In smell's shadow: Materials and politics at the edge of perception

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Abstract

This article examines the politics of smell at the edge of perception. In January 2014, the municipal water supply of Charleston, West Virginia was contaminated by an under-characterized chemical, crude MCHM. Even when instrumental measurements no longer detected the chemical, people continued to smell its licorice-like odor. In a space where nothing was certain, smell became the only indicator of potential harm. Officials responded by commissioning state-funded sensory testing of crude MCHM to determine its sensory threshold. Via the critical passage point of sensory science, some instances of embodied attunement were allowed to enter into the evidentiary regimes of perception, while other, similarly trained moments of attunement were excluded from the process. This, I show, produced knowledge about the spilled chemical that maintained the systems that contributed to the spill in the first place. Drawing on new materialist thought, I riff on biology and ‘transduce’ the ephemeral phenomena of smelling crude MCHM into a new medium: Rather than thinking of smell as a volatile molecular material (an odorant), I show that consideration of smell as a manipulable object that one can imagine as having tangible substance and shape offers a way to experiment with disciplinary forms. I suggest an alternate future, where sensory science acts to record sensory labor that produces facts about collective experience that cannot (easily) travel through current systems, a process that is one possible way of beginning to unravel entrenched systems of toxic harm.

Keywords

disaster, expertise, olfaction, sensing, sensory science, water

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Before you begin reading this, I invite you to find a piece of black licorice. Hold it in your hand. Look at it closely. Sniff it. If you are willing, plug your nose and take a bite. Roll the candy around in your mouth, chew a bit. Close your eyes momentarily. Breathe out. Hold this sensory memory. You are now ready to begin.¹

Imagine that it is a cold, dark January morning and a smell not unlike the smell permeating your mouth and nose is suddenly everywhere. On January 9, 2014, West Virginians in and around Charleston learned that copious amounts of a relatively uncharacterized chemical mixture, including crude 4-methylcyclohexane methanol (MCHM),² had leaked into the water supply from a storage tank owned and operated by Freedom Industries. That evening, the governor issued a blanket do-not-use order for the affected area and declared a state of emergency. Underlying the accumulating signs of disrupted lives – the empty bottles and boxes piling up in homes, plastic bags over faucets and drinking fountains, closed businesses and seemingly endless news reports – was a cloying, odorific reality.

Crude MCHM smelled.

According to many, like black licorice.

Four days after the spill, the governor began lifting the do-not-use order. However, as inhabitants flushed their homes in accordance with the official protocol released by authorities, it became clear that an additional crisis was unfolding. The licorice odor was intermittently reappearing in homes and schools during flushing. Some, but not all, continued to smell crude MCHM even as authorities repeatedly confirmed the water had no detectable traces of the chemical left, pitting individual experience against that of scientific authority rooted in instrumental analysis.

The contested sensing highlighted above, where bodies and their sensory capabilities are more sensitive than instrumental measurements, is in many ways a twentieth-century phenomenon. Human bodies were respected sensors through much of the nineteenth century (Kiechle, 2017). However, twentieth-century ideals of scientific objectivity, interwoven with the Cartesian repudiation of taste and smell as too subjective for scientific purposes, increasingly wrote taste and smell out of official methods of gathering knowledge about the world.

Despite the trend towards excluding smell and taste from evidentiary systems in favor of instrumentalized measurements, in a few fields these practices continue to shape knowledge production. For example, the individual bodies of the ‘connoisseur’ of the wine world and ‘nose’ of the perfumer are recognized as carrying expertise distinct from instruments. This expertise persists, especially due to the fact that instrumental measurements of the molecular make-up of substances consistently fails to result in exact replication (Agapakis and Tolaas, 2012). This form of embodied expertise contrasts with the distributed expertise encouraged and embraced by the field of sensory science. Writ large, the sensory sciences seek to replace the fallible body of the individual expert with the more reliable, cog-like structure of sensory evaluation panels, a move facilitated by the explanatory power of statistical aggregation (Phillips, 2016). Since the mid-twentieth century, researchers working at the ‘grey area’ between industry and academia (Gerontas, 2014) have actively used sensory science to shape what I think of as the ingestible environment. Deliberate, repeated exposure to tastants or odorants, trains bodies to become measuring instruments (Muniesa and Trébuchet-Breitwiller, 2010), increasingly able to

mobilize what Ulloa (2019) terms sensory acuity (see also Butler, 2018; Spackman, 2018) in the pursuit of measuring sensory experience. That knowledge in turn circulates to facilitate the enchantment of consumer mouths, the creation of uniform sensation (Lahne, 2018), or as an argument for the physical emplacement of sensation critical to maintaining name-denomination systems (Shields-Argèles, 2019; Trubek, 2008). Via the critical passage point of the sensory sciences, human perception is allowed a small place in what Murphy (2006) terms regimes of perception.

Within the sensory science laboratory, practices and technologies of measurement are the result of trained and untrained attunement. Some of the measurements are used to shape the design of products. Others have additional purposes. Of special interest here are threshold measurements, tests that determine the concentration at which a certain chemical can be identified by the human senses. Threshold levels are part and parcel of the definitional characteristics used to describe molecules. These characteristics define a molecule's identity through a range of physical characteristics, from molecular formula to properties such as evaporation point and odor characteristics (assuming the molecule is volatile); defining molecules facilitates the governance of toxicological information. Hepler-Smith (2019) terms this 'molecular bureaucracy': the 'legal structures, administrative procedures, regulatory lists, information systems and nomenclature conventions' (see also Nading, 2017). Once identified, thresholds of perception identify the point at which instrumental measurement, and the infrastructures that support them, are granted authority over identifying levels of safety and risk. Thresholds bound official recognition of perception.³

Outside of the sensory science laboratory, attunement is part of the everyday processes humans use to navigate the world. Here, attunement indexes transition from states of normal to abnormal. Scholars of environmental justice who study risk and harm in late industrialism – a period characterized by accumulating levels of infrastructural, regulatory and ecological collapse (Fortun, 2012) – note what Fiske (2018) refers to as the 'central role of bodily knowledge in apprehending harm'. Unserved by regulatory systems, unprotected by political will, the body becomes that which both bears witness to harm and is called on to evidence harm. This failure of official evidentiary systems to attend to or even recognize embodied knowledge has given rise to efforts to bring in alternative modes of capturing and marshalling proof. Bucket brigades (Ottinger, 2013), sensory tracking devices (Ballesterio, 2019; Helmreich, 2019), animal sentinels (Gramaglia and Mélard, 2019), and individual embodied practices (Kenner, 2018) all come together to create alternative forms of evidence.

Attunement, then, provides a useful model for examining how repeated exposure to perceptible molecules shifts awareness of the ingestible environment. For those studying chemical exposure, attunement refers not only to processes of learning to attend to certain perceptible environmental signals (Choy and Zee, 2015; Stewart, 2011), it can also extend to the imperceptible, as the slowly building awareness that something is no longer 'right' – what Shapiro (2015) terms the chemical sublime – and in the process 'dysplace' individuals from places of belonging (Jackson, 2011). This attunement may be twin to the sensory attunement developed by the wine connoisseur, but it is neither recognized as such, nor rewarded. Rather, attunement becomes an aesthetic registration of the way that individual lives are entangled in systems of molecular attention. Attunement operates at the edge of perception.

In a recent special issue in this journal, Liboiron et al. (2018) argue that the ‘locus of toxicity is not harm at the cellular level’; rather, structures define toxicity. ‘Toxic harm’, they write, not only carries the capacity to disrupt ‘order and existing relations, it also *maintains* systems’ (p. 333). In some cases, those may be systems of evidentiary regimes, political structures, modes of extraction and production, or beyond. Building on this call, I wish to redirect conversations about attunement in STS, environmental studies, and food studies away from bodies that are becoming attuned and towards the knowledge infrastructures that measure attunement. Attending to how these infrastructures function not only offers to help parse the sensory politics at play around attunement (e.g. what forms of attunement does sensory science introduce to the realm of scientific and policy debates as a scientific instrument, and what forms of attunement are excluded), it also highlights potential alternates.⁴

To explore the role of sensory science in maintaining systems of toxic harm, I elaborate on the concept of ‘sensory labor’. Sensory labor involves practices of tasting and smelling capable of ‘*produc[ing] a valuable fact* about collective experience’ (Spackman and Lahne, 2019: 143; see also Spackman, 2018). Approaching sensory labor from the viewpoint of industrial food production acknowledges that everyday and attuned practices of tasting and smelling enroll bodies in specific forms of cognitive work. These forms of work are, as Barwich (2017) argues, distinct from each other: ‘active engagement with stimulus features in perceptual processing shapes the phenomenological content, so much so that the perceptual structure of trained smelling varies significantly from naive smelling’. This is work that explicitly or implicitly produces value for others. The crisis in Charleston has since been overshadowed by an ongoing litany of more permanent and less easily perceptible crises, such as the lead contamination in Flint, Michigan. Nonetheless, the Charleston case, with contamination teetering on the edge of perception offers insights into how sensory science practices currently reproduce toxic harm while offering a pattern for a different future, one in which sensory science undermines toxic harm.

This paper starts then at the edge of perception, where there is a large amount of conflicting evidence. The recurring odor of crude MCHM in homes and businesses throughout the Charleston region pitted bodily perception against instrumental measurement. Orienting myself via the physical reality that crude MCHM readily volatilizes, which means that it smells, and continues to be detectable to most human noses at concentration levels below instrumental detection limits, I explore how sensory information about odorific molecules is transduced. Transduction, a term that toggles between different histories of sound, biology and computation, here encompasses the process whereby sensory information is made legible to individual bodies at a specific time and place *and* the process whereby sensory information is made legible and shareable across time and place. I situate olfaction as an ingestive process, examining how the mobilization of an official form of sensory labor – the threshold test – patterned responses to the spill in Charleston that maintained, rather than changed, the system. Drawing on the work of Liboiron (2017), Shapiro (2019), Murphy (2017) and others in the STS Making and Doing community in exploring alternative modes of making science, I offer my own transductive move to suggest a path for thinking otherwise. I do this by introducing a potential future where a more capacious sensory science could operate, one that invites

in, rather than ignores, knowledge understood as ‘contaminated’ or biased from previous experience. This alternative method records the type of sensory labor that produces a different form of valuable fact: facts about collective experience that cannot (easily) travel through the systems that profit from knowledge about the molecular behavior of contaminants. This is not only a start towards recognition of the retraining of brain and body imposed by exposure, it is more critically a step towards reorienting sensory science away from maintaining systems of toxic harm and towards building new systems of accountability.

Methodology

Attention to the interface between the human and the nonhuman as it yields to and undoes human sensory organization ... must necessarily engage radical interdisciplinarity. (Tompkins, 2016)

My analytical approach brings together my training and work across the fields of molecular biology, food chemistry and food studies through the theoretical and methodological commitments of science and technology studies. I draw primarily on participant observation conducted in Los Angeles during post-crisis testing of the sensory qualities of crude MCHM in March 2014, as well as fourteen formal and sixteen informal interviews with scientists, journalists and inhabitants of Charleston, conducted between March 2014 and May 2015. Charleston-based interlocutors were identified through a purposeful sampling technique that began with a woman who had experienced negative health effects after exposure to the fumes of crude MCHM, and snowballed out into her personal community network of work, church and shopping. This methodological decision reflects the intimate ways in which knowledge about harm and health circulate in times of uncertainty (Jasaravic, 2015). In interviews with non-scientists, I paid specific attention to discussions of sensory experience, risk, trust and health concerns, and in interviews with scientists paid attention to questions of knowledge, instrumentation and practice. Recorded interviews were transcribed; transcripts and notes from informal interviews were analyzed along the axis of interest I have just highlighted. I also gathered and analyzed information from twitter feeds, news reports and scientific reports. I have conducted two Freedom of Information Act requests that returned nothing.

The physicality of smells

Difficult to contain, the sensory signals known as odors cross literal and figurative boundaries in confounding and surprising ways. An odor’s physical properties play a large part in this obduracy: molecular structure and external conditions such as pressure and temperature directly influence biological perception, as does the state of the sensing body. Thus, from the standpoint of physiologists or biochemists, the materiality of molecules largely determines whether mouths and noses can detect, analyze and make decisions based on the information produced from that molecule, a process that can, as Corbin (1986) shows in his examination of shifting conceptions of smells in eighteenth- and nineteenth-century France, actively drive efforts to effect political change.

Biological composition of sensing noses and mouths also shapes this obduracy. Sensing, scientists and everyday experience affirm, differs between species; dogs, for example, are differently aware of odors than humans. Similarly, sensing differs within species; some humans are more sensitive than others. Further complicating this ‘sensory unevenness’ (Spackman and Burlingame, 2018) are popular as well as scientific understandings that odors can act as invisible signals that carry the potential to alter the functioning of the organism itself. This context, where olfaction is an unreliable witness to experience, undergirded official response to the smell.

The mattering of sensory materials

On that cold January morning, the chemical spill was identified not because of any test, but because of one core material characteristic of the spilled chemical: it smelled. This isn’t the first time that residents in the area have smelled a chemical in the air or experienced a spill disrupting their lives. Charleston is located in the mineral-rich Appalachian Kanawha River region, colloquially known as the ‘Chemical Valley’. Mineral resources became the impetus for expanding chemical manufacturing throughout the region, especially as World War I resulted in the loss of access to chemicals and other critical materials overseas. World War II further pushed growth. The region came to national attention in the mid-1980s after the Union Carbide chemical disaster in Bhopal India exposed more than half a million people to a toxic gas. The only other place in the world that manufactured the gas lay just outside of Charleston (Fortun, 2001). Inhabitants with whom I spoke are both comfortable with and deeply uneasy about the tangled relationship between the presence of the chemical industry, job security and risks to their own health. At the heart of this concern is an understanding of the natural and man-made materials in the world surrounding them as full of potential, potential to bring wealth and prosperity, but also the potential to harm bodies and lives.

Coole and Frost (2010), in a volume on new materialism, note that since the seventeenth century Western thought has come to see materials as identifiably discrete, passive things to be acted upon. This approach, Coole and Frost point out, divides the thinking subject from the unthinking object. Recently, scholars in STS, anthropology and other fields have challenged that thinking, either focusing on how materials act and what their actions can teach us or understanding action as spread across humans and non-humans (e.g. Alač, 2020). This has proven a useful ground for scholars trying to dismantle the clear lines often drawn between nature and culture in conversations about molecules, harm and health.

Indeed, the boundary between nature and culture is already fuzzy for materials such as crude MCHM. Human-made, these materials nonetheless operate with their own, and often ill-defined, material logics, within larger systems of trade secrets and intellectual rights that facilitate an ongoing ignorance about these materials. Although new, this new materialist approach (as exemplified by the work of scholars such as Bennett (2010) and Barad (2003)) often adapts and uses scientific insights and language in an effort to highlight new ways to ‘be’ differently in the world, to ontologically reorient oneself. But all is not rosy in this turn towards investigating how the materiality of matter *matters*. Focusing on new materiality, Paxson and Helmreich (2013, 169) warn, ‘risks veering

towards universalizing metaphysical claims about the nature of ‘matter’ as such, and also, at times, taking scientific truth claims about the world at face value’. There is a danger inherent in thinking through the lively, wily nature of materials, especially molecular materials. One risks taking scientific insights at face value, saying that ‘science is’ rather than looking at what ‘science does’.

A scholar unpacking sensory experiences of smelling or tasting from a materialistic perspective finds herself facing a bind – can one think with the stuff of sensing and about experiences of sensing without being thoroughly embedded in the framing of sensory experience as always/already biological? Or, as Landecker (2016a) notes in her study of antibiotic resistance, is there ‘no getting out of this particular petri dish’ where examining the interaction of molecule, body and mind calls for acceptance of current scientific models of sensing?

Thinking with odors, if we read them as molecular materials, embroils one in multiple controversies. Not only does it open up for examination the sensory politics shaping knowledge production about things perceived outside the laboratory, it also calls for finding a balance between the new materialists and their cautionary critics. I propose using the ‘senses as theoreticians’ as Berlant (2011) puts it, drawing on Marx, to think with and against the ways that molecular materiality enters circuits – not just of potential toxicity – but more critically, circuits of toxic harm. To do this, I start with a core concept from cellular biology known as signal transduction.

Transducing signal transduction

When crude MCHM is considered as an odorific chemical mixture, efforts to understand the sensorial contradictions associated with the spill enter into already existing knowledge structures where signal transduction is considered central to olfactory experience. What is transduction? Landecker (2016b), in her examination of how hormone biologists drew on cybernetics to conceptualize the way in which outside materials shape genetic response, defines transduction as a ‘noun form of the verb *transduce*; referring to the ability to convert variations in a medium into corresponding variations in another medium’. The concept of a signal is central to the contemporary epistemology of the life sciences. Signals initiate processes in the cell. Without signals, nothing changes. Signal transduction, as cellular and molecular biologists understand it, occurs when an external signal such as a hormone or chemical interacts with cell membrane receptors. In this framing, signal transduction is the node that enables a molecule present in the environment to affect the body.

Through much of the twentieth century, scientists understood smell as caused by a *singular* moment of touch between two surfaces: a specific molecular odorant to a specific cellular receptor. More recently, scientists’ understandings of how smell works have shifted. Shaped by the discoveries of Linda Buck and Richard Axel (and their larger research cohort), smell is now articulated as part of a signaling system that mediates between specific odorants located external to the cell and a general signaling system on the inside (Buck and Axel, 1991). Once bound by an odorant, these receptors, (known as G-Protein Coupled Receptors), are understood to change shape, a physical transformation that transduces the bound odorant into a series of general ‘signals’ inside the cell:

actions and interactions that notify the brain of the odorant's presence. Taken individually, these signals do not indicate anything specific about the odorant other than its presence. Rather, scientists note, it is the *combination* of differently activated receptors that lead to a single odorant being read in a particular way. Contemporary scientists understand the body's interaction with sensory signals found in the environment through signal transduction. This framing not only shapes conversations about gene expression in the face of environmental exposure, it also reduces experiences like smelling and tasting within scientific discourse and practice to the molecular.⁵

I was trained to think with these signaling pathways. I love their explanatory order. Indeed, signal transduction is a deeply seductive ontological approach to understanding the world in part because it has proved so powerful in helping explain – and medically intervene in – the functioning of the body. But what if, instead of thinking of these pathways as signaling systems, where signal *a* (an odorant) binds to a receptor, which changes shape and turns on signal *b* which in turn activates signal *c*, we rather draw on Barad (2003) and read the bundled experience of smell, composed of odorant, receptor, signals and unevenly sensing bodies, as a phenomena? And what if we then take it a step further, and riff on biology itself to transduce the ephemeral phenomena of smelling into a new medium: an object?

Thinking of smell as not just a volatile molecular material (an odorant), but rather as a manipulable object that one could imagine as having tangible substance and shape, places us at the messy intersection between art and science. Both disciplines are interested in materials, in their effects. Both disciplines ask one to engage 'an epistemic focus on uncertainty' to step up to the edge of the unknown and, as Yang (2015) puts it, 'to experiment with a discipline's forms; to test [its] edges or standards of practice'. And uncertainty is the adjective that best describes what the various actors local to Charleston, as well as actors further afield such as the US Centers for Disease Control, were experiencing.

Approaching meaning sideways

Readers of this article who have taken a drawing class have probably been through the exercise of taking a circle and then transforming it into something that has depth and substance. Through shading, you create a shadow. You give meaning to the material – meaning that can exist outside of language. Shadows are fascinating things. Apart from an imagined space with a perpetually constant source of light or a photographic moment of inscription, shadows, in the real world, constantly change. They call attention to the way that an object interacts with its environment. Shadows can exist without the object, although that is often a space of horror. As such, the shadow can indicate the presence of a thing without one ever seeing the thing itself.

By conceptualizing smell as a material object, we can then draw on sight and touch to synesthetically read smell as having a shadow. I make this move not to once again reinscribe the primacy of visual modes of knowing the world. Rather, I do this to acknowledge that sensing flavor, or its individual parts of smell and taste, happens in the daily wild within the context of a body that is also attentive to some combination of texture, sound, temperature and beyond. Thinking with shadows, I propose, offers a way to

understand and theorize objects that are hard to see, to capture, or to conceptualize – objects that like crude MCHM exist in spaces of uncertainty. With that in mind, I return to crude MCHM, sitting at the edge of perception, to consider what modes of making knowledge about the perceptible material were allowed to matter.

Crude MCHM is one of many cogs in the assemblage known as clean coal technology. Since introduction of the Clean Coal Technology Demonstration Program, authorized by President Reagan in 1986, coal producers have adopted a range of techniques to remove mineral impurities from coal. Among these is ‘washing,’ where coal is crushed and then floated in a chemical/water bath. As air bubbles are introduced into the mixture, the surface-active properties of water and oil-soluble washing agents such as crude MCHM help coal stick to the bubbles rising to the surface behind mineral contaminants. It results in cleaner-burning coal (Ozma and Aktas, 2006). Crude MCHM has helped maintain coal production in West Virginia to some extent, allowing coal to continue circulating in an economy and climate that increasingly desires and demands other forms of energy. Crude MCHM’s spilled presence in the waters of West Virginia reflects larger economic and political concerns about government intervention, regulation, and the tension between economic growth and the environment (Bell and York, 2010; Osno, 2014), as well as the infrastructural decay of late industrialism.

A child of the twentieth century’s chemical exuberance, crude MCHM was produced and exists in a state of ignorance. Not ignorance of its chemical composition, although the exact chemical makeup of the mixture remained (and remains) partially unknown due to analytical challenges and Freedom Industries’ refusal to share the composition of their proprietary mixture (Adams et al., 2014). Rather, crude MCHM exists in a state of willful ignorance about how it *may* function and circulate outside of its prescribed pathways. This ignorance is made possible in part by the regulatory legacy of the Toxic Substances Control Act. Fortun (2001) notes there are more than 100,000 chemicals circulating in the world, registered for routine use, but research evaluating their safety hasn’t been done.

When water treatment workers at the West Virginia American Water Company first learned of the crude MCHM spill, they had no protocols in place for detecting the chemical. Lacking any standardized methodology for measuring and detecting the MCHM mixture, in the early hours of the crisis, workers used smell as a screening tool. Information indicating that the chemical acted as a flocculent – a type of substance regularly used to remove impurities from water – gave workers direction; they initiated standard emergency treatment protocols for flocculating compounds (Public Service Commission, 2014: 10). The appearance of a ‘very strong black licorice or anise-like odor’ hours after implementation of emergency protocols marked the failure of the emergency steps, leading to the do-not-use order (Public Service Commission, 2014). The morning after the spill, January 10th, West Virginia American Water’s president, Jeff McIntyre, told attendees at a press conference covered by the *Charleston Gazette*,

We can detect the material, but we don’t know how to quantify it. ... [We are] working with toxicologists, physicians, and industrial hygienists to try and understand the risk assessment component of this product, what kinds of quantities can be present in drinking water and not pose harm to our customers. We don’t know that the water’s not safe, but we can’t say that it is safe.

Once spilled into the Charleston water supply, crude MCHM's molecular materiality – the fact that the chemical easily evaporates at low temperatures, and thus is free to interact with olfactory receptors – transitioned the molecule from its ignored place in the economic engine of West Virginia. Smelled, crude MCHM became simultaneously known *and* unknown. Indeed, in the early hours of the spill, the only detection devices of use were people's noses. No other tests existed to measure it in drinking water. No potential spill protocol even existed, despite the fact that Freedom Industries storage tanks were visibly next to the river. The contamination of the drinking water supply of more than 300,000 people had transformed an entire population into what the managing director of the Chemical Safety and Hazard Investigation board called a 'toxicity experiment' (Johnson and Hogue, 2014: 7).

Officials turned to the US Centers for Disease Control and Prevention (CDC) for assistance. The agency developed a screening protocol and safety level of 1 part per million (ppm) based on two studies of the toxicity of pure MCHM in rats and told state officials that 'chemical concentrations would have to get below 0.1 ppm for residents to not notice the smell or color changes' (CDC, 2014; Ward, 2014b). The municipal water company, state laboratories, and an Army mobile analytical chemistry unit began screening water at the treatment plant. Press releases and news reports from January 10th indicate that officials believed the chemical spill would quickly pass.

Four days after the spill the governor began lifting the do-not-use order. West Virginia American Water asked residents to flush their water systems before use. Instructions told users to flush hot water taps for 15 minutes, cold water taps for five, to flush every toilet in the building at least once, and finally to flush any remaining appliances, discarding water filters and other devices that might be contaminated (West Virginia American Water, 2014). 'Any lingering smell, which is expected, is not a health issue', claimed the text at the bottom of the written instructions. The noses and bodies of many members of the public claimed otherwise. Reports such as Lori Kersey's January 15, 2014 article in the *West Virginia Gazette* of local emergency rooms crowded with people afflicted with rashes, headaches, upset stomachs and diarrhea raised awareness that, for some, the strong 'licorice-like' odors coming out of faucets when flushing might not be safe. In contrast, for those of my interlocutors who noticed nothing out of the ordinary as they flushed, much of the controversy appeared as 'mass hysteria', media hype or as the calculated first steps of someone planning a lawsuit. The smell of crude MCHM reappearing during the flushing process signaled the emergence of a new contested object – the presence, or absence, of a 'real' sensory signal.

Encounters with the fumes from crude MCHM in homes and institutions after following the flushing procedure differed notably from encounters with crude MCHM on January 9th in how and where the smell was detected. The first few days after the spill brought together an entire population in a shared sensorial event: Anyone could detect the presence of the chemical by simply walking or driving into downtown Charleston. No one questioned whether the chemical was present. In contrast, the second encounter with the odor of crude MCHM occurred in some, but not all, of the enclosed spaces spread throughout the entire distribution system, a much larger geographical area. This left open the question of whether these experiences were real.

Official response to concerns about the flushing was mixed: the Federal government released a revised recommendation on January 15th, noting ‘that the CDC recommends that pregnant women drink bottled water until there are no longer detectable levels of MCHM in the water distribution system’, even as it continued to identify the water as safe for general consumption (Commissioner’s Office, State of West Virginia Department of Health and Human Resources, Bureau for Public Health, 2014; Friden, 2014). On January 18th, the Agency for Toxic Substances and Disease Registry (an arm of the CDC) suggested flushing until the smell was gone, and the Governor’s office issued a press release alerting residents that crude MCHM might temporarily adhere to plastic plumbing. This, the governor’s office noted, ‘could result in a lingering smell for some time. The chemical is such that you can continue to smell it, even at 100,000 times below the no observable adverse effect level’ (Ward, 2014a). The Governor’s office lowered the state’s screening limit to a non-detect level of 10 parts per billion, 100-fold lower than the CDC’s screening level (Community, 2014). Despite these ostensibly protective moves, both local and federal officials continued classifying the presence of crude MCHM in people’s homes as acceptable, pitting public officials’ claims against a subset of individuals’ personal experiences.

The ability to enter personal experiences of sensory exposure into evidentiary systems lies at the heart of many environmental contamination controversies (Ottinger, 2013; Reno, 2011; Shapiro, 2015). In the US, municipal water suppliers are accustomed to complaints about off-flavors and odors; water treatment manuals such as those published by the American Water Works Association outline strategies for sorting and responding to complaints (Lauer, 2014). Underlying these strategies is the idea that consumers – and I use this word specifically to indicate the way in which one literally consumes water, as well as gesturing towards the larger capitalistic structures that seek to turn everyday necessities into consumable goods – are sensitive detection agents of changes in the water supply *and* easily fooled by psychological and physiological cues. For example, returning from vacation may trigger a complaint that the water tastes different. This complaint encompasses physiological and psychological cues: The consumer may have failed to run the tap for a short period of time to remove stagnant water before drinking, which would result in the water tasting different. More often, however, the consumer has simply lost habituation to the taste and odor of their water; upon encountering what was once familiar the brain must learn to again establish a baseline of familiarity. At the same time, producers consider spikes in consumer complaints as useful indicators of problems. Complaints of off tastes or odors thus fall within the realm of informative, but not necessarily authoritative, evidence of a potential problem (Reno, 2011: 523). Variation in West Virginians’ sensory experiences post-flushing entered into an already-present infrastructure of knowledge production in local and national water management. In this infrastructure, sensory encounters, while acknowledged as potential sentinel devices (Dietrich, 2006), call for scientific, instrumentally-mediated validation to confirm the presence of a known contaminant before action is taken. Sensory encounters activate sensory politics.

Official responses: Reading surfaces, ignoring shadows

The continued, yet inconsistent, presence of the ‘black licorice odor’ in homes and institutions after flushing challenged claims that the water was then safe. The odor even emerged when inhabitants obediently followed official directives in their homes and businesses. As one woman told me:

Everyone was falling back on what the CDC would say. We weren’t sure where they were getting their measurements and samples. There were too many information points. You don’t know what’s real. The government is saying it’s safe at this level, and others are saying it’s safe at this level, and others are saying ‘this is what’s happening in my house’. Do you risk [drinking] it? I’ve got a six-year-old in my house. At a certain level they are saying it’s safe to drink, but at the same time you could smell it. I mean, come on. You could smell and taste it. Nobody was believable.

The odor of crude MCHM, even just a hint of it, undermined relationships of trust between inhabitants and institutions.

The response of public health officials reflects the perceived lack of trustworthiness of consumers’ sensorial experiences. EJ Scharman and AF Pizon of the West Virginia Poison Center reported to the 2014 Annual Meeting of the North American Congress of Clinical Toxicology that, ‘although clinical effects reported were consistent with MCHM toxicity predicted by chemical structure and animal data, it is unlikely that all reported effects were directly related to MCHM toxicity. MCHM has a noxious licorice odor ... odors can result in physiological or psychological responses’ (Sharman and Pizon, 2014: 685). Scharman and Pizon’s statement acknowledges the sensory information produced by crude MCHM as capable of engaging cell signaling pathways. However, the statement reflects an understanding of the odor of crude MCHM as innocuous, simply an emotional, psychological response to a material. This reading posited smell as contained, separate from any toxicological danger.

In positing smell as contained, Scharman and Pizon articulate an odor that stops at the initial surface of contact where an odorant binds to a receptor. I am not saying that they did not imagine signal transduction at all, but rather that the form of transduction imagined is contained to this moment, this body. The lack of clinical evidence of known risk encouraged dismissal of sensorial experiences during the flushing procedure; it made what had been a shared sensorial experience into a contested object. For those who reported the presence of crude MCHM in their homes as they flushed their water systems, their inability to transduce smell into a shareable medium butted up against systems of knowledge making the call for evidence that can be inscribed and shared. Although public health officials and politicians *acknowledged* the presence of the smell of licorice after flushing, they *dismissed* the sensorial effects as simply emotional and psychological, continually returning to quantifiable measurements of crude MCHM levels as they spoke to the public about the potability of Charleston’s municipal water. At the same time, the identification of crude MCHM proved a moving target: labs tasked with analysis continually adapted and modified their analytical approach, seeking ever more sensitive methodologies and generating thousands of test results.

This is a reading that we might consider as flat; a surface without a shadow. Some inhabitants saw it otherwise, placing this spill, marked by the smell, within the context of the longer legacy of living in the Chemical Valley. For example, one interviewee recalled childhood episodes of seeing a massive fish kill in the river. 'It looked like every fish from the river was on the riverbank (big ones!), as far as you could walk. ... No warning, no tape, nothing warning that this was happening. It was weird that the fish kill was a secret. Did no one care?' His comments reflect a distrust exacerbated by the mismatch between lived experience and official statements, a distrust informed by the long history of weak environmental regulation paired with industrial might in West Virginia.

The persistent sensory information stream caused by the nature of crude MCHM created a political problem. Uncertain of the long-term risks associated with exposure, of why it persisted in some spaces, those in charge of governing the crisis sought a new form of information generation. They sought a form that could better account for the apparent reality that crude MCHM was detectable by noses at levels below the 10 ppb non-detect threshold that had, at that point, come to represent the limits of instrumental knowledge. They did so by announcing, on February 10th, 2014, the creation of the West Virginia Testing Assessment Project (WVTAP).⁶

By acting outside of the idealized framing of information production and circulation, crude MCHM's odor highlights the integral role that traceability – the ability to detect, inscribe, track, and, report – plays in shaping official and public responses to risk. The state-funded WVTAP brought together a group of 'independent, scientific experts' to: (1) conduct initial testing in homes at the tap (previous tests had been conducted as water left the treatment plant), (2) evaluate the safety factor proposed by the CDC, and (3) to determine the odor threshold for MCHM (Office of Governor Tomblin, 2014). These aims sought to cut through the excess of evidence coming in from the CDC, the army, independent researchers, and individual inhabitants. One can sense what might seem desperation from the governor's office in the creation of WVTAP: When Virginia Tech-based researcher Andrew Whelton and Jeffrey Rosen of the Massachusetts-based Corona Environmental Consulting proposed a plan for evaluating the 'contradictory consistent odor of licorice with the consistently below detection level analytical results to evaluate the safety of the treated water', they received approval within less than 24 hours (Rosen et al., 2014). Bringing in outside experts offered to bound the evidence, helping to mitigate inhabitants' distrust of their local, state and even federal governments. It also offered a possibility of reigning in the material's olfactory mischief, bringing the material back within the realm where sensory properties could be traced, quantified, and thus known.

Transforming uncertainty into certainty

Sensory knowledge is normally sought for very specific situations. A company may bring in consumers for the initial or final stages of product development, may seek them out for 'liking' studies, or may use their complaints to screen for failures in production systems. Sensory science methodologies operate by seeking to enact a doubled transduction: first to use tastants and odorants to transduce a molecule into sensation, and second, to use sensation to transduce an individual's unique, subjective sensory experience into objective measurements (see Shapin, 2012). These methodologies depend on an

assemblage of everyday people and trained experts who use their mouths or noses to act as sensors, and researchers who seek to carefully control and sift out any contaminating ‘bias’ through experimental design and statistical analysis (Howes, 2015; Phillips, 2016).

To better understand the consumer response to crude MCHM, WVTAP recruited engineer Michael McGuire to characterize the sensory aspects of the chemical in February 2014. McGuire and Irwin (Mel) Suffet, with a small team of graduate students, conducted two different sets of tests. The first used an expert panel, trained in the sensory science methodology of Flavor Profile Analysis (favored by the water industry), to determine the odor threshold concentration, odor recognition concentration and odor objection concentrations for expert consumers aware they were testing MCHM (McGuire et al., 2014a). The second, which I analyze below, drew together 60 untrained consumers randomly sampled from the testing center’s mailing list. These people were recruited to (1) test the threshold detection levels of consumers naïve to crude MCHM, (2) to use their own descriptors to describe the presence of an unknown sample in water (crude MCHM), and (3) to identify the threshold of objection which would lead to action (McGuire et al., 2014b).

Transforming the *uncertainty* of sensory encounters with crude MCHM into *certain* knowledge called for a three-step approach of screening, naming and testing. Potential panelists, in accordance with standardized sensory methodology that posits extraneous information as contaminating (Howes, 2015; Lawless and Heymann, 2010), were first individually screened for their ability to smell. McGuire and Suffet conducted the screening in a nondescript room off of the lobby of the consumer testing center, introducing potential panelists to the project by explaining that, ‘We’re going to sniff water samples, sniff drinking water. We’re just looking for regular people like you and those out in the room who will help us describe odors in drinking waters. We just want your description, your memories, your words.’ To facilitate participants’ ability to act as instruments, they were given limited information about samples they encounter. Potential panelists were then asked to name, in their own terms, the odor wafting up from the amber glass bottle during the initial screening session. This side-stepped the common, and time-intensive, challenge of developing a shared vocabulary around a sensory stimulus. Two panelists who struggled to find any words to describe the odor were excluded. Successful passing of the screening test depended on an individual’s ability to transduce not only odorant into perceived signal, but also to perform the additional alchemy of giving words to the sensations.

Terms introduced during the two initial screening sessions I observed varied widely. Panelists described the smell as alcohol, menthol, flowery, tapioca/vanilla, lightly floral perfume, sweet-fruity, medicinal, turpentine, minty cleaner, violets, Luden’s cough drops, almond, watermelon jellybean, Flowerbomb perfume, herby-spicy, play dough, soapy, cough syrup, coconut, clinical, NyQuil, rose water, Robitussin, caramel brown sugar and jasmine. These descriptors – all linked to the memories, experiences, and physiology of the individuals recruited for the test – reflect an overall positive perception of the odor of crude MCHM. Notably, the word ‘licorice’, used from the very first day of the chemical spill to describe the odor, appeared only four times in California, a semantic complication of the narrative put into play by politicians and journalists during the crisis.⁷

Selected participants who passed the screening were then tested for their ability to detect the chemical and name it in their water using their own descriptors via a sniff test.

Seated together in a different, nondescript room, each participant received a series of eight samplings of three samples, each labeled with a three-digit identifying code. Their instructions asked them to identify the sample cup that had a different odor than the other two samples had (the standardized procedure for a common sensory science tool, the forced-choice triangle test – Lawless and Heymann, 2010: 83). They were also instructed to describe the odor in the different cup, using their own words. ‘If the odor is like the odor in the sample you smelled before the panel, use that descriptor’, the instructions noted. Finally, panelists were asked to record whether they would complain about the water (Y/N) and rate their degree of liking on a 9-point hedonic scale, with 1 being ‘I would be very happy to accept this water as my everyday drinking water’ and 9 being ‘I can’t stand this water in my mouth and I could never drink it’ (SSP, 2014). The test produced three series of thresholds, detection, recognition, and the decision to actively object.

Near the end of the testing session, McGuire explained, ‘We’re using your noses like a very fine analytical instrument. Your noses, collectively, are better than any analytical instrument around.’ In focusing on the power of the nose, McGuire’s statement inadvertently highlights one of the key ‘domains of imperceptibility’ (Murphy, 2006) built into standardized sensory testing procedures: the knowledge held by those trained outside of formal mechanisms to be attuned to a sensation need to be designed around. McGuire’s comment acknowledges the limits of analytical instruments, limits that compounded the crisis in West Virginia. It highlights the ability of olfactory receptors to detect and signal the presence of the odorant.⁸ The testing approach used reflects a larger imagination of smelling (and tasting) as discrete moments of marking presence or absence that not only can, but should be removed from their contexts with the aim of producing generalizable knowledge.

The WVTAP final report notes that repeated exposure to crude MCHM in the water supply – exposure exacerbated by the flushing protocol, exposure that continued as plastic pipes slowly desorbed the chemical in the following months – had most likely created a series of expert tasters across an entire population. That conclusion obscures an important fact: considered contaminated or biased sensors due to weeks of exposure to crude MCHM, consumers from West Virginia were implicitly written out by the accepted, standardized procedures of identifying and selecting panelists from the process of determining the detection and the objection thresholds for water contaminated with crude MCHM. These ‘tasters’ were not a professional, expert panel working in a laboratory setting, yet repeated exposure to the odor of crude MCHM *had* trained the bodies of those living in the spill area; it made them into measuring instruments. As West Virginia Public Broadcasting’s CEO, Scott Finn, blogged on February 23, 2014 of the experience, ‘After state officials finally stopped the MCHM from entering the water supply, after they told us to flush our pipes, you could still smell it in the water for weeks. I would engage in a nervous ritual: run the tap, lean in a little and sniff three times – and there it would be.’ Sensing ‘in its particularity’ (Marks, 2002) threatens to contaminate scientific knowledge.

Transducing sensory science

Contemporary science and philosophy about olfaction largely understands smell as chemical and biological, a moment of touch between odorant and body. This

conceptualization of sensing as simply signal appeared in the approaches of West Virginia's Public Health officials as they tracked visits to emergency rooms and physicians' offices. It also appeared in the recruitment and testing processes used by sensory scientists working on the other side of the country. All conceptualized the exposure to crude MCHM as happening within a molecular context. This move flattened out experience. It ignored another, critically important, form of transduction: affective transduction. Affective transduction transformed smell into fear; it called up the difficulties of life upended, the betrayal of trust. This move also trivializes what we might call temporal transduction, the ability of sensorial memory to appear and re-appear not only when the molecule is present, but also in other situations. In essence, 'good' science – science capable of creating objective knowledge about the spilled chemical – required bodies unfamiliar with crude MCHM. 'Good' science treated the West Virginia incident as divisible from the knowledge production process, as a contaminating context.

In contrast, synesthetically reading smell as an object that carries a shadow allows us to both encompass the biological model of signal transduction and move beyond it, to call for a science that acknowledges future potentialities as well as past moments of occurrence. The spill, in rendering potentially dangerous everyday activities, heightened citizens' sensory awareness of the world around them. Thinking of smell as an object with a shadow invites one to imagine and anticipate the wide range of transductive moments that exist after an odorant binds a molecular receptor, to rather make accessible the ways in which forgotten histories, political choices, economic drivers, built infrastructures and beyond get transduced into everyday life, and potentially inscribed in bodies, genomes and future well-being.

Conclusion

What might bringing smell's shadow into sensory science look like? To think through this, it is useful to step back and look at what the information produced by the sensory tests did, and how it continues to circulate. The tests run in California demonstrated that expert consumers could detect crude MCHM at levels well below the screening level developed by the CDC (McGuire et al., 2014a), while naïve consumers could detect the chemical at levels equivalent to the most sensitive screening method (McGuire, 2014). The results 'validated' the experience of the community. But the results did something more. They entered into and are now traveling throughout the 'molecular bureaucracy' propping up late industrialism's continued existence. The most recent Material Safety Data Sheet (MSDS) for crude MCHM published by Eastman Chemical notes that the odor threshold is 0.15 ppb, and characterizes the odor as 'alcohol, licorice' (Eastman, 2019). In contrast, the 2011 MSDS, the one available at the time of the spill, lists 'no data available' for the odor threshold, while simply characterizing the odor as 'alcohol' (Eastman, 2011). In other words, inhabitants of West Virginia, at significant personal and fiscal cost, bore the burden of making knowledge for Eastman and its customers. Apart from the word 'licorice', no trace remains of their lived experience in the MSDS sheet. This is due primarily to molecular bureaucracy. But it is also due in part to the failure of sensory science itself to think beyond its legacy as a science that came into being in service of military and industry. Rather than serving the community, knowledge about crude

MCHM's sensory properties has re-entered the system that brought it into production and allowed a tank full of an uncharacterized chemical to sit within mere feet of the region's major source of drinking water.

When enrolled in responding to environmental contamination episodes, sensory science invites embodied expertise into conversations and debates where it otherwise might not be welcome. However, it follows the logics of a science seeking to create knowledge that can be free of the places and bodies that produced it. This process is facilitated by an understanding of how sensory experience works, where the presence of a perceptible molecule is communicated to the brain and body via signal transduction. Sensory science measures this signal, using aggregate moments of deliberately stimulated sensory experience, conducted in places far away from outside influences, to calculate the threshold at which a molecular entity becomes perceptible. In doing so, the contexts that brought the sensing body to perceive as naïve consumers or trained experts disappear.

At the opening of this paper, I invited you to join in a temporally and spatially disparate, embodied disruption of this understanding of olfaction. Take a moment and reflect back. You may or may not have found a piece of black licorice, but undoubtedly every time you encountered the word in this text your body reacted in some way. You may have salivated a little, if, like me, you enjoy black licorice. If statistics are any indication, a significant number of you responded otherwise, drawing on your own 'shadow' that compiled together a single, or multiple, interactions with the anise-like flavor of the candy to navigate the sensory cues in this paper. Sensory scientists are aware of this. Yet the testing procedures used to create knowledge about environmental contaminants insist on excluding the shadows of modes of attunement created by late industrialism's decay.

There is a different future possible. In it, sensory science could still produce valuable information about materials and their thresholds (paid for by the companies who produce these materials). But sensory science wouldn't stop there. Cognizant of the discipline's historic role in maintaining systems of harm, sensory scientists responding to environmental contamination crises would reject the discipline's recruitment procedures that position affected inhabitants as contaminated or biased. Instead, sensory scientists would see affected inhabitants as experts whose lives and neurological pathways have been altered and trained through experience, attuned to sensation. In this alternative future, sensory scientists recruited to determine thresholds would invite these local experts, and would pay them, to take part in the tests conducted. The tests conducted would then produce facts that cannot (easily) travel through the systems that spread knowledge about chemicals. Rather, these facts would be valuable because, like shadows, they would always harken back to the objects and infrastructures that made them. These are facts that recognize the labor imposed on bodies and brains by moments of perceptible contamination. These are facts that, in their making, require a reorientation of the entire scientific enterprise that produces them, and in the process offers the potential to reorient sensory science away from maintaining systems of toxic harm and towards building new systems of accountability.

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Notes

1. I include this exercise as a gesture towards the ‘doing [not-quite] ethnography in late industrialism’ that Fortun proposes. It is partially inspired by Ingold’s (2007) introduction, and by a common taste education exercise where one takes a bite of something with the nose plugged, and then unplugs the nose. What does it mean to just read words on a paper about a sensory experience that disappears and re-appears? How do we account for the materials that are understood as objects with material potential but ignored as objects with the ability to transduce a signal? What neural modifications are happening in your own body as you read and eat and sense?
2. Although subsequent months and years would result in the identification of additional chemicals, the total composition of the mixture spilled is still not known (Whelton et al., 2017). For ease, I use ‘crude MCHM’ throughout this paper, in part to reflect the initial conversations about the spill, and in part to reflect the ongoing unknown-ness of the complete composition.
3. Hoover (2017) provides an in-depth examination of how definitional practices of identifying contaminants fail to account for their further circulations.
4. I am deeply indebted to the work of Liboiron, Murphy, Ottinger and Shapiro in shaping my thinking this way.
5. Making olfacto-gustatory sensation molecular not only occurred because of the adoption of theories of signal transduction. The instrumental revolution in chemistry and subsequent rise of gas chromatography-olfactometry and mass spectroscopy as tools for understanding the molecular, accompanied these shifts in biological theory (Berenstein, 2017). This assemblage of tools facilitated the quantification of smell or taste. Made molecular, odorants or flavorants can be reduced to their bundles of material properties. They can then be manipulated for other uses, such as selling products to hungry mouths or desiring noses. They can also be used to argue that a molecule is, or is not, toxic.
6. The creation of WVTAP deserves its own treatment, examining how NSF-based funding structures, academic publish-or-perish infrastructures, institutional rankings, and outside consultants intersected with the political need to appear to be actively responding to the ongoing crisis. It is worth noting that the political pressure to do *something* was strong enough that Governor Tomblin earmarked \$650,000 for initial research efforts less than 24 hours after announcing WVTAP.
7. I have not yet had any success in interviewing the reporter who first used the word ‘licorice’.
8. For a critique of this engrained approach that ‘attaches objects or material structures to matching contents of sensory perception’ see Barwich (2014).

References

- Adams C, Whelton A and Rosen J (2014) *Health Effects for Chemicals in 2014 West Virginia Chemical Release: Crude MCHM compounds, PPH and DiPPH*. West Virginia Testing Assessment Project, Literature Review, Ver 1.5. Available at: <http://dhsem.wv.gov/WVTAP/>

- testresults/Documents/POSTED_WVTAP%20Health%20Effects%20Lit%20Review%20v1.5%20031714.pdf (accessed 24 March 2020).
- Agapakis C and Tolaas S (2012) Smelling in multiple dimensions. *Current Opinion in Chemical Biology* 16(5–6): 569–575.
- Alač M (2020) Beyond intersubjectivity in olfactory psychophysics I: Troubles with the Subject. *Social Studies of Science* 50: 440–473.
- Ballesterio A (2019) Touching with light, or, how texture recasts the sensing of underground water. *Science, Technology, and Human Values* 44(5): 762–785.
- Barad K (2003) Posthumanist performativity: Toward an understanding of how matter comes to matter. *Signs* 28(3): 801–832.
- Barwich A-S (2014) A sense so rare: Measuring olfactory experiences and making a case for a process perspective on sensory perception. *Biological Theory* 9(3): 258–268.
- Barwich A-S (2017) Up the nose of the beholder? Aesthetic perception in olfaction as a decision-making process. *New Ideas in Psychology* 47: 157–165.
- Bell S and York R (2010) Community economic identity: The coal industry and ideology construction in West Virginia. *Rural Sociology* 75(1): 111–143.
- Bennett J (2010) *Vibrant Matter: A Political Ecology of Things*. Durham: Duke University Press.
- Berenstein N (2017) *Flavor added*. PhD Thesis, University of Pennsylvania, Philadelphia, PA.
- Berlant L (2011) *Cruel Optimism*. Durham: Duke University Press.
- Buck L and Axel R (1991) A novel multigene family may encode odorant receptors: A molecular basis for odor recognition. *Cell* 65(1): 175–187.
- Butler E (2018) Tasting off-flavors: Food science, sensory knowledge and the consumer sensorium. *Senses and Society* 13(1): 75–88.
- CDC (2014) *Information about MCHM*. Available at: <http://emergency.cdc.gov/chemical/MCHM/westvirginia2014/mchm.asp> (accessed 24 March 2020).
- Choy T and Zee J (2015) Condition-suspension. *Cultural Anthropology* 30(2): 210–223.
- Commissioner's Office, State of West Virginia Department of Health and Human Resources, Bureau for Public Health (2014) *Water Advisory for Pregnant Women*. Available at: <http://www.wvdhhr.org/Advisory1152014.pdf> (accessed 23 April 2020).
- Community (2014) Gov. Tomblin directs Dr. Tierney and General Hoyer to Host Conference Call Addressing Community Concerns, 18 January, 4:16 pm. <http://www.governor.wv.gov/media/pressreleases/2014/Pages/GOV.-TOMBLIN-DIRECTS-DR.-TIERNEY-AND-GENERAL-HOYER-TO-HOST-CONFERENCE-CALL-ADDRESSING-COMMUNITY-CONCERNS.aspx>.
- Coole DH and Frost S (eds) (2010) *New Materialisms: Ontology, Agency, and Politics*. Durham: Duke University Press.
- Corbin A (1986) *The Foul and the Fragrant: Odor and the French Social Imagination*. Cambridge: Harvard University Press.
- Dietrich AM (2006) Aesthetic issues for drinking water. *Journal of Water and Health* 4(S1): 11–16.
- Eastman (2011) *Safety Data Sheet, Crude MCHM, Version 2.0*. Available at: <https://online.wsj.com/public/resources/documents/Eastman.pdf> (accessed 9 March 2020).
- Eastman (2019) *Safety Data Sheet, Crude MCHM, Version 3.3*. Available at: http://ws.eastman.com/ProductCatalogApps/PageControllers/MSDS_PC.aspx?Product=71014291 (accessed 9 March 2020).
- Fiske A (2018) Dirty hands: The toxic politics of denunciation. *Social Studies of Science* 48(3): 389–413.
- Fortun K (2001) *Advocacy after Bhopal: Environmentalism, Disaster, New Global Orders*. Chicago: University of Chicago Press.

- Fortun K (2012) Ethnography in late industrialism. *Cultural Anthropology* 27(3): 446–464.
- Friden T (2014) *Letter to Secretary Karen Bowling*. Available at: www.dhsem.wv.gov/Documents/CDC%20Letter.pdf (accessed 24 March 2020).
- Gerontas A (2014) Creating new technologists of research in the 1960s: The case of the reproduction of automated chromatography specialists and practitioners. *Science and Education* 23(8): 1681–1700.
- Gramaglia C and Mélard F (2019) Looking for the cosmopolitical fish: Monitoring marine pollution with anglers and congers in the Gulf of Fos, Southern France. *Science, Technology, and Human Values* 44(5): 814–842.
- Helmreich S (2019) Reading a wave buoy. *Science, Technology, and Human Values* 44(5): 737–761.
- Hepler-Smith E (2019) Molecular bureaucracy: Toxicological information and environmental protection. *Environmental History* 24(3): 534–560.
- Hoover E (2017) *The River is in Us: Fighting Toxics in a Mohawk Community*. Minneapolis: University of Minnesota Press.
- Howes D (2015) The science of sensory evaluation: An ethnographic critique. In: Drazin A and Küchler S (eds) *The Social Life of Materials: Studies in Materials and Society*. London: Bloomsbury, 81–98.
- Ingold T (2007) Materials against materiality. *Archaeological Dialogues* 14(1): 1–16.
- Jackson DD (2011) Scents of place: The displacement of a First Nations community in Canada. *American Anthropologist* 113(4): 606–618.
- Jasaravic L (2015) The thing in a jar: Mushrooms and ontological speculations in post-Yugoslavia. *Cultural Anthropology* 30(1): 36–64.
- Johnson J and Hogue C (2014) Toxicity unknown. *Chemical & Engineering News* 91(3): 7.
- Kenner A (2018) *Breathtaking: Asthma Care in a Time of Climate Change*. Minneapolis: University of Minnesota Press.
- Kersey L (2014) Residents visit ERs with water-related complaints. *Charleston Gazette-Mail*, 15 January. Available at: <http://wvgazette.com/News/201401150044> (accessed 24 March 2020).
- Kiechle MA (2017) *Smell Detectives: An Olfactory History of Nineteenth-Century Urban America*. Seattle: University of Washington Press.
- Lahne J (2018) Standard sensations: The production of objective experience from industrial technique. *Senses and Society* 13(1): 6–18.
- Landecker H (2016a) Antibiotic resistance and the biology of history. *Body & Society* 22(4): 19–52.
- Landecker H (2016b) The social as signal in the body of chromatin. *The Sociological Review Monographs* 64(1): 79–99.
- Lauer WC (2014) *Water Quality Complaint Investigator's Field Guide*. 2nd ed. Denver: American Water Works Association.
- Lawless HT and Heymann H (2010) *Sensory Evaluation of Food: Principles and Practices*, 2nd ed. New York: Springer.
- Liboiron M (2017) Compromised agency: The case of BabyLegs. *Engaging Science, Technology, and Society* 3: 499–527.
- Liboiron M, Tironi M and Calvillo N (2018) Toxic politics: Acting in a permanently polluted world. *Social Studies of Science* 48(3): 331–349.
- Marks LU (2002) *Touch: Sensuous Theory and Multisensory Media*. Minneapolis: University of Minnesota Press.
- McGuire MJ (2014) *Technical Memorandum: Consumer Panel Estimates of the Odor Threshold Concentration, Odor Recognition Concentration and Odor Objection Concentration for Crude 4-methylcyclohexanemethanol in Water*. Technical Memorandum. Available at:

- [https://dhsem.wv.gov/wvtap/testresults/Documents/Final%20Consumer%20Panel%20Technical%20Memo%20033114%20\(1\).pdf](https://dhsem.wv.gov/wvtap/testresults/Documents/Final%20Consumer%20Panel%20Technical%20Memo%20033114%20(1).pdf) (accessed 19 March 2020).
- McGuire MJ, Rosen J, Whelton AJ, et al. (2014a) An unwanted licorice odor in a West Virginia water supply. *Journal AWWA* 106(6): 72–82.
- McGuire MJ, Suffet IH and Rosen J (2014b) Consumer panel estimates of odor thresholds for crude 4-methylcyclohexanemethanol. *American Water Works Association* 106(10): E445–E458.
- Muniesa F and Trébuchet-Breitwiller A-S (2010) Becoming a measuring instrument. *Journal of Cultural Economy* 3(3): 321–337.
- Murphy M (2006) *Sick Building Syndrome and the Problem of Uncertainty: Environmental Politics, Technoscience, and Women Workers*. Durham: Duke University Press.
- Murphy M (2017) Alterlife and decolonial chemical relationships. *Cultural Anthropology* 32(4): 494–503.
- Nading AM (2017) Local biologies, leaky things, and the chemical infrastructures of global health. *Medical Anthropology* 36(2): 141–156.
- Office of Governor Tomblin (2014) *Governor Tomblin Directs Health Official to Move Forward with Home Testing Project*. Available at: <http://www.dhsem.wv.gov/wvtap/news/Pages/Governor-Tomblin-Directs-Health-Officials-to-Move-Forward-with-Home-Testing-Project.aspx> (accessed 19 March 2020).
- Osnos E (2014) Chemical Valley: The coal industry, the politicians, and the big spill. *New Yorker*, 7 April. Available at: <http://newyorker.com/magazine/2014/04/07/chemical-valley> (accessed 24 March 2020).
- Ottinger G (2013) *Refining Expertise: How Responsible Engineers Subvert Environmental Justice Challenges*. New York: New York University Press.
- Ozmak M and Aktas Z (2006) Coal froth flotation: Effects of reagent adsorption on the froth structure. *Energy Fuels* 20(3): 1123–1130.
- Paxson H and Helmreich S (2013) The perils and promises of microbial abundance. *Social Studies of Science* 44(2): 165–193.
- Phillips CJ (2016) The taste machine: Sense, subjectivity, and statistics in the California wine world. *Social Studies of Science* 46(3): 461–468.
- Public Service Commission (2014) Public Service Commission of West Virginia, Charleston. Respondent exhibit JLM-D, Case No. 14-0872-W-GI: General investigation pursuant to W. Va. Code § 24-2-7 into the actions of WVAVC in reaction to the January 9, 2014 chemical spill, direct testimony of Jeffrey L. McIntyre.
- Reno J (2011) Beyond risk: Emplacement and the production of environmental evidence. *American Ethnologist* 38(3): 516–530.
- Rosen J, Whelton AJ, McGuire M, et al. (2014) *WV TAP Final Report*. Available at: <http://www.dhsem.wv.gov/WVTAP/testresults/Documents/WV%20TAP%20Final%20Report.pdf> (accessed 19 March 2020).
- Scharman EJ and Pizon AF (2014) Human effects of 4-methylcyclohexanemethanol. *Clinical Toxicology* 52(7): 682–818.
- Shapin S (2012) The sciences of subjectivity. *Social Studies of Science* 42(2): 170–184.
- Shapiro N (2015) Attuning to the chemosphere: Domestic formaldehyde, bodily reasoning, and the chemical sublime. *Cultural Anthropology* 30(3): 368–393.
- Shapiro N (2019) Persistent ephemeral pollutants. In: Boucher M-P, Helmreich S, Kinney LW, et al. (eds) *Being Material*. Cambridge: MIT Press, 154–161.
- Shields-Argèles C (2019) A cooperative model of tasting: Comté cheese and the jury terroir. *Food, Culture, and Society* 22(2): 168–185.
- Spackman C (2018) Perfumer, chemist, machine: Gas chromatography and the industrial search to ‘improve’ flavor. *Senses and Society* 13(1): 41–59.

- Spackman C and Burlingame B (2018) Sensory politics: The tug-of-war between potability and palatability in municipal water production. *Social Studies of Science* 48(3): 350–371.
- Spackman C and Lahne J (2019) Sensory labor: Considering the work of taste in the food system. *Food, Culture & Society* 22(2): 142–151.
- SSP (Society of Senory Professionals) (2014) *The 9-point hedonic scale*. Available at: <https://www.sensorysociety.org/knowledge/sspwiki/Pages/The%209-point%20Hedonic%20Scale.aspx> (accessed 24 April 2020).
- Stewart K (2011) Atmospheric attunements. *Environment and Planning D* 29(3): 445–453.
- Trubek A (2008) *The Taste of Place: A Cultural Journey into Terroir*. Berkeley: University of California Press.
- Ulloa AM (2019) The chef and the flavorist: Reflections of the value of sensory expertise. *Food, Culture, and Society* 22(2): 186–202.
- Ward K Jr (2014a) Feds advised flushing until chemical odor gone. *The Charleston Gazette*, 19 January. Available at: https://www.wvgazettemail.com/news/special_reports/feds-advised-flushing-until-chemical-odor-gone/article_e7597225-055a-5c4c-ac5b-81fb624aca34.html (accessed 24 March 2020).
- Ward K Jr (2014b) What is ‘crude MCHM’? Few know. *The Charleston Gazette*, 10 January. Available at: https://www.wvgazettemail.com/news/special_reports/what-is-crude-mchm-few-know/article_69043f50-8e34-56df-9c26-0c749560baee.html (accessed 24 March 2020).
- West Virginia American Water (2014) *How to Flush Your Plumbing System*. <http://www.governor.wv.gov/Documents/How%20to%20Flush%20Your%20Plumbing%20System.pdf> (accessed 7 March 2014).
- Whelton AJ, McMillan L, Novy CL-R, et al. (2017) Case study: The crude MCHM chemical spill investigation and recovery in West Virginia USA. *Environmental Science Water Research and Technology* 3(2): 312–332.
- Yang A (2015) That drunken conversation between two cultures: Art, science, and the possibility of meaningful uncertainty. *Leonardo* 48(3): 318–321.

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