The Social Life of the “Forever Chemical”

PFAS Pollution Legacies and Toxic Events

Daniel Renfrew and Thomas W. Pearson

ABSTRACT: This article examines the social life of PFAS contamination (a class of several thousand synthetic per- and polyfluoroalkyl substances) and maps the growing research in the social sciences on the unique conundrums and complex travels of the “forever chemical.” We explore social, political, and cultural dimensions of PFAS toxicity, especially how PFAS move from unseen sites into individual bodies and into the public eye in late industrial contexts; how toxicity is comprehended, experienced, and imagined; the factors shaping regulatory action and ignorance; and how PFAS have been the subject of competing forms of knowledge production. Lastly, we highlight how people mobilize collectively, or become demobilized, in response to PFAS pollution/toxicity. We argue that PFAS exposure experiences, perceptions, and responses move dynamically through a “toxicity continuum” spanning invisibility, suffering, resignation, and refusal. We offer the concept of the “toxic event” as a way to make sense of the contexts and conditions by which otherwise invisible pollution/toxicity turns into public, mass-mediated, and political episodes. We ground our review in our ongoing multisited ethnographic research on the PFAS exposure experience.

KEYWORDS: chemicals, environmental health, environmental justice, environmental regulation, late industrialism, PFAS, toxic event, toxicity continuum

A class of several thousand synthetic chemicals, simultaneously a legacy pollutant and an emergent contaminant, is drawing increasing attention as one of the most vexing environmental health challenges of the twenty-first century. A dizzying array of products derive their ability to repel oil and water from per- and polyfluoroalkyl substances, which are known as “PFAS.” First invented in the World War II era and encompassing thousands of variants developed throughout the decades since, these chemicals are found in nonstick cookware, waterproof and stain-resistant textiles, food packaging, medical devices, and even personal care products. They are also a key ingredient in specialized firefighting foams known as aqueous film-forming foams (AFFF). The remarkable properties of PFAS chemicals make them uniquely troublesome from an environmental health perspective. They have been called “forever chemicals” because they resist natural processes of degradation, some never fully breaking down. After decades of commercial use, they are also an inescapable fact of contemporary life. In some ways, the PFAS crisis compares to other toxic legacies of the modern industrial age that have altered the very biology of humanity and that will haunt us for generations, such as PCBs and nuclear radiation (Altman 2019). But the PFAS crisis, we contend, also requires new frameworks for understanding life in a toxic and permanently polluted world (Liboiron et al. 2018; Nading 2020).

PFAS enter the environment through wastewater disposal and air emissions at manufacturing plants, leaching at landfills or dump sites, and the spraying of AFFF. Human exposure is considered ubiquitous for a few reasons. In addition to being persistent and pervasive, PFAS are known to bioaccumulate, concentrating in animals such as fish and in humans (CDC 2017). Beyond fence-line communities, people come into contact with these chemicals through interaction with ordinary consumer products. The Centers for Disease Control and Prevention, for instance, have found PFAS in the blood serum of “nearly all of the people tested,” meaning these chemicals already occupy the bodies of virtually everyone in the United States (CDC 2017). Some PFAS chemicals are also highly mobile. They move through soil and find their way into surface and groundwater, and they even travel with rainwater. As of March 2021, more than 2,330 known PFAS drinking or groundwater contamination sites have been identified across the United States, meaning up to 110 million Americans drink tap water tainted with PFAS (Evans et al. 2020; EWG 2021).

Despite the long history of PFAS, scientists have only scratched the surface of how exposure affects humans. Companies such as 3M and DuPont, two of the major manufacturers of PFAS chemicals and products, began studying PFAS toxicity in the 1960s and found troublesome levels of the chemicals in plant workers as early as the 1970s (Lerner 2018a). Over the decades, the companies collected data about potential health consequences and only partially informed regulatory agencies about what they had found (Richter et al. 2018). Two of the most prevalent and extensively studied PFAS chemicals, perfluorooctanoic acid (PFOA, also known as C8) and perfluorooctane sulfonate (PFOS), were voluntarily phased out of US production in the early 2000s due to concerns of pervasive contamination. Subsequent litigation against DuPont and 3M has unearthed internal industry studies and fueled scrutiny of the health impacts of PFAS exposure, sparking a surge of interest among scientists, regulators, and the public.

Many experts are troubled by the fact that extremely low levels of PFAS are associated with a wide range of health problems (Blum et al. 2015). One of the largest epidemiological studies ever conducted, completed in 2012 as part of DuPont litigation, linked PFOA exposure in Parkersburg, West Virginia, with testicular cancer, kidney cancer, ulcerative colitis, thyroid disease, pregnancy-induced hypertension, and hypercholesterolemia (Science Panel 2020). Studies also suggest an association between PFAS and liver damage, asthma, decreased fertility, reduced antibody response to vaccines, and other health problems (ATSDR 2021). Although PFOA and PFOS were phased out of US production, they will remain in the environment for decades to come. Industry invents additional PFAS chemicals every year, and substances such as GenX, an ostensibly safer alternative to PFOA introduced by DuPont in 2009, has prompted new environmental and health concerns (Lerner 2017). Due to the environmental persistence and mobility of PFAS, their widespread use, even newer versions considered safe by industry, “will lead to irreversible global contamination” with “currently unknown consequences” for human health (Cousins et al. 2019: 1804).

In a world tragically accustomed to industrial pollution, chemical exposure, and contamination events—whether from lead, asbestos, PCBs, dioxins, oil spills, pesticides, or other harmful substances—PFAS are familiar yet disturbingly unique. Because they are not only toxic but also so pervasive, persistent, and mobile, one CDC official described PFAS as being among “the most seminal public health challenges of the coming decades” (Turkewitz 2019). In this article, we offer an ethnographically informed analysis of what social science brings to light in understanding responses to PFAS contamination. The nascent social science research has unpacked the “social discovery” of PFAS pollution, including growing lay awareness, the production of knowledge and ignorance about toxicity in relation to ineffective regulatory frameworks, the role of litigation, and new forms of advocacy (PFAS Project 2020). Building on this work, we

highlight the recent processes and conditions through which PFAS contamination is sometimes transformed from a status of largely invisible, normalized toxicity into a crisis that reshapes lived experience.

In what follows, we review the history and social life of PFAS chemicals in relation to late industrialism; corporate manipulation of environmental regulation; the dynamics through which toxicity is made visible; and the affective and sociopolitical dimensions of how communities respond to pollution and frame experiences of toxicity. We refer to the process through which routinized toxicity comes to be collectively perceived as unacceptable as a “toxic event.” Localized and variable, toxic events represent an interruption of everyday life, symbolic-material assemblages mobilized and acted upon through highly contested scientific, media, and public discourses, including new forms of community organizing and citizen engagement. Toxic events entail transformative processes that bring into being novel understandings of self and community, of place and environment, of local history and industrial legacy. Social scientists often document episodes in which contamination is discovered and contested in a community, but we wish to draw further attention to the locally situated and dynamic psychosocial reordering that people experience (Edelstein 2004). Such experiences register along what we call a “toxicity continuum,” ranging from invisibility or unacknowledged exposure to different forms of suffering, resignation, and refusal.

We ground our article with data collected through our ongoing collaborative, multisited ethnographic research on community responses to PFAS contamination in the Upper Great Lakes and Mid-Ohio Valley regions of the United States. We are conducting fieldwork at interconnected sites to illuminate varied local experiences with PFAS contamination stemming from the manufacture, use, and disposal of PFAS chemicals and PFAS-treated products. These include two epicenters of the PFAS crisis, 3M’s chemical plant in Cottage Grove, Minnesota, and DuPont’s plant in Parkersburg, West Virginia, as well as several recently discovered contaminated communities across Wisconsin and Michigan linked to manufacturing, landfills, airports, and military installations. Our ethnographic fieldwork began in late 2018 and is most developed in Marinette, Wisconsin, the location of Tyco Fire Products, a company that produces and tests firefighting foams. Methods have included participant observation in dozens of community forums; observation of dozens of local and state government agency meetings in both Minnesota and Wisconsin related to the development of regulatory responses in those states; participation in NGO advocacy networks; dozens of open-ended interviews with residents in contaminated communities; and the ongoing review of media coverage, technical documents, and archival materials.

Late Industrialism

PFAS trace back to the 1930s, and companies such as 3M began to commercially produce PFAS chemicals in the 1950s, a period when the chemical industry bonded tightly with industrial and military power, ushering forth the so-called “Chemical Century” (Agard-Jones 2014; Langston 2010). DuPont’s Teflon was used in the Manhattan Project during World War II and helped create warheads, liquid-fuel tanks, and Fat Man, the nuclear bomb that destroyed Nagasaki (Altman 2019; Bilott 2019). This “miracle of science” was also used in cutting-edge applications for the Apollo space program and new medical technologies (Lyons 2007). Out of the destruction of World War II, the chemicals were quickly applied to mass-produced consumer goods. Several researchers involved in the Manhattan Project joined 3M to further develop PFAS (Altman 2019; MacKay 1991). Originally founded in 1902 as the Minnesota Mining and Manufactur-

ing Company, 3M became a multinational conglomerate engaged in diverse industries once it turned to chemical manufacturing. Its massive research and production plant opened in 1947 in Cottage Grove, southeast of St. Paul, where the company is headquartered. 3M began producing PFOA in 1951, which was sent to DuPont's new Washington Works plant in Parkersburg, which was built to manufacture Teflon products (Lerner 2018a). Today, the Washington Works plant is operated by Chemours, a DuPont spinoff.

Two years after it began producing PFOA for DuPont, 3M invented its Scotchgard fabric coating, which utilized PFOS. Both Teflon and Scotchgard became iconic brands, coating everything from pans to pants. Scotchgard and other stain- and water-resistant coatings were used for decades on upholstery, carpeting, shoes, camping gear, and clothing. PFOA and PFOS also found their way into protective coatings for other products, including food packaging such as pizza boxes, fast food wrappers, and microwave popcorn bags. PFAS chemicals appear in a head-spinning array of items, from plastics and papers to ski wax, artificial turf, cosmetics, dental floss, and sunscreen (Boronow et al. 2019).

In the 1960s, 3M began producing specialized firefighting foams in collaboration with the US military (Lerner 2018b). Firefighting foams known as AFFF are used to extinguish the intense blazes powered by flammable liquids such as oil, gasoline, and jet fuel. PFAS chemicals are an ingredient in the film barrier that smothers fire and prevents reignition. Produced and tested in places like Marinette, Wisconsin, at the Tyco Fire Products training facility, they are used at fire stations, airports, port facilities, and military installations around the world (Bond 2021; Pearson 2020; Turkewitz 2019).

Even as people's lives became intimately entangled with PFAS chemicals, most remained unaware of the expanding hazard. Consumers unsuspectingly exposed themselves through interaction with ordinary products; workers trusted industry assurances of safety; airport, seaport, and military personnel deployed AFFF as part of routine testing and training; and residents near factories, airports, military bases, or dump sites remained oblivious to the chemicals infiltrating groundwater, the air, and their bodies. Now acknowledged as hazardous, PFAS epitomize the modern risk society, which is vulnerable to and preoccupied with managing dangers of its own design (Beck 1992).

Pervasive, routinized exposure to PFAS, however, also calls into question notions of risk management, as if the concept has simply been abandoned, surrendered to the interests of capitalist growth and consumer convenience. If the modern risk society was about identifying, managing, and communicating industrial hazards and uncertainty, much of it was ultimately predicated on a sense of stable order—a faith in material infrastructure and technoscientific reason, no matter how threatened from the outside. Late industrialism, by contrast, describes a moment when previously predictable infrastructures, systems, and knowledge regimes fail and “fall apart,” or are revealed to have always been inadequate (Fortun 2012). Risk is not just about threats to an established order created by industrial development; rather, it inheres *in* the rotting, crumbling order itself (Mah 2012; Tsing 2015; Zeiderman 2015).

The late industrial violence of PFAS exposure works through the nebulous boundaries between bodies and the environment, and across different environmental systems (Ford 2019). PFAS contaminate the wells that people use for drinking water, bathing, irrigation, and animal care. It reaches individuals all over the world through airborne industrial emissions and global networks of trade and consumption. It migrates in underground plumes that stretch and morph unpredictably through subterranean systems, confounding environmental engineers. It even rains from the sky (Lyons 2007). PFAS, moreover, do not break down easily and trace amounts build up in organisms indefinitely, a “chemical residue” (Boudia et al. 2018) marking an uncertain present and a future of potentially “reverberating crises” (Masco 2015).

PFAS also illuminate how inequality shapes the hazards of late industrialism, including the racialization of toxic pollution and uneven institutional responses. PFAS pollution is universal and global in scale, a product of capitalist modernity and rampant consumerism, and is in many ways an apt reflection of late industrial risk society. But the risk society idea arguably reveals the anxieties of White middle-class citizens trying to protect raced and classed “hallmarks of suburban privilege” from industrial and consumerist chemical exposures (Murphy 2004: 276). In addition to universal exposure, the PFAS crisis flashes out in geographically dispersed hotspots of contamination, each with its own unique history, each shaped by the structural inequities of the capitalist order and varied forms of environmental racism and classism (Bullard 2005; Harvey 1996; Hoover 2017; Pellow 2007).

In our research, PFAS contamination does not obviously follow the racial disparities and histories of residential segregation that structure other environmental inequalities in the United States. In recent years, contaminated sites are being discovered in economically distressed towns and rural communities dependent upon a few major industrial or military enterprises. To consider environmental inequality in the suburbs surrounding 3M in Cottage Grove, Minnesota, or the communities impacted by DuPont’s plant in Parkersburg, West Virginia, or the rural-industrial landscapes contaminated by Tyco Fire Products in Marinette and Peshtigo, Wisconsin—towns or small cities with majority-White populations, wealth mixed with relatively high rates of poverty—encourages us to think beyond the ways scholars and activists typically imagine environmental justice in the United States. In these settings, it is more often the class and rural, rather than racial and urban, based character of differential risk and environmental injustice that takes precedence, and the unacknowledged privileges of Whiteness that shape institutional responses. They also reveal the pernicious role of corporate power in creating conditions of vulnerability (Kirsch 2014).

Regulatory Responses

The regulatory response to PFAS in the United States has been slow and fragmented, meaning that PFAS are often considered a contaminant of “emerging concern,” and have only recently been viewed as urgent despite decades of warning signs. In the absence of strong federal action, many states are scrambling to fill the regulatory void. The fragmented regulatory response illuminates the forces shaping environmental governance and the social production of scientific knowledge and ignorance under late industrialism.

The creation of the US Environmental Protection Agency (EPA) in 1970 marked a period of landmark reforms aimed at reining in the excesses of industrial pollution “externalized by capitalist ledger books” (Murphy 2017: 495) and shifted onto people, the environment, and future generations. But environmental governance quickly became a site of competing agendas, with corporations mobilizing through trade associations and similar organizations to influence regulatory actions (Hepler-Smith 2019; Richter et al. 2020). State institutions are also susceptible to regulatory capture by industry, leading to “deep capture” during antiregulatory neoliberal times (Dietrich 2013). As a result, a “regime of imperceptibility” took shape around PFAS, hiding it from meaningful regulatory action for half a century (Murphy 2006).

Despite many successes since the 1970s, the regulatory system also contributes to the perpetuation of toxic pollution (Fortun 2001; Hepler-Smith 2019; Murphy 2004). Federal laws such as the Toxic Substances Control Act (TSCA) of 1976 exempted existing chemicals, meaning thousands of substances, including PFOA and PFOS, simply eluded scrutiny from scientists outside of industry (Richter et al. 2020). DuPont, for instance, began studies of PFOA toxicology in the

1960s and 3M was collecting data on worker exposure in the 1970s. But PFOA did not become a focus of concern for regulators until the late 1990s and early 2000s because the companies failed to disclose their internal data about human exposure and health risks (Bilott 2019; Richter et al. 2020). The TSCA was also designed to allow quick marketing of new chemical products, to protect confidential business information, and to require regulators to demonstrate harm before acting, even when they lack the necessary data and analytical methods, concealed by industry, to evaluate toxicity.

This limits the ability to meaningfully review chemicals, “producing selective ignorance” and instilling a “culture of forbidden [corporate] knowledge within the EPA” (Richter et al. 2020). Without the ability to independently test chemicals, the EPA often relies on industry to self-report concerns. For decades, industry simply asserted that PFAS were safe (Bilott 2019). In the first reform since its inception, the 2016 Lautenberg Act updated the TSCA to establish new chemical prioritization rules for EPA oversight and new notification and reporting requirements, but under the Trump administration EPA leadership was slow to implement changes that would favor public health over industry chemical use (Richter et al. 2020). As the nationwide PFAS crisis grows, it is clear now that the EPA’s corporate-friendly regulatory structure trickles down in the form of tremendous gaps in data and spheres of ignorance among independent scientists and state regulators who seek to understand the impacts of PFAS. There is no data on total PFAS production, as the chemicals are not regulated as a class (Kwiatkowski et al. 2020). And toxicologists and other health experts are researching only a few dozen of the several thousand (and growing) chemical compounds comprising PFAS (EPA 2020).

Beginning in 1999, Rob Bilott led a series of lawsuits against DuPont that helped reveal the extent of PFOA contamination around Parkersburg as well as how the company dodged regulation. His book *Exposure* (2019) details how DuPont covered up in-house occupational health and toxicity studies, the emissions from its Washington Works plant, and ongoing leaching from illegally dumped hazardous waste. DuPont spent years buying up contaminated wells and land adjacent to the plant for *in situ* emissions and dumping, but the waste leached into nearby creeks, rivers, and other wells, eventually contaminating the drinking water of tens of thousands of people in West Virginia and Ohio. As scrutiny increased, DuPont followed the familiar playbook of other twentieth-century hazardous industries (Markowitz and Rosner 2002; Oreskes and Conway 2010). Their lawyers and representatives destroyed documents, threatened lawsuits and gag orders, engaged in smear campaigns, stifled whistleblowers, deployed sophisticated public relations campaigns to defend its corporate image, partnered with politicians and regulators to undermine oversight, labeled the results of independent scientific studies as “junk science,” and fought and dragged out litigation for nearly two decades (Bilott 2019; Lyons 2007; Lerner 2015).

Bilott denounces the revolving door between government regulators and industry, in one example describing collusion in forming a joint investigative panel to deflect further inquiry. An EPA investigation into the mysterious deaths of dozens of cows on the Tennant farm near Parkersburg—the case that served as the detonator of the PFOA/C8 scandal—revealed no company wrongdoing. Flexing its political muscle, DuPont negotiated who would serve on the Cattle Team panel, which subsequently did not test specifically for PFOA as it was not a registered substance dumped at the nearby Dry Run landfill, even though internal company documents later revealed full cognizance of toxic dumping at that site (Bilott 2019; Lerner 2015).

The gradual discovery of PFAS contamination near 3M’s operations in Minnesota was similarly shaped by regulatory capture and industry efforts to manufacture doubt (Oreskes and Conway 2010). Unfolding over decades, 3M caused what equates to permanent groundwater contamination stretching some 150 square miles, impairing the drinking water of over 150,000

people (MDH 2020). From the 1950s to the 1970s, 3M disposed of waste at four dump sites east of St. Paul, including one municipal landfill, in compliance with existing laws at the time. During the 1990s, residents of Cottage Grove, including a former 3M employee, began to raise concerns about groundwater contamination stemming from the dump sites, but they were reassured of the water's safety, even as 3M internally studied and discussed the hazards of PFAS (Lerner 2018a; Richter et al. 2018). In 2000, 3M announced that it was ending PFOA and PFOS production, while maintaining that the chemicals pose no risk to human health. But in 2002, 3M notified the Minnesota Pollution Control Agency (MPCA) that it had found contaminated groundwater at its Cottage Grove plant, triggering a wider investigation. As scrutiny of the chemicals increased and litigation unfolded around DuPont in Parkersburg, Fardin Oliaei, a MPCA scientist, began to find high levels of PFAS chemicals in fish samples taken near 3M's plant. Oliaei claims that her requests to expand her research were blocked by her supervisors, including MPCA commissioner Sheryl Corrigan, a former 3M manager appointed in 2003. Corrigan maintained that MPCA is a regulatory agency, not a scientific institution—the science should be left to other entities, such as 3M. Oliaei filed a whistleblower lawsuit, the settlement of which included her departure from MPCA in 2006 and led to Corrigan stepping down as MPCA commissioner (Edgerly and Aslanian 2005; Oliaei 2006).

Over two decades, the state expanded its investigation of the 3M dump sites and has tested a growing number of wells to fully grasp the extent of the groundwater contamination. In 2007, 3M reached an agreement with MPCA in a legally binding consent order to pay for remediation costs associated with PFAS contamination at three dump sites. But state officials still alleged that 3M knowingly released hazardous chemicals for decades, contaminating drinking water and putting people's health at risk. The attorney general sued 3M in 2010 and sought \$5 billion in damages. Like Bilott's lawsuits against DuPont, the discovery process unearthed numerous internal 3M documents, fueling media coverage and public interest in 3M's activities. Just before the trial in 2018, 3M settled for \$850 million but denied wrongdoing. Currently, the state is overseeing a complicated planning process to use the settlement funds to ensure access to safe drinking water for the dozens of affected communities.

As the DuPont and 3M cases illustrate, an “out of sight, out of mind” approach has guided regulatory responses to PFAS, along with self-monitoring and self-reporting expectations by which companies inconsistently abide (Bilott 2019; Frickel and Elliot 2018). Industry exploited a regulatory system that favored market-based incentives for production over public health concerns. As scrutiny has increased, the EPA remains hampered by corporate-friendly mechanisms such as the TSCA and for years has relied on voluntary phaseouts, negotiated consent agreements, and unenforceable recommendations. 3M phased out its production of PFOS in 2002, and the EPA negotiated the PFOA Stewardship Program in 2006, an agreement in which eight multinational corporations, including DuPont and 3M, committed to voluntarily phase out PFOA from production by 2015. Critics such as Bilott view the voluntary phaseouts as a corporate strategy to pull them from the marketplace in an effort to evade financial liability, and as part of its agreement with DuPont he suggests the EPA delayed further regulatory action on the chemicals until 2016 (Bilott 2019). The EPA also oversaw nation-wide testing of municipal drinking water in 2013–2015 as part of its monitoring of unregulated contaminants and issued a health advisory for PFOA and PFOS in drinking water, which amounts to mere guidance for local water providers. For two decades now, critics have wondered why the EPA has not set enforceable Maximum Contaminant Levels (MCLs) under the Safe Drinking Water Act (SDWA), despite growing evidence about the dangers of PFOA, PFOS, and other PFAS chemicals. Under the new Biden administration, the EPA now says it will initiate another round of nation-wide testing of drinking water and finally move to regulate PFOA and PFOS under

the SDWA (EPA 2021). For the first time, nearly 200 PFAS were added to the EPA’s Toxic Release Inventory in 2020, with first reporting due in July 2021.

With the inability of the EPA to regulate PFAS as a class and its astoundingly slow response to PFOS and PFOA, many states are now setting their own limits for PFAS in drinking water and otherwise seeking to hold industry accountable. Even as companies such as DuPont and 3M assume some of the costs of environmental remediation through legal settlements, they continue to downplay health concerns and deny wrongdoing. Beyond the blatant secrecy, unethical behavior, and criminality exposed by lawyers, whistleblowers, and investigative journalists, PFAS toxicity has remained obscured because the regulatory system has *allowed* in-house industrial science to be kept from public view. As Lauren Richter and colleagues (2018) put it, rather than constituting “undone science” (Hess 2009), PFAS research advanced for decades but remained “unseen.” Regulatory systems produce both knowledge *and* ignorance, creating conditions such that the inevitable discovery of PFAS contamination in communities across the United States is repeatedly experienced as a surprise (Richter et al. 2020; see also Boudia et al. 2018; and Proctor 2008).

Seeing PFAS Toxicity

Lack of effective chemical regulation shifts the burden of proving harm to exposed citizens, perpetuating cycles of popular epidemiology in which people mobilize and endeavor to link their health problems to toxic exposure (Brown 2007; Richter et al. 2018). If regulatory systems contribute to the social production of scientific ignorance, late industrial PFAS toxicity is also unseen because of its complex temporalities, geographic mobility, and utter pervasiveness (Goldstein 2017). Toxicity is often the product of the temporally accumulating and geographically dispersed “attritional catastrophes,” which Rob Nixon (2011) has now famously referred to as “slow violence,” a form of harm that builds gradually over time. Structurally hidden, accountability for such violence often remains elusive.

Many sources of present-day PFAS pollution stem from past practices forgotten by design or simply with the passage of time. The use of AFFF firefighting foams, for instance, has occurred for decades across the country as part of training exercises, periodic testing, or in response to emergencies, and in many cases records of use do not exist. Long-shuttered airports or military bases are also emerging as sources of groundwater contamination. Industry practices of disposing of waste onsite, sometimes to escape regulatory oversight, also fold over into the present with land use changes and new development. Without detailed records, this industrial and residential “churning” makes identification and containment of potentially hazardous sites difficult (Frickel and Elliot 2018). In the case of 3M in Cottage Grove, Minnesota, suburban development over the past 40 years has brought tens of thousands of people into closer proximity to what was once a remote manufacturing plant and its constellation of dump sites that have leached for decades.

Even in places with more gradual demographic change, rural–urban churning intersects with pollution. In Marinette, Wisconsin, where Tyco Fire Products has developed and tested firefighting foams for several decades, Tyco assumed that groundwater contamination discovered in late 2017 was limited to a handful of private wells in the Town of Peshtigo, just beyond city boundaries and adjacent to its outdoor testing facility. It has recently come to light that contaminated biosolids from the city’s wastewater treatment plant have been applied to farm fields in the surrounding agricultural communities since the 1990s, potentially seeding a nebulous plume of contamination. State officials have found that their existing protocols for dealing

with contamination events are unsuited for PFAS. As Christine Haag, a Department of Natural Resources (DNR) remediation director, explained in January 2020:

If this were petroleum, or many of the other contaminants that we work with in the environment, we could say that groundwater flow is a big predictor on where this contamination ends up. That's not the case with PFAS. There's volumes and volumes of things that the world does not understand about PFAS. But one of the things that most people can agree on is that this doesn't behave like anything else in the environment. Therefore, the traditional ways we investigate contaminants doesn't work in this situation.

PFAS from firefighting foams has seeped into groundwater for decades, flowing through streams and ditches that empty into Lake Michigan, cycling through the city's wastewater treatment plant, traveling with biosolids, possibly wafting with air emissions and plumes of smoke from training exercises conducted at a fire school, and likely accumulating in fish and deer consumed by humans.

Evolving regulatory standards also make toxicity visible where it has previously been ignored. In 2001, for instance, West Virginia state toxicologist Dr. Dee Ann Staats declared that detection of PFOA in drinking water at levels below 150 ppb (parts per billion, or 150,000 parts per trillion) constituted "low levels" and "would not cause harm to humans" (Bilott 2019: 157), even as DuPont's internal documents in the 1990s and early 2000s listed a much stricter safety threshold for its workers of 1 ppb. In 2016, the EPA finally issued a health advisory of 0.07 ppb (or 70 ppt) for PFOA and PFOS in drinking water. In recent years, many toxicologists and activists have argued for a 1 ppt safety threshold for PFOA and PFOS, and many states test for dozens of additional PFAS chemicals and have recommended exposure limits much lower than the EPA's current advisories (Cordner et al. 2019; Post 2021). As health-based thresholds are refined, more communities become classified as having polluted water.

The scientific research on PFAS and health is also in its nascent stages, fraught with inherent uncertainty and often heavily contested, with industry routinely asserting that PFAS exposure is benign while casting doubt on research that points to health impacts. The "dominant epidemiological paradigm" is predicated upon very large, statistically significant sample sizes that are often impossible to capture at the local or community level and do not reflect experiential understandings of contamination and disease (Brown 2007; Checker 2007). While PFAS is increasingly associated with several negative health outcomes, illness may occur years or decades after exposure. Establishing a causal relationship between toxic exposures and illness is also confounded by "toxic layering," or the "accumulation of multiple and potentially interacting industrial toxins" (Goldstein and Hall 2015: 640). If illness eventually manifests, it is difficult to pinpoint a cause, much less tie it to a specific exposure or chemical.

At other times scientific knowledge production is embedded within and reproduces dominant cultural narratives that "other" and blame the victims of industrial poisoning, thus delimiting the scope and possibilities of data collection (Renfrew 2018). Industry, for instance, may point to everyday consumer products as a source of exposure in an effort to sidestep responsibility and deflect blame onto individual behaviors. In their original investigation of possible pollution on the Tennant farm adjacent to the Dry Run landfill near Parkersburg, DuPont blamed poor animal husbandry practices for the precipitous deaths of dozens of cattle (Bilott 2019). This type of victim-blaming often seeks to map contamination onto vulnerable or marginalized subjects (Checker 2005; Hoover 2017).

Toxic harm under late industrialism has also become routinized, turned into the "chemical background noise of everyday life" (Shapiro 2015: 387). Thousands of synthetic chemicals have trespassed into ecological systems and human bodies, making it increasingly hard to differen-

tiate the natural from the chemically altered and permeable somatic self (Altman 2019; Fortun 2012; Graeter 2019; Murphy 2008; Roberts 2017). Employees at Washington Works, for example, rationalized their experiences of chemical harm by referring to their symptoms as merely the “Teflon flu” (Bilott 2019: 183). This also allows companies responsible for PFAS contamination to create doubt and uncertainty by noting the ubiquity of PFAS in daily life. In Marinette and Peshtigo, it has proven difficult to pinpoint the sources and pathways of pollution in order to hold Tyco accountable, a challenge complicated by the necessity to distinguish Tyco’s pollution from what one official called “naturally occurring” background levels of PFAS, a reference to how ubiquitous these chemicals have become in the surrounding environment.

One of the resounding outcomes of lawsuits against DuPont in the early 2000s was to establish now widely recognized linkages between PFAS exposure and health, generating research that would become a reference point for many states and communities currently grappling with PFAS contamination. Settlement of a class action lawsuit resulted in an epidemiological study to examine PFOA exposure among Parkersburg residents and the creation of a panel of impartial, world-renowned experts to determine potential links to disease. From 2005 to 2006, what was called the C8 Health Project managed to gather health and exposure data from over 69,000 individuals (Bilott 2019). Then for several years, the associated C8 Science Panel investigated linkages between PFOA exposure and health. During the process, DuPont responded throughout by defaming as “junk science” any studies that found links between PFAS and health injuries. It hired a PR firm to publish white papers to “seed” the scientific literature with doubt and used an industry front group to mount a public relations counter-offensive, denouncing “those who spew chemical-phobia in their crusade to eliminate the tools modern industrial chemistry has given us” (Bilott 2019: 266; cf. Oreskes and Conway 2010). Finally, in 2012, the panel issued its conclusions determining a “probable link” between PFOA exposure and several diseases (Science Panel 2020). The probable link determinations opened the door for further litigation, and DuPont settled lawsuits in 2017 for over \$670 million in damages with 3,500 individuals (Bilott 2019).

As federal and state guidelines evolve, and as monitoring for PFAS in water supplies expands, contamination is now routinely discovered, and toxicity is becoming increasingly visible. Scientific knowledge production has developed in concert with multifaceted processes and actors associated with the domains of litigation, regulation, the media, and impacted communities. As science studies scholars have long demonstrated, “science is embedded in social contexts, and scientific discoveries and their applications are neither linear nor inevitable” (Richter et al. 2018: 704). Both knowledge and ignorance, seeing and unseeing, are socially produced through scientific and regulatory practices (Boudia et al. 2018; Button 2010; Frickel et al. 2010; Proctor 2008). PFAS is thus a co-created material, first invented and manufactured as a class of substances by “chemicocapital” (Povinelli 2017), but then reconstituted over time as an artifact and a “matter of concern” by diverse scientific, social, and political actors (Murphy 2004).

Becoming a Toxic Event

After decades of inaction, the social discovery of PFAS as a previously unseen chronic pollution problem has set the stage for what we term publicly recognized “toxic events,” ruptures to everyday life that reorient lived experience and serve as a platform for the generation of new forms of subjectivity and, potentially, rights claims (Petryna 2002). The lived experience of toxic exposure may register along what we call a “toxicity continuum,” which ranges from the invisibility and ignorance of routinized, everyday exposure to recognized suffering, resignation, or

refusal. Suffering encompasses the somatic effects and psychological stress of known toxic exposure, while resignation describes a helplessness or fatefulness, a doubting of the possibilities of redress and change. Refusal captures that impulse toward collective organization and action. Toxic events take shape when harm or hazard becomes visible and is socially and institutionally acknowledged. They unfold within an approximate geographic space and temporal frame, an assemblage constituted by the materiality of pollution, the public discourse and knowledge production surrounding it, and the suffering and refusal-oriented dimensions of the toxicity continuum.

Toxic events are informed by a context-specific set of dynamics, including the negotiation of scientific and experiential causality between a contaminant and its health or environmental impacts (Brown 2007; Checker 2005); the materiality of the toxic substance itself and the ability to establish a temporal horizon of exposure (Agard-Jones 2014; Boudia et al. 2018; Hoover 2017); the complexity of its layering or churning with other toxic substances *in situ* or throughout time (Frickel and Elliott 2018; Goldstein and Hall 2015; Little 2014); the role of the media and allied researchers in illuminating the hazards and risks of exposure (Ahmann 2018; Langston 2010; Murphy 2004; Wylie 2018); the degree to which independent science over corporate interest informs the regulatory process (Button 2010; Dietrich 2013; Jasanoff 1998; Schuller and Button 2016); and the strength of grassroots groups in engaging in citizen science, humanizing the victims of toxic suffering, or pressuring for recognition and action (Brown 2007; Bullard 2005; Kimura and Kinchy 2019; Lerner 2010; Pearson 2017; Pellow 2007; Renfrew 2018).

The fact that the still-unfolding social discovery of PFAS took decades is illustrative. We note above the fundamental role played by litigation as both a response to and catalyst of media exposure, regulatory action, scientific research, and community activism. Sometimes these realms directly overlapped. In the early 2000s, the Environmental Working Group (EWG) became involved in PFAS advocacy, serving as a media-savvy, science-based advocacy group. Researchers with the Social Science Environmental Health Research Institute (SSEHRI) at Northeastern University have also been unpacking the social discovery of PFAS contamination, the factors shaping community exposure experiences, and why the risks associated with PFAS remained “structurally hidden” and unexamined for so long (Cordner et al. 2019; Cordner et al. 2016; Judge et al. 2016; Richter et al. 2018). The SSEHRI has partnered with NGOs to build citizen-science networks, and it maintains an online contamination site tracker in collaboration with the EWG (EWG 2020; PFAS Project 2020).

Around the country, PFAS contamination sites are currently coalescing into toxic events, drawing together activists, scientists, lawyers, and the media in new and often innovative political communities (Bond 2020, 2021; Shapiro and Kirksey 2017). The C8 Health Project, for instance, was only possible because the litigation team suing DuPont used the \$70 million in mediated settlement to fund a massive blood sampling of tens of thousands of people in Parkersburg, generating epidemiological data that DuPont had banked on as an impossibility (Bilott 2019). Lawyers and volunteers paired with community activists, libraries, and churches. They held town hall meetings and focus groups. Local media announced testing sites and times. Tech-savvy youth helped the elderly navigate the Internet and the 79-page health questionnaire, and organizers reached the most rural and isolated points of the region. Journalist Callie Lyons describes the project as a “cultural and anthropological phenomenon” and an “exceptionally collective experience” (2007: 88–91). Fellowship was forged through the daily sharing of computers, information, stories, and PFOA blood level numbers, people mobilizing around a common cause and collective acknowledgment of toxic suffering.

Not all toxic events translate into refusal or collective action, and it is just as common for people to feel traumatized, resentful, or powerless (Pearson 2017). Toxic exposure upsets core

assumptions about health, the environment, and basic community structures, as well as expectations of security and order associated with notions of home, generating a sense of disorientation (Edelstein 2004; Willow et al. 2014). The uncertainty that accompanies toxic exposure only deepens distress and itself contributes to poor health outcomes (Mah 2012). Government officials, reluctant to raise the alarm and frequently dependent on the expertise of industry, may be slow to respond, while industry in turn disputes causal connections or downplays risk (Lerner 2010; Renfrew 2018). Sometimes people engage in denial or disavowal, dismissing contamination or defending polluting industries as a source of livelihood (Ahmann 2018, 2020; Graeter 2019; Stawkowski 2018). The outcome may be indifference or a paralyzing sense of confusion, a social production of incapacitating uncertainty or ambivalence (Auyero and Swistun 2009; Button 2010; Singer 2011).

Within the toxicity continuum, ebbing between recognition and ignorance, action and silence, people encounter what Michael Edelstein (2004) refers to as the “mitigatory gap,” or the temporal chasm between the discovery of toxic contamination and its remediation. This is a period of immense uncertainty and stress. Science and interpretations of hazard are contested, and various parties dispute who is responsible and what to do about it. Even though the discovery of groundwater contamination linked to 3M’s plant in Cottage Grove, Minnesota, occurred in the early 2000s, settlement funds for a long-term drinking water solution only became available in 2018, and dozens of communities are engaged in a multiyear effort to develop a regional plan. Short-term fixes have included installing point-of-entry water filters on individual homes and upgrading municipal wells with expensive filtration systems. In the meantime, the state is working with consultants to develop a sophisticated groundwater model to visualize and predict how the contamination plumes will behave over time. The model *should* allow communities to use the settlement funds to drill new wells, filter their water, or develop other plans for an alternative water supply. The 3M settlement focuses on damages to natural resources, not to human health, however, and some residents still worry about the health consequences of past exposures (Fellner 2018). Even when a drinking water plan is developed for the 150,000 affected people, the settlement funds will only last about 20 years, leaving uncertainty about future costs.

In other places, the recent discovery of PFAS contamination draws residents into an unexpected and urgent reassessment of community life. Marinette is a small city of roughly 10,000 people on the shores of Lake Michigan, and historically has been home to paper mills, a shipbuilding company, and small-scale chemical manufacturing. Tyco Fire Products, now owned by Johnson Controls International (JCI), was founded there in the early twentieth century. When PFAS contamination was discovered in late 2017 in the adjacent Town of Peshtigo, where residents rely on private wells, it initially drew a muted response. Many local officials and residents were reluctant to question an industry with deep roots. A few residents organized into what has since become a vibrant citizen-action group called S.O.H2O, pushing the Wisconsin DNR to take a tough stance against Tyco, including referring the case to the state’s Department of Justice. They also pressed Tyco to put up PFAS warning signs near contaminated ditches and persuaded the DNR to create a reporting system to catalog when foam, which can form when PFAS pollution agitates in moving water, is spotted by residents in local rivers. Some also connected with Rob Bilott, who formed part of a legal team that reached a proposed class action settlement with Tyco in early 2021 for \$17.5 million.

As more is discovered about the scale of contamination around Marinette and Peshtigo, an increasing number of residents have drawn connections between health and PFAS exposure from drinking water or air emissions. Access to blood testing has become a symbolically potent but contested issue, with some residents seeking testing to bolster their claims of toxic suffering. State health officials, however, are reluctant to initiate any health studies. They discourage resi-

dents from pursuing blood tests, since the science is not developed enough to draw causal connections between PFAS exposure and illness, and information about blood PFAS levels cannot guide healthcare treatment, regardless of the standards adopted in legal settlements. Residents face a confounding scenario: they are told that PFAS pose a serious problem in need of remediation but not to associate their health issues with exposure (Pearson 2020).

Many residents now speak passionately about what they have come to experience as patterns of illness in their neighborhoods. They not only express alarm about PFAS but question the history of pollution from Tyco and other industries, telling stories about odors, plumes of smoke, and arsenic contamination stretching back to the 1960s. As one resident recounted in 2019:

We had continuous bloody noses, sore throats, blood coming out of ears. The stench was so bad when the wind blew across the river that we had to keep our doors closed. We didn't know what was going on. We were told not to make any waves, because the chemical company could move away and take all the jobs with them.

Recognition of toxic layering has become a basis for mobilization. Dozens of residents have given heartbreaking testimony at public forums about health problems, sharing stories that transform the typically individual plight of illness into a form of collective suffering. At a January 2020 forum, one man who endured three different forms of testicular cancer before his 21st birthday called on his neighbors to act. "Part of me has always known," he said, "there's something in the water."

Conclusion

PFAS represents an industrial chemical legacy that is also an emergent danger, our past colonizing the future. The current PFAS crisis encompasses the dilemmas of late industrial society, an era when chemical exposure is widespread and routinized, simultaneously dispersed through the everyday low-dose pathways of consumer culture yet also associated with heavily polluted sites such as manufacturing plants, airports, and military installations. The regulatory regimes of modern environmental governance have not only failed to prevent the crisis but enabled it through the production of ignorance and acquiescence to corporate interests.

PFAS have faced mounting scrutiny over the last two decades, becoming visible and increasingly acknowledged as a form of pollution by a range of actors and institutions. As more communities discover PFAS contamination, we suggest that it is essential to examine the circumstances under which such discoveries become toxic events—episodes in which people come to know and act on contaminated environments, including their own embodiment of synthetic chemicals along a toxicity continuum that includes ignorance, resignation, suffering, and refusal. Sometimes the ubiquitous, routine exposure we are all subject to becomes recognized or expressed through forms of suffering. We need to better understand why some people embrace resignation, including the politics of disavowal, whereas for others toxic suffering catalyzes broader mobilization and participation in struggles for sociopolitical change.

Toxic events have the capacity to recalibrate local political and community dynamics, and it is important to recognize that PFAS contamination is usually layered onto or intersects with a myriad of other forms of pollution, as well as other types of resource conflicts and environmental inequalities. Our approach seeks to illuminate how the discovery of PFAS contamination is experienced; how it is influenced by local historical and political economic factors; how it takes shape among intersecting forms of inequality based on race, class, and other disparities; and

how community responses vary depending on local histories of activism and political engagement. Multisited ethnography that is attentive to how local context enmeshes with wider systems helps bring into focus the PFAS chemical lifecycle and its relationship to different forms of slow violence and toxic harm (Shapiro and Kirksey 2017). These systems unfold across wide temporal and geographic scales as PFAS substances move through sites of production or manufacturing and along commodity chains that entail various uses and applications, with eventual disposal or release into the environment.

More broadly, we suggest that social science should also contribute to building mechanisms of corporate accountability and to restoring a regulatory system that acts independently of industry influence. As governments at different levels scramble to develop a regulatory response to PFAS, we need to foster discussions about how society might prevent chemical companies from operating with impunity, and we should aid efforts to define concepts of essential use as part of a global phaseout of PFAS (Cousins et al. 2019). Social science, finally, helps expose the fiction that PFAS chemicals are a necessary and inevitable feature of late industrial life.

■ ACKNOWLEDGMENTS

We are grateful for support from a Wenner-Gren Foundation research grant (2020–2021).

■ **DANIEL RENFREW** is Professor of Anthropology at West Virginia University and the author of *Life without Lead: Contamination, Crisis, and Hope in Uruguay* (University of California Press, 2018). He is Associate Editor of the *Journal of Latin American and Caribbean Anthropology* (JLACA), and a faculty member of the Sectorial Commission of Scientific Research on Anthropology and the Environment at the Universidad de la República (Uruguay). Email: daniel.renfrew@mail.wvu.edu

■ **THOMAS W. PEARSON** is a Cultural Anthropologist and teaches at the University of Wisconsin-Stout. Much of his writing has focused on environmental activism in Central America and the United States, and he is the author of *When the Hills Are Gone: Frac Sand Mining and the Struggle for Community* (University of Minnesota Press, 2017). Email: pearson@uwstout.edu

■ REFERENCES

- Agard-Jones, Vanessa. 2014. “Spray.” *Somatosphere*, 27 May. <http://somatosphere.net/2014/spray.html/>.
- Ahmann, Chloe. 2018. “‘It’s Exhausting to Create an Event out of Nothing’: Slow Violence and the Manipulation of Time.” *Cultural Anthropology* 33 (1): 142–171. doi:10.14506/ca33.1.06.
- Ahmann, Chloe. 2020. “Toxic Disavowal.” *Somatosphere*, 17 January. <http://somatosphere.net/2020/toxic-disavowal.html/>.
- Altman, Rebecca. 2019. “Time-Bombing the Future.” *Aeon*, 2 January. <https://aeon.co/essays/how-20th-century-synthetics-altered-the-very-fabric-of-us-all>.
- ATSDR (Agency for Toxic Substances and Disease Registry). 2021. *Toxicological Profile for Perfluoroalkyls*. Washington, DC: US Department of Health and Human Services. <https://www.atsdr.cdc.gov/toxprofiles/tp200.pdf>.

- Auyero, Javier, and Débora Alejandra Swistun. 2009. *Flammable: Environmental Suffering in an Argentine Shantytown*. New York: Oxford University Press.
- Beck, Ulrich. 1992. *Risk Society: Towards a New Modernity*. London: Sage.
- Bilott, Rob. 2019. *Exposure: Poisoned Water, Corporate Greed, and One Lawyer's Twenty-Year Battle against DuPont*. New York: Atria Books.
- Blum, Arlene, Simona A. Balan, Martin Scheringer, Xenia Trier, Gretta Goldenman, Ian T. Cousins, . . . , and Miriam Diamond. 2015. "The Madrid Statement on Poly- and Perfluoroalkyl Substances (PFASs)." *Environmental Health Perspectives* 123 (5): A107–111. doi:10.1289/ehp.1509934.
- Bond, David. 2020. "Understanding PFOA." *Medical Anthropology Quarterly Critical Care Series*, 16 November. <https://medanthroquarterly.org/critical-care/2020/11/understanding-pfoa/>.
- Bond, David. 2021. "The US Military Is Poisoning Communities across the US with Toxic Chemicals." *The Guardian*, 25 March. <http://www.theguardian.com/commentisfree/2021/mar/25/us-military-toxic-chemicals-us-states>.
- Boronow, Katherine E., Julia Green Brody, Laurel A. Schaidler, Graham F. Peaslee, Laurie Havas, and Barbara A. Cohn. 2019. "Serum Concentrations of PFASs and Exposure-Related Behaviors in African American and Non-Hispanic White Women." *Journal of Exposure Science & Environmental Epidemiology* 29 (2): 206–217. doi:10.1038/s41370-018-0109-y.
- Boudia, Soraya, Angela N.H. Creager, Scott Frickel, Emmanuel Henry, Nathalie Jas, . . . , and Jody A. Roberts. 2018. "Residues: Rethinking Chemical Environments," *Engaging Science, Technology, and Society* 4:165–178. doi:10.17351/ests2018.245.
- Brown, Phil. 2007. *Toxic Exposures: Contested Illnesses and the Environmental Health Movement*. New York: Columbia University Press.
- Bullard, Robert D. 2005. "Environmental Justice in the Twenty-First Century." In *The Quest for Environmental Justice: Human Rights and the Politics of Pollution*, ed. Robert D. Bullard, 19–42. San Francisco: Sierra Club Books.
- Button, Gregory. 2010. *Disaster Culture: Knowledge and Uncertainty in the Wake of Human and Environmental Catastrophe*. Walnut Creek, CA: Left Coast Press.
- CDC (Centers for Disease Control and Prevention). 2017. "Per- and Polyfluorinated Substances (PFAS) Factsheet." *National Biomonitoring Program*. https://www.cdc.gov/biomonitoring/PFAS_FactSheet.html (accessed 03/01/2020).
- Checker, Melissa. 2005. *Polluted Promises: Environmental Racism and the Search for Justice in A Southern Town*. New York: NYU Press.
- Checker, Melissa. 2007. "But I know It's True: Environmental Risk Assessment, Justice, and Anthropology." *Human Organization* 66 (2): 112–124. doi:10.17730/HUMO.66.2.1582262175731728.
- Cordner, Alissa, Lauren Richter, and Phil Brown. 2016. "Can Chemical Class Approaches Replace Chemical-by-Chemical Strategies? Lessons from Recent U.S. FDA Regulatory Action on Per-And Polyfluoroalkyl Substances." *Environmental Science & Technology* 50 (23): 12584–1291. doi:10.1021/acs.est.6b04980.
- Cordner, Alissa, Vanessa Y. De La Rosa, Laurel A. Schaidler, Ruthann A. Rudel, Lauren Richter, and Phil Brown. 2019. "Guideline Levels for PFOA and PFOS in Drinking Water: The Role of Scientific Uncertainty, Risk Assessment Decisions, and Social Factors." *Journal of Exposure Science & Environmental Epidemiology* 29 (2): 157–171. doi:10.1038/s41370-018-0099-9.
- Cousins, Ian T., Gretta Goldenman, Dorte Herzke, Rainer Lohmann, Mark Miller, Carla A. Ng, . . . , and Sharyle Patton. 2019. "The Concept of Essential Use for Determining When Uses of PFAS Can Be Phased Out." *Environmental Science: Processes & Impacts* 11 (21): 1803–1815. doi: 10.1039/C9EM00163H.
- Dietrich, Alexa S. 2013. *The Drug Company Next Door: Pollution, Jobs, and Community Health in Puerto Rico*. New York: NYU Press.
- Edelstein, Michael R. 2004. *Contaminated Communities: Coping with Residential Toxic Exposure*. Boulder, CO: Westview Press.
- Edgerly, Mike, and Sasha Aslanian. 2005. "MPR: Toxic Traces." *Minnesota Public Radio News*, February. <http://news.minnesota.publicradio.org/projects/2005/02/toxictraces/>.

- EPA (Environmental Protection Agency). 2020. “Master List of PFAS Substances.” https://comptox.epa.gov/dashboard/chemical_lists/pfasmaster (accessed 2 August 2020).
- Evans, Sydney, David Andrews, Tasha Stoiber, and Olga Naidenko. 2020. “PFAS Contamination of Drinking Water Far More Prevalent Than Previously Reported.” *Environmental Working Group*, 22 January. <https://www.ewg.org/research/national-pfas-testing/>.
- EWG. 2020. “Mapping the PFAS Contamination Crisis.” Environmental Working Group. https://www.ewg.org/interactive-maps/pfas_contamination/ (accessed 25 March 2021).
- Fellner, Carrie. 2018. “Toxic Secrets: The Town that 3M Built—Where Kids Are Dying of Cancer.” *The Sydney Morning Herald*, 15 June. <https://www.smh.com.au/world/north-america/toxic-secrets-the-town-that-3m-built-where-kids-are-dying-of-cancer-20180613-p4zl83.html>.
- Ford, Andrea. 2019. “Introduction: Embodied Ecologies.” *Theorizing the Contemporary, Fieldsights*, 25 April. <https://culanth.org/fieldsights/introduction-embodied-ecologies>.
- Fortun, Kim. 2001. *Advocacy after Bhopal: Environmentalism, Disaster, New Global Orders*. Chicago: University of Chicago Press.
- Fortun, Kim. 2012. “Ethnography in Late Industrialism.” *Cultural Anthropology* 27 (3): 446–464. doi:10.1111/j.1548-1360.2012.01153.x
- Frickel, Scott, Sahia Gibbon, Jeff Howard, Joanna Kempner, Gwen Ottinger, and David J. Hess. 2010. “Undone Science: Charting Social Movement and Civil Society Challenges to Research Agenda Setting.” *Science, Technology, and Human Values* 35 (4): 444–473.
- Frickel, Scott, and James R. Elliot. 2018. *Sites Unseen: Uncovering Hidden Hazards in American Cities*. New York: Sage.
- Goldstein, Donna M. 2017. “Invisible Harm: Science, Subjectivity and the Things We Cannot See.” *Culture, Theory and Critique* 58 (4): 321–329. doi:10.1080/14735784.2017.1365310.
- Goldstein, Donna M., and Kira Hall. 2015. “Mass Hysteria in Le Roy, New York: How Brain Experts Materialized Truth and Outsourced Environmental Inquiry.” *American Ethnologist* 42 (4): 640–657. doi:10.1111/amet.12161.
- Graeter, Stefanie. 2019. “Mineralized Biologies.” *Fieldsights*, 25 April. <https://culanth.org/fieldsights/mineralized-biologies>.
- Harvey, David. 1996. *Justice, Nature, and the Geography of Difference*. Cambridge: Wiley-Blackwell.
- Hepler-Smith, Evan. 2019. “Molecular Bureaucracy: Toxicological Information and Environmental Protection.” *Environmental History* 24 (3): 534–560. doi:10.1093/envhis/emy134.
- Hess, David. 2009. “The Potentials and Limitations of Civil Society Research: Getting Undone Science Done.” *Sociological Inquiry* 79(3): 306–327.
- Hoover, Elizabeth. 2017. *The River Is in Us: Fighting Toxics in a Mohawk Community*. Minneapolis: University of Minnesota Press.
- Jasanoff, Sheila. 1998. *The Fifth Branch: Science Advisers as Policymakers*. Cambridge, MA: Harvard University Press.
- Judge, J. Matthew, Phil Brown, Julia Green Brody, and Serena Ryan. 2016. “The Exposure Experience: Ohio River Valley Residents Respond to Local Perfluorooctanoic Acid (PFOA) Contamination.” *Journal of Health and Social Behavior* 57 (3): 333–350. doi:10.1177/0022146516661595.
- Kimura, Aya H., and Abby Kinchy. 2019. *Science by the People: Participation, Power, and the Politics of Environmental Knowledge*. New Brunswick, NJ: Rutgers University Press.
- Kirsch, Stuart. 2014. *Mining Capitalism: The Relationship between Corporations and Their Critics*. Oakland: University of California Press.
- Kwiatkowski, Carol F., David Q. Andrews, Linda S. Birnbaum, Thomas A. Bruton, Jamie C. DeWitt, Detlef R. U. Knappe, . . . , and Maricel V. Maffini. 2020. “Scientific Basis for Managing PFAS as a Chemical Class.” *Environmental Science and Technology Letters* 7: 532–543. doi:10.1021/acs.estlett.0c00255.
- Langston, Sharon. 2010. *Toxic Bodies: Hormone Disruptors and the Legacy of DES*. New Haven, CT: Yale University Press.
- Lerner, Sharon. 2015. “The Teflon Toxin: DuPont and the Chemistry of Deception.” *The Intercept*, 11 August. <https://theintercept.com/series/the-teflon-toxin/>.

- Lerner, Sharon. 2017. "New Teflon Toxin Found in North Carolina Drinking Water." *The Intercept*, 17 June. <https://theintercept.com/2017/06/17/new-teflon-toxin-found-in-north-carolina-drinking-water/>.
- Lerner, Sharon. 2018a. "3M Knew about the Dangers of PFOA and PFOS Decades Ago, Internal Documents Show." *The Intercept*, 31 July. <https://theintercept.com/2018/07/31/3m-pfas-minnesota-pfoapfos/>.
- Lerner, Sharon. 2018b. "The U.S. Military Is Spending Millions to Replace Toxic Firefighting Foam with Toxic Firefighting Foam." *The Intercept*, 10 February. <https://theintercept.com/2018/02/10/firefighting-foam-afff-pfos-pfoa-epa/>.
- Lerner, Steve. 2010. *Sacrifice Zones: The Front Lines of Toxic Chemical Exposure in the United States*. Cambridge, MA: MIT Press.
- Liboiron, Max, Manuel Tironi, and Nerea Calvillo. 2018. "Toxic Politics: Acting in a Permanently Polluted World." *Social Studies of Science* 48 (3): 331–349. doi:10.1177/0306312718783087.
- Little, Peter C. 2014. *Toxic Town: IBM, Pollution, and Industrial Risks*. New York: NYU Press.
- Lyons, Callie. 2007. *Stain-Resistant, Nonstick, Waterproof, and Lethal: The Hidden Dangers of C8*. Westport, CT: Praeger.
- MacKay, Neil. 1991. *A Chemical History of 3M: 1933–1990*. Minneapolis: 3M.
- Mah, Alice. 2012. *Industrial Ruination, Community, and Place: Landscapes and Legacies of Urban Decline*. Toronto: University of Toronto Press.
- Markowitz, Gerald, and David Rosner. 2002. *Deceit and Denial: The Deadly Politics of Industrial Poisoning*. Berkeley: University of California Press.
- Masco, Joseph. 2015. "The Age of Fallout." *History of the Present: A Journal of Critical History* 5 (2): 137–168. doi:10.5406/historypresent.5.2.
- MDH. 2020. "History of Perfluoroalkyl Substances (PFAS) in Minnesota." Minnesota Department of Health. <https://www.health.state.mn.us/communities/environment/hazardous/topics/history.html> (accessed 2 August 2020).
- Murphy, Michelle. 2004. "Uncertain Exposures and the Privilege of Imperception: Activist Scientists and Race at the U.S. Environmental Protection Agency." *Osiris* 19: 266–282. doi:10.1086/649406.
- Murphy, Michelle. 2006. *Sick Building Syndrome and the Problem of Uncertainty*. Durham, NC: Duke University Press.
- Murphy, Michelle. 2008. "Chemical Regimes of Living." *Environmental History* 13 (4): 695–703. <https://www.jstor.org/stable/25473297>.
- Murphy, Michelle. 2017. "Afterlife and Decolonial Chemical Relations." *Cultural Anthropology* 32 (4): 494–503. doi:10.14506/ca32.4.02.
- Nading, Alex M. 2020. "Living in a Toxic World." *Annual Review of Anthropology* 49: 209–224. doi:10.1146/annurev-anthro-010220-074557.
- Nixon, Rob. 2011. *Slow Violence and the Environmentalism of the Poor*. Cambridge, MA: Harvard University Press.
- Oliaei, Fardin. 2006. "Letter Explaining Resignation from MPCA." *Minnesota Public Radio News*, 6 February. http://news.minnesota.publicradio.org/features/2006/02/05_sommererm_fardinsletter/.
- Oreskes, Naomi, and Erik M. Conway. 2010. *Merchants of Doubt: How a Handful of Scientists Obscured the Truth on Issues from Tobacco Smoke to Global Warming*. New York: Bloomsbury Press.
- Pearson, Thomas W. 2017. *When the Hills Are Gone: Frac Sand Mining and the Struggle for Community*. Minneapolis: University of Minnesota Press.
- Pearson, Thomas W. 2020. "Communities Grapple with Exposure to 'Forever Chemicals.'" *SAPIENS*, 31 July. <https://www.sapiens.org/culture/pfas-contamination/>.
- Pellow, David Naguib. 2007. *Resisting Global Toxics: Transnational Movements for Environmental Justice*. Cambridge, MA: MIT Press.
- Petryna, Adriana. 2002. *Life Exposed: Biological Citizenship after Chernobyl*. Princeton, NJ: Princeton University Press.

- PFAS Project. 2020. "Per- and Polyfluoroalkyl Substances: The Social Discovery of a Class of Emerging Contaminants." Social Science Environmental Health Research Institute, Northeastern University. <https://pfasproject.com/> (accessed 1 August 2020).
- Post, Gloria B. 2021. "Recent US State and Federal Drinking Water Guidelines for Per- and Polyfluoroalkyl Substances." *Environmental Toxicology and Chemistry* 40 (3): 550–563. doi:10.1002/etc.4863.
- Povinelli, Elizabeth. 2017. "Fires, Fogs, Winds." *Cultural Anthropology* 32 (4): 504–513. doi:10.14506/ca32.4.03.
- Proctor, Robert N. 2008. "Agnotology: A Missing Term to Describe the Cultural Production of Ignorance (and Its Study)." In *Agnotology: The Making and Unmaking of Ignorance*, ed. Robert N. Proctor and Londa Schiebinger, 1–33. Stanford, CA: Stanford University Press.
- Renfrew, Daniel. 2018. *Life without Lead: Contamination, Crisis, and Hope in Uruguay*. Oakland: University of California Press.
- Richter, Lauren, Alissa Cordner, and Phil Brown. 2018. "Non-Stick Science: Sixty Years of Research and (in)Action on Flourinated Compounds." *Social Studies of Science* 48 (5): 691–714. doi:10.1177/0306312718799960.
- Richter, Lauren, Alissa Cordner, and Phil Brown. 2020. "Producing Ignorance Through Regulatory Structure: The Case of Per- and Polyfluoroalkyl Substances (PFAS)." *Sociological Perspectives*. doi:10.1177/0731121420964837.
- Roberts, Elizabeth F. S. 2017. "Exposure." *Fieldsights*, 18 June. <https://culanth.org/fieldsights/1152-exposure>.
- Schuller, Mark, and Gregory Button, eds. 2016. *Contextualizing Disaster*. New York: Berghahn Books.
- Science Panel. 2020. "C8 Science Panel." <http://www.c8sciencepanel.org/> (accessed 25 March 2021).
- Shapiro, Nicholas. 2015. "Attuning to the Chemosphere: Domestic Formaldehyde, Bodily Reasoning, and the Chemical Sublime." *Cultural Anthropology* 30 (3): 368–93. doi:10.14506/ca30.3.02.
- Shapiro, Nicholas, and Eben Kirksey. 2017. "Chemo-Ethnography: An Introduction." *Cultural Anthropology* 32 (4): 481–493. doi:10.14506/ca32.4.01.
- Singer, Merrill. 2011. "Down Cancer Alley: The Lived Experience of Health and Environmental Suffering in Louisiana's Chemical Corridor." *Medical Anthropology Quarterly* 25 (2): 141–63. doi:10.1111/j.1548-1387.2011.01154.x.
- Stawkowski, Magdalena. 2018. "'I Am a Radioactive Mutant': Emergent Biological Subjectivities at Kazakhstan's Semipalatinsk Nuclear Test Site." *American Ethnologist* 43 (1): 144–157. doi:10.1111/amet.12269.
- Tsing, Ana Lowenhaupt. 2015. *The Mushroom at the End of the World: On the Possibility of Life in Capitalist Ruins*. Princeton, NJ: Princeton University Press.
- Turkewitz, Julie. 2019. "Toxic 'Forever Chemicals' in Drinking Water Leave Military Families Reeling." *New York Times*, 24 February. <https://www.nytimes.com/2019/02/22/us/military-water-toxicchemicals.html>.
- Willow, Anna J., Rebecca Zak, Danielle Vilaplana, and David Sheeley. 2014. "The Contested Landscape of Unconventional Energy Development: A Report from Ohio's Shale Gas Country." *Journal of Environmental Studies and Sciences* 4 (1): 56–64. doi:10.1007/s13412-013-0159-3.
- Wylie, Sara Ann. 2018. *Fractivism: Corporate Bodies and Chemical Bonds*. Durham, NC: Duke University Press.
- Zeiderman, Austin. 2015. "Spaces of Uncertainty: Governing Urban Environmental Hazards." In *Modes of Uncertainty: Anthropological Cases*, ed. Limar Samimian-Davash and Paul Rabinow, 182–200. Chicago: University of Chicago Press.