knowledges constitute people's understanding of the air they breathe? We conducted a survey in three housing colonies—as they are termed in Delhi—in the same district in NW Delhi on the fringe of the city in the summer of 2016. Fifty randomly selected residents—from every third house on a transect— were interviewed in each of the sites. The three settlements belong to different housing typologies of Delhi. Colony A is a now-legalised formerly unauthorized colony, colony B is a Jhuggi Jhopdi Cluster (or officially sanctioned slum area), and colony C is a planned colony, constructed by the Delhi Development Authority. As one would expect, colony C is home to relatively well-off residents, and colony B has the least wealthy residents of the three. Colony A, according to visible markers, property values and residents' occupations and educational qualifications, falls somewhere in between the two.

We asked residents if they were familiar with popular technical terms related to air pollution (such as AQI, PM2.5, PM10, NOx, SOx) and with government and private responses (e.g. conversion of transport to CNG, odd/even experiment, air purifiers, air masks). We also asked the respondents to rank the causes of air pollution (e.g. vehicles, industries, garbage burning, dust, household cooking), and also which groups were most and least exposed to air pollution (choices were among construction workers, rickshaw pullers, autorickshaw drivers, women using *chulha*, and office workers). We realise that the sample is not large enough for robust statistical findings, but basic crosstabulations show some interesting and insightful patterns, which can form the basis for further research. We find that the respondents' duration of stay in Delhi was about the same for the three sites (41/50 in A and B, and 43/50 in C have been in Delhi for over 15 years), so it could be discounted as a meaningful variable for our sake. As it turned out, an equal number of male (23/50) and female (27/50) respondents were interviewed in each location, so at the level of the sites, this again was not a meaningful variable. Respondents in A and C were relatively better educated, with 35/50 and 43/50 having finished at least high school respectively. The corresponding number was 22/50 in site B. Residents of colony A and C were more active consumers of mass media: 28/50 and 29/50 in A and C respectively read the newspaper (whether hardcopy or online) daily, 41/50 and 33/50 watched TV newschannels everyday, and 21/50 and 17/50 were daily listeners of radio. In comparison, 17/50 read newspapers, 19/50 watched TV news, and 12/50 listened to radio everyday in site B.

We found that 47/50 respondents in site A and 50/50 in site C were familiar with some or all of the technical terms related to air pollution, while the corresponding figure was 13/50 in site B. However, in terms of the responses and interventions related to air pollution, all 50 in A and C, and 43/50 in B were familiar with some or all. 125/150 respondents knew about the conversion of public transport fleet to CNG and 101/150 were aware that masks may help with pollution abatement. Interestingly, only 22/150 were familiar with the Air Quality Index (AQI) across the sites, which is insightful, since it is an innovation designed primarily for public communication of air pollution levels. Despite their ubiquity in the debate as proxies for air quality, PM2.5 and PM10 were familiar to an equal and small number (14/150, respectively) of respondents. In terms of the causes of air pollution, the majority in sites A and C laid the blame on vehicular emissions (28/46 and 25/49, respectively), while the most popular cause in site B were industries (20/44). The sites differed in a similar pattern in terms of exposure as

well. To residents of A and C, construction workers were most at risk (19/43 and 19/46, respectively), while those in site B answered rickshaw pullers (19/45). Overall, construction workers, rickshaw pullers and women cooking with biomass-based fuel were considered the most at risk in that order. The results show that there is a fairly good understanding of the causes and impacts of air pollution, though the technical concepts through which experts view it are not as well understood. CNG and masks are part of everyday experiences of the city, while PM2.5 and AQI are abstractions that require investment in expert knowledge regimes.

The field insights from Okhla area are perhaps even more insightful. Tekhand village is around 800 years old, with its subsistence drawn in most part from agriculture and dairy business. In the 1950s, the Okhla industrial area was constructed by acquiring the lands of the village. Later, the container depot was also developed *via* the same process. Thousands of migrant workers made their way to the place, and in time, the villagers turned to renting their properties to them and investing in petty businesses. The better-off villagers have moved to planned housing complexes, while continuing to draw rents. Next door, a slum area with over 6,000 residents came up to house industrial and other workers. In the 1990s, residents were given legal tenure. This micro airshed, dominated by landfill fires lit by footloose methane, comprises of a diverse population, with variable resources and different stakes in the city. As Auyero and Swiston (Auyero and Swiston 2009) note in a toxic zone of Buenos Aires, it is not given that an objective relation with toxicity will result in popular action demanding larger change; it may as well be part of a general precarity of life in a difficult urban context. For people living here, bad air then is not so much a phenomenon accessed *via* apps as it is an intimate one. For one thing, odour on account of the landfill is as much of a lived issue as is dust—because of the action of wind on deposited debris—in the neighbourhood, even though odour is not objectively a metric of toxicity for studies of pollution. One of the submissions of the local MLA introduced above to the Speaker of the Delhi Assembly—which he shared with us—is worth quoting in detail (translated from Hindi original):

"I wish to draw your attention [to the landfill], which was supposed to be closed ten years back. It was planned to be 20-meter-high, but today, it is over 50 meters. As a result, the people of [neighboring settlements] are forced to live in a highly polluted environment, especially as it concerns groundwater. Most people here consume water drawn from tubewells and suffer from several diseases. Even more unfortunately, there is a large hospital next door where thousands of people arrive for treatment, and many others are admitted. Due to the odour and pollution caused by the landfill, not only do the patients not get adequate treatment, but they very likely leave with new complications."

Families, in turn, keep windows closed or open depending on how bad they *feel* the air is. They visit the neighborhood 'jholachhaap'—unregistered—medical practitioner for remedies for cough, and for more serious ailments such as breathing difficulties, they have to travel to one of the larger public or private hospitals outside the neighborhood. Moreover, risks are in negotiation and calibrated with finding work and piecing together a toehold in the city. The urban village and JJ colony in the area are far more affordable for those with precarious

livelihoods, than most other parts of the city. People's consciousness of the city and its air is then far more complex than the binary of presence/absence of knowledge will have us believe. Leachate from a neighboring landfill, flooding during rain, and garbage fires make up the overall experience of living in these places. In this scenario, it should not be a surprise that the landfill is the fulcrum of local environmental politics, and air a part of the discourse.

We believe, then, if there is to be a politics around air pollution that brings the technosciences in productive conversation with residents of highly stressed zones, it must turn on healthcare rather than air per se. As we showed in the sections above, the one type of the expert institutional knowledges of air pollution that brings in situated and lived experiences is that which is interested in the exposure to health pathway. On the ground, for the inhabitants of risk zones such as Okhla, whether it is dengue, typhoid, or asthma is immaterial; what matters are bodily conditions that do not allow their lives to function adequately enough to earn daily subsistence. When bodies break down, accessible and quality health care must be at hand. The general deterioration of public institutions and the boom in private healthcare have produced added vulnerability. Yet, building the case for healthcare interventions has not yet been part a central element of air pollution advocacy, which has gone heavily into the treadmill of monitoring data (Shapiro et al. 2017). The Delhi government has begun the process of strengthening primary healthcare through what they term 'Mohalla' or neighborhood clinics. These are by and large run efficiently, and consultations and medicines are free of cost. Gaps in coverage need to be addressed, as well as the blindspots in many peri-urban regions, which often fall through the cracks between different administrative units.

6 Conclusions

In December 2018 we were participants in a consultation on air pollution organised by a large private university. The event brought together advocates, academics, lawyers, scientists and journalists to discuss the issue. Speakers were given a seemingly simple prompt: propose solutions, rather than 'the problem'. By evening, the list of solutions was long. Among others, panelists spoke about artificial rain, clean diesel, happy seeders and harvesters, nasal cover, waste-to-energy plants, electric buses, and low-cost monitors. As we have discussed in the previous sections, in the debate on Delhi's air, established scientific networks and infrastructures often find themselves challenged by alternate networks beyond the state. But as this event shows, there is a broader consensus that air must be understood through appropriate scientific tools and solved *via* technical solutions. Only two interventions of fourteen—by one of the authors and another by a senior environmental journalist—tried to problematize the consensus, by pointing out other perspectives on environmental change: historical, aesthetic, and political.

In this background, this paper has focused on the trajectory of the debate on Delhi's air, parsing out the stakes and dilemmas of various agents while critically analysing the publics part of and (un)represented in the discussion. In her landmark essay, Sheila Jasanoff (Jasanaoff

1987) notes that different institutional contexts influence how scientists respond to boundary disputes. The American approach is shaped by science responding to adversarial positions between environmental justice activists and industrial lobbies, contesting to demonstrate (or not) the effects of accumulated and chronic exposure to underserved communities. In such cases, regulatory science has responded by either continuing to seek scientific consensus or stating that such dilemmas are out of scientific reach. Expertise of scientists to adjudicate on policy-relevant issues is largely unquestioned in European contexts. In India, we observe that air pollution science-policy contests do not respect these categories: the central government does not use available evidence and expertise, nor does it respond appropriately to the concerns of activists. In this scenario, the non-state technosciences are called upon to transcend the confines of their laboratories and computers. They often collaborate with airpreneurs, who translate scientific and technical advances into usable techno-fixes, while also engaging in direct activism. For them, the 'people' remain limited as subjects whose behavior must be changed, given the urgency of the situation. They conceive risk communication as a link between knowledge and action. However, as we argue, even in subaltern settlements of Delhi's highly toxic zones, there is a high degree of knowledge of risk, though it isn't articulated as specific to air or in terms that the technical debate presupposes.

When we shift attention to localizing air, we find that scientized and expert-driven dialogue on air can distract from problems of coordinational capacity or a critique of the public health system. Just as experts find it difficult to talk about air in isolation, it is important to remember that people, too, do not experience air in isolation. Instead, they experience chemical, embodied and political ecologies of toxicity. Our first call is to urge the technosciences to engage with the wider debate on environmental health and public healthcare for meaningful action and lasting impacts. Our second call is for researchers across sciences, social sciences, and the humanities to attend to when and how environmental advocates collaborate. Analyzing the place of the public in technoscientific documents and discussions is a starting point for this approach, because much of the collaboration endeavor is framed in public interest. The next step would be to think historically and politically about the dilemmas and possibilities of these collaborative endeavors. These two calls may converge in offering tactics of collaboration and asking where scientific questions are asked from as environmental researchers and advocates take on the difficult and persistent challenges of the present.

Acknowldgement

The authors would like to thank Professor NC Narayanan and Dr. Govind Gopakumar for organizing the IIT-Bombay workshop on 'The Technoscientific Consensus' and for putting together this special issue.

References

1. Bolia, N., and Khare, M. 2018, November 9 A passage to clean air. *Indian Express,* Retrieved fromhttps://indianexpress.com/article/opinion/columns/a-passage-to-clean-air/, 30 January 2020.
2. Guttikunda, S. K. 2016 What it means to take a long view on air pollution in Delhi. *The Wire*. Retrieved fromhttps://thewire.in/environment/delhi-parking-fee-brick-kilns, 12 September 2018.
3. Dubash, N. and Guttikunda, S. K. 2018 Delhi has a complex air pollution problem. *Hindustan Times*. Retrieved fromhttps://www.hindustantimes.com, 02 March 2020.
4. Negi, R. and Srigyan, P. 2021 *Atmosphere of Collaboration: Air Pollution Science, Politics and Ecopreneurship in Delhi.* New Delhi: Routledge.
5. Jasanaoff, S. 1987 Contested Boundaries in Policy-relevant Science. *Social Studies of Science*, **17**(2), 195-230.
6. Bickerstaff, K. 2004 Risk perception research: socio-cultural perspectives on the public experience of air pollution. *Environment International*, **30** (6), 827– 840.
7. Cupples, J. 2009 Culture, Nature and Particulate Matter – Hybrid Reframings in Air Pollution Scholarship. *Atmospheric Environment*, **43**(1), 207–217.
8. Ottinger, G. 2010 Buckets of Resistance: Standards and the Effectiveness of Citizen Science. *Science, Technology, & Human Values*, **35**(2), 244-270.
9. Kimura, A., & Kinchy, A. 2016 Citizen Science: Probing the Virtues and Contexts of Participatory Research. *Engaging Science, Technology, and Society*, **2**, 331-361.
10. Choy, T. 2010 Air's Substantiations. Paper for Berkeley Environmental Politics Colloquium. Retrieved from http://globetrotter.berkeley.edu/bweb/colloquium/papers/ChoyAirEP.pdf, 9 September 2019.
11. Garnett, E. 2016 Developing a Feeling for Error: Practices of Monitoring and Modelling Air Pollution Data *Big Data & Society* **3**(2), 1–12.
12. Garnett, E. 2017 Air pollution in the Making: Multiplicity and Difference in Interdisciplinary Data Practices. *Science, Technology, & Human Values*, **42**(5), 901-924.
13. Ministry of Health and Family Welfare. 2015 *Report of the Steering Committee on Air Pollution and Health Related Issues*. New Delhi: Ministry of Health and Family Welfare, Government of India.
14. Guttikunda, S. K. 2018 Air Pollution Monitoring 101. Retrieved from http://

www.urbanemissions.info/blog-pieces/air-monitoring-101/, 18 November 2019.

15. Sharma, M. and Dikshit, O. 2016 Comprehensive Study on Air Pollution and Green House Gases (GHGs) in Delhi. Indian Institute of Technology, Kanpur.
16. India State-Level Disease Burden Initiative Air Pollution Collaborators. 2018 The impact of air pollution on deaths, disease burden, and life expectancy across the states of India: The Global Burden of Disease Study 2017. *Lancet Planetary Health*, **3** (1), e26-e39.https://doi.org/10.1016/S2542-5196(18)30261-4.
17. Negi, R. 2018 Regionalizing Air: On the Possibilities of Transborder Collaborations. *Ecology, Economy and Society*, **1**(2), 87-89.
18. Gordon, T. 2018 Air pollution health research priorities for India: Perspectives of the Indo-
19. Guttikunda, S. K., Nishadh, K. A., and Jawahar, P. 2019 Air Pollution Knowledge Assessments (APnA) for 20 Indian Cities. *Urban Climate,* **27**, 124-141.
20. Centre for Environment and Energy Development. 2017 Background Note. *Proceedings from National Conference: HealthyAir: Collaborating efforts to mitigate pollution in the Indo-Gangetic Plain.* Delhi: Shakti Shakti Sustainable Energy Foundation.
21. Sundaray, N. K. and Bhardwaj, S. R. (eds.) 2019 NCAP: National Clean Air Programme. New Delhi: Ministry of Environment, Forest & Climate Change.
22. Pant, P., Guttikunda, S. K., and Peltier, R. E. 2016 Exposure to Particulate Matter in India: A Synthesis of Findings and Future Directions. *Environmental Research*, **147**, 480-496.
23. Balakrishnan, K., and Ghosh, S. 2018, December 20 Public health in India a casualty of air pollution, Hindustan Times. Retrieved from https://www.hindustantimes.com, 18 January 2020.
24. Centre for Science and Environment. 2001 *Smokescreen of lies: Myths and facts about CNG.* Delhi: Centre for Science and Environment.
25. Sharma, B., and Nagpure, A. S. 2019 Does India Have the Skilled Workforce Needed to Fight Air Pollution? *The Wire*. Retrieved fromhttps://thewire.in/environment/does-india-have-the-skilled-workforce-needed-to-fight-air-pollution, 29 April 2020.
26. Indian Institute of Management Lucknow 2010. Evaluation of Central Pollution Control Board (CPCB) submitted to Ministry of Environment and Forest, Government of India. Available at http://www.indiaenvironmentportal.org.in/files/Rpt_CPCB.pdf
27. Ottinger, G., and Cohen, B. (eds.). 2011 *Technoscience and Environmental Justice: Expert Cultures in a Grassroots Movement.* Cambridge, Massachusetts: The MIT Press.
28. World Bank. 2004 Urban Air Pollution in India: Perceptions of Stakeholders. South Asia Urban Air

Quality Management Briefing Note No. 15. Retreived from https://documents1.worldbank.org/curated/en/340301468267574425/pdf/339040REV0Briefing1Note1No115.pdf, 23 April 2016.

29. Saksena, S. 2011 Public Perceptions of Urban Air Pollution Risks. *Risk, Hazards & Crisis in Public Policy*, **2**(1), 1-19.
30. Mehta A. and D'Souza, R. 2019 *Hazy Perceptions: Public Understanding of Air Quality and its Health Impact in South and Southeast Asia, 2015-2018*. New York: Vital Strategies.
31. URJA. 2019 A Study on Delhi's Perception & Accountability on Air Pollution. Delhi: URJA. Retrieved from https://www.indiaspend.com/wp-content/uploads/2019/01/RTI-Survey-Report-on-Delhis-GRAP-URJA.pdf, 8 April 2020.
32. Bush, J., Moffat, S., and Dunn, C. E. 2001 Keeping the public informed? Public negotiation of air quality information. *Public Understanding of Science*, **10**(2), 213–229.
33. Bickerstaff, K., and Simmons, P. 2009 Absencing/presencing risk: Rethinking Proximity and the Experience of Living with Major Technological Hazards. *Geoforum*, **40** (5), 864–872.
34. Ramaswami, A., Baidwan, N. K., and Nagpure, A. S. 2016 Exploring Social and Infrastructural Factors Affecting Open Burning of Municipal Solid Waste (MSW) in Indian Cities: A Comparative Case Study of Three Neighborhoods of Delhi. W*aste Management & Research,* **34** (11), 1164–1172.
35. Hoffmann, K. 2011 From Science-based Legal Advocacy to Community Organizing: Opportunities and Obstacles to Transforming Patterns of Expertise and Access In *Technoscience and Environmental Justice: Expert Cultures in a Grassroots Movement* (eds. G. Ottinger and B.Cohen), pp. 41-62. Cambridge, Massachusetts: The MIT Press.
36. Johnson, J. R. and Ranco, D. R. 2011 Risk Assessment and Native Americans at the Cultural Crossroads: Making Better Science or Redefining Health? In *Technoscience and Environmental Justice: Expert Cultures in a Grassroots Movement* (eds. G. Ottinger and B. Cohen), pp. 179-200. Cambridge, Massachusetts: The MIT Press.
37. Liévanos, R. S., London, J. K., and Sze, J. 2011 Uneven Transformations and Environmental Justice: Regulatory Science, Street Science, and Pesticide Regulation in California In *Technoscience and Environmental Justice: Expert Cultures in a Grassroots Movement* (eds. G. Ottinger and B. Cohen), pp. 201-228. Cambridge, Massachusetts: The MIT Press.
38. Powell, M. and Powell, J. 2011 Invisible People, Invisible Risks: How Scientific Assessments of Environmental Health Risks Overlook Minorities — and How Community Participation can Make them Visible In *Technoscience and Environmental Justice: Expert Cultures in a Grassroots Movement* (eds. G. Ottinger and B. Cohen), pp. 149-178. Cambridge, Massachusetts: The MIT Press.

39. Public Health Foundation of India (PHFI). 2017 Air Pollution and Health in India: A Review of the Current Evidence and Opportunities for the Future. New Delhi: Centre for Environmental Health, PHFI.
40. Roychowdhury, A., Chattopadhyaya, V. and Shukla, S. 2016 Reinventing Air Quality Monitoring: Potential of Low Cost Alternative Monitoring Methods. New Delhi: Centre for Science & Environment.
41. Choudhary, S. 2019 India to develop own certification facility for air pollution monitoring equipment. *Livemint.* Retrieved fromhttps://www.livemint.com, 21 May 2020.
42. Air Quality in India Blog. 2018, September 18 Workshop notes: Real-time nationwide low-cost sensor network for air quality monitoring. Retrieved from https://indiaaq.blog/2018/09/18/workshop-notes-real-time-nationwide-low-cost-sensor-network-for-air-quality-monitoring/, 12 December 2019.
43. Almeida, R. 2017, March 13 Profiles of 6 Delhi citizens who are fighting for clean air in different ways. *Homegrow*n. Retrieved fromhttps://homegrown.co.in, 30 January 2020.
44. Sirur, S. 2018 Godrej is Now Selling "Clean Air" with its Gurugram Flats. *The Print.* Retrieved fromhttps://theprint.in/india/governance/godrej-is-now-selling-clean-air-with-its-gurugram-flats/166373/, 20 November 2019.
45. Singh, N. 2017 In Polluted Delhi, a Super-luxury Hotel will Offer the 'Cleanest' Air to the Rich & Famous. *The Print.* Retrieved fromhttps://theprint.in/report/polluted-delhi-luxury-hotel-cleanest-air-rich-famous/25877/, 20 November 2019.
46. Dalborne, J. and Galusky, W. 2011 Toxic Transformations: Constructing Online Audiences for Environmental Justice, In *Technoscience and Environmental Justice: Expert Cultures in a Grassroots Movement* (eds. G. Ottinger and B. Cohen), pp. 63-92. Cambridge, Massachusetts: The MIT Press.
47. Neumann, R. 2009 Political Ecology: Theorizing Scale. *Progress in Human Geography*, **33**(3), 398-406.
48. Beig, G., and Parkhi, N. 2017 Scientific assessment of Delhi Winter Air Quality Crisis (6^{th}-16^{th} November 2017). Pune: SAFAR-India, Indian Institute of Tropical Meteorology.
49. Gopakumar, G. 2009 Investigating Degenerated Peripheralization in Urban India: The Case of Water Supply Infrastructure and Urban Governance in Chennai. *Public Works Management & Policy*, **14**(2), 109-129.
50. Sharan, A. 2014 *In the City, Out of Place: Nuisance, Pollution and Dwelling in Delhi c. 1850-2000.* Oxford University Press: New Delhi.

51. Goswami, S. 2017 Badarpur power plant pumping toxins into Delhi's air. *Hindustan Times.* Retreived fromhttps://www.hindustantimes.com/delhi-news/badarpur-power-plant-pumping-toxins-into-delhi-s-air/story-RBKs6dP6sVxFWwz4lsc1OM.html, 12 December 2018.
52. Tayebulla, F. 2016 Understanding Urban Environmental Activism: Study of Okhla Waste to Energy Plant. Unpublished MA Dissertation, School of Human Ecology, Ambedkar University Delhi.
53. Auyero, J. and Swiston, D. 2009 *Flammable: Environmental Suffering in an Argentine Shantytown.* Oxford: Oxford University Press.
54. Shapiro, N., Zakariya, N. and Roberts, J. A. 2017 A Wary Alliance: From Enumerating the Environment to Inviting Apprehension. *Engaging Science, Technology, and Society*, **3**, 575-602.