Sensory Politics: The Tug-of-War Between Potability and Palatability in Municipal Water Production

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Abstract:
Sensory information signaled the acceptability of water for consumption for lay and professional people into the early twentieth century. Yet as the twentieth century progressed, professional efforts to standardize water-testing methods have increasingly excluded aesthetic information, preferring to rely on the objectivity of analytic information. Despite highly publicized cases where consumers report negative health effects from aesthetic contaminants in the water supply, consumer complaints remain peripheral to the making and regulating of drinking water. This exclusion is often attributed to the unreliability of the human senses in detecting danger. However, through examination of technical discussions among water professionals during the twentieth century, we suggest that this exclusion is actually due to *sensory politics,* the institutional and regulatory practices of inclusion or exclusion of sensory knowledge from systems of action. Water workers developed and turned to standardized analytical methods for detecting chemical and microbiological contaminants, and more recently sensory contaminants, a process that attempted to mitigate the unevenness of human sensing. In so doing, they created regimes of perception that categorized consumer sensory knowledge as aesthetic. By silo-ing consumers' sensory knowledge about water quality into the realm of the aesthetic instead of accommodating it in the analytic, the regimes of perception implemented during the twentieth century to preserve health have marginalized subjective experiences. Discounting the human experience with municipal water as irrelevant to its quality, control, and regulation is out of touch with its intended use as an ingestible, and calls for new practices that engage consumers as valuable participants.

Keywords: water, regulation, senses, pollution, expertise, aesthetics

Introduction

Palatable waters are not always potable
- Mallevialle and Suffet (1987, p. 2)

In January 2014, residents of Charleston, West Virginia learned that a relatively uncharacterized, smelly chemical, crude 4-methylcyclohexane methanol (MCHM) had contaminated their municipal water. The governor banned *all* uses except for toilet flushing. Eight months later, residents in Toledo, Ohio were similarly banned from using municipal water due to high levels of microcystin, an odorless, tasteless cyanobacterial toxin, in their water. In early 2015, residents in Flint, Michigan found that their water had elevated concentrations of chlorine disinfection byproducts; by mid-year the American Civil Liberties Union and others reported that the water also contained dangerous levels of lead. Like more readily definable disasters, these cases all disrupted residents' daily lives, activated local, state, and federal aid mechanisms, and resulted in significant financial loss to individuals, businesses, and communities.

The similarities and differences between these drinking water disasters raise a variety of issues. No federal regulation requires monitoring for microcystins, nor for odorous contaminants like crude-MCHM, whereas disinfection byproducts and lead carry federally regulated maximum levels. The chemical that leaked into Charleston's water supply was not on any watch list, nor did officials have any existing analytical means for monitoring it. However, its smelly materiality made detection by both lay people and water workers possible. In contrast, the toxins in Toledo's water and the lead in Flint's were neither smell-able nor taste-able, although the greenish hue in Toledo's source water indicated to producers that something was amiss, as should have the brownish-red colors coming out of taps in Flint. The only *actionable* proof of toxic danger came from analytical tests conducted in labs.

Reliance on the human senses for detection of unsafe water is risky. Age, sensory dysfunction, bias, health, and social cues all influence how one senses. Additionally, sensory perception and imperception unpredictably combine: clear waters can hide millions of microbes. Off flavors in drinking water—the muddy flavor of geosmin or the cucumber flavor of trans,2-cis,6 nonadienal, for example—falsely signal danger to drinkers' mouths and noses (Mallevialle and Suffet, 1987). In contrast, other categories of off flavors, such as copper from corroding pipes or high levels of chlorine from a chemical overfeed, signal true danger. Similarly, an *absence* of off flavor may hide dangerous levels of lead, pathogenic bacteria, parasites, or cyanobacterial toxins (Mallevialle & Suffet, 1987). Sensing is uneven; as such, throughout the twentieth-century municipal water workers—a wide ranging group which includes engineers, water department managers, filtration plant workers, scholars, chemists, technologists, and politicians (see, for example, *Journal. American Water Works Association*, 1914)—and regulators have understood it as unreliable information for taking action and making decisions.

Despite contemporary concerns over sensory unevenness, for centuries ears, hands, noses, eyes, and mouths have done the work of assessing the safety of ingestibles. Yet from the mid-nineteenth into the twentieth century, advances in chemical and biological analyses, coupled with the turn toward the germ theory of disease and away from miasmatic conceptions of disease, have shifted the responsibility—and the authority—for judging the safety of the ingestible environment in the U.S. from individual mouths, noses, and eyes to those of scientific authorities housed in public and private institutions (Hamlin, 1990; Kiechle, 2017; Liboiron, 2012). While this shift in responsibility for knowing from individual to expert certainly reflects the professionalization of science writ large, at the same time it is distinctly different: opening ones' mouth and ingesting is dangerous work that places the onus of responsibility, and the consequences of ingestion, on the individual—and has been understood as doing so long before the Pasteurian turn (Albala, 2002; Smith, 2013). Thus, although the nascent professional corps of chemists, engineers, and sanitarians working on municipal water in the late 1800s and early 1900s tracked pollution sources and judged a water's healthfulness through their senses just as individual consumers did (Bureau of Water, Philadelphia, 1898), over the twentieth century the engineers, chemists, operators, and superintendents associated with public and private water works, as well as their professional associations, have sought to standardize, and make objective sensorial modes of measuring. In the process, how sensory knowledge was produced, and more importantly, whose sensory knowledge mattered, subtly shifted. We historically situate scientific, technological, and regulatory responses to sensory unevenness to ask: What power relationships are revealed when regulatory institutions are examined through the noses and mouths of the everyday person? What types of sensing are allowed, and what types are dismissed? How have shifting conceptions of the aesthetic shaped institutional response to lay sensory information?

To answer these questions, we draw on historical research conducted by Spackman examining published regulations, Standards Methods manuals (1905-1975) found at the Library of Congress, published professional discussions between water workers during the twentieth century, as well as on Burlingame's 35 years of experience in managing drinking water quality for the Philadelphia Water Department, a tenure that includes more than 30 years studying the sensory aspects of water. Municipal water provides a potent locus for considering how scientific and regulatory practices include or exclude sensory information. Unlike other foods—and other waters—municipal water is routinely framed in contemporary discourse as best when flavorless. Additionally, municipal water is the only industrially produced foodstuff that is directly delivered into homes; an infrastructural reality that subtly alters the producer-consumer relationship by cutting out both the visible delivery person or the opportunity to examine a product before it enters the home. We thus examine the twentieth-century development of expert practices of measuring tastes and odors in water in the U.S. to illustrate how institutions and regulations have shaped contemporary discussions of aesthetic contaminants, demonstrating the need for a shift in the conception of municipal water to one that more fully embraces its uses across a range of categories, from industrial to culinary.

We show that municipal water providers never stopped attending to the taste and odor of the water they produce. However, the ways that institutions—which we understand to encompass professional groups as well as local, state, and federal governing bodies and agencies—conceptualize, measure, and respond to the taste and odor, and to their constituents' tasting and smelling, of water has changed throughout the twentieth century, ultimately minimizing official regard for water's gustatory qualities. As the methods for making and monitoring water evolved, regulatory attention to sensory information bifurcated along lines of safety and toxicity. The types of sensory information permitted to shape the management of water similarly bifurcated, as official discourses divided sensory information into relevant and irrelevant categories.

Sensorial Uncertainty

To explore how institutions respond to sensory knowledge about unwanted tastes and odors in drinking water, glossed in institutional and regulatory parlance as aesthetic contaminants, we bring together STS and political science scholarship examining practices of definition and measuring. Scholars such as Michelle Murphy (2006) and Nicholas Shapiro (2015) highlight that somatic sensing of chemicals challenges scientific and regulatory understandings of toxicity. [Some] Bodies, they argue, sense environmental contamination in ways that defy mechanical measurement. 'There is a dual uncertainty,' Murphy notes, 'when it comes to chemical exposures: first, any incidence of chemical exposure is difficult to pinpoint . .

. second, contemporary experts disagree about the import and even the existence of widespread, low-level exposures' (2006, p. 10). The 'dual uncertainty' inherent in identifying and pinpointing chemical exposure further complicates the unevenness of human sensing. Murphy argues that development of twentieth-century methods for measuring toxicity—which took techniques of isolating humans in sealed chambers from experimental physiology and re-appropriated those techniques for use on measuring animal's physiological responses to chemical exposure—gave rise to regimes of perceptibility while also creating 'domains of imperceptibility' (Murphy, 2006, pp. 84–91).[i] For Murphy, regimes of perceptibility and imperceptibility are 'the way a discipline or epistemological tradition perceives and does not perceive the world' (2006, p. 10). In other words, how one measures toxicity determines what one perceives: scientists, courts, and physicians traditionally perceive and acknowledge toxicity using standardized, quantitative measures grounded in early twentieth century ideas about assimilative capacity (Liboiron, 2012, pp. 43–62), while methods such as popular epidemiology and bucket brigades highlight the failures of traditional measurement techniques to capture localized lived experiences of exposure (Ottinger, 2013, pp. 12–14).

How bodies respond, their ability to perceive toxicity in the consumable environment of air, water, and food is tangled up in the twentieth-century move towards what Timothy Mitchell characterizes as the 'rule of experts' (2002). For Mitchell, claims that techno-scientific expertise could improve nature, the economy, and society proved to be key supports of the power structures that drove national development (2002, p. 15). 'The practices that form the economy operate, in part, to establish equivalences, contain circulations, identify social actors or agents, make quantities and performances measurable, and designate relations of control and command,' Mitchell argues (2002, p. 8). The credibility of ones measurements, and thus their ability to enter the regulatory context, Theodore Porter maintains, is directly related to how one measures, and the impersonality of ones measurement (1996). Max Liboiron (2012) further highlights the ontological role definitional practices play in demarcating the boundaries or limits around which concepts such as pollution, safety, and danger are mobilized in regulatory practice. Following Mitchell, Porter, and Liboiron, the ability to define and measure objects that have previously remained undefined and unmeasured not only creates new regimes of perception, it also draws boundaries around whose practices of perceiving are allowed to spur action.

Individual, subjective experiences of tasting and smelling have proved especially difficult to quantify and measure. Philosophers have long debated the scientific validity of embodied knowledge produced by tasting and smelling, arguing that the subjective nature of taste excluded the creation of shareable standards of judgment (Korsmeyer, 1999). Standards of taste were best left to connoisseurs, they argued, a historical move that implicitly separated aesthetic experiences from scientific measurement. 'The taste-judgment distinction has traditionally had its being in aesthetics, especially in the eighteenth-century efflorescence of concern with the beautiful and the good,' Steven Shapin notes (2012, p. 173). Objects or experiences, once labeled as aesthetic, enter into what Pine and Liboiron (2015) term the 'politics of measurement and action,' that guard which forms of information are allowed to enter into the informational infrastructures that shape policy decisions.

Despite well-publicized cases of consumers reporting negative health effects from highly odorific contaminants that make their way into ground or surface waters, so-called “aesthetic” contaminants in drinking water remain minimally regulated. Dietrich and Burlingame (2015) point out the failure of the only federal regulatory tool in the U.S. for monitoring aesthetic characteristics of drinking water, the Secondary Maximum Contaminant Levels (SMCLs), to provide up-to-date, accurate, and effective regulatory guidance. As the infrastructural decay of late industrialism (Fortun, 2012) continues to expand, and novel technologies such as hydraulic fracturing place ground waters at increased risk for contamination, the framing of sense-able contaminants as aesthetic—and thus simply affecting consumer perceptions—fails to acknowledge the potentially toxic effects of common industrial chemicals. Unfortunately, even as scholars explore the links between senses, affect, and toxicity, outside the world of disability studies (Serlin, forthcoming) the “problem” of what we call the unevenness of sensing continues to receive inadequate attention.

Andrew Barry, writing about the role of materials in political life, argues that processes of monitoring, assessment, and regulation of the ‘unpredictable and lively behavior of objects and environments should be understood as integral to the conduct of politics’ (2013, p. 2). As a material, water is deeply imbricated in social and technological projects of urbanization, industrialization, and modernization; water has become the subject of new forms of local, regional, and state governance (Anand, 2017; Bakker, 2012, p. 617; Pritchard, 2012). We see sensory experience, which brings together the ‘unpredictable and lively behavior’ of both sense-able materials and biological sensing mechanisms, as similarly enmeshed in the conduct of politics even as it is ignored. These *sensory politics* are practices of inclusion and exclusion of sensory knowledge from the making of institutional and regulatory practices.[ii] To describe the rise of sensory politics and its implications in health promotion efforts, we mobilize Michelle Murphy’s conception of regimes of perceptibility and imperceptibility to historically examine how U.S. institutions have come to interact with, ignore, or engage with expert and non-expert ways of sensing aesthetic contaminants.

The Shifting Aesthetics of Drinking

For centuries, water was considered ‘of good quality and potable when it is fresh, clear, without odor, when its taste is minimal, that it is neither disagreeable, nor insipid, nor salty, nor sweet; when it contains little foreign matter; when it contains a sufficient amount of dissolved air; when it dissolves soap without forming a scum and it perfectly cooks vegetables’ (*Traité de L’Epuration des Eaux Naturelles et Industrielles*, 1893: 95).[iii] Sensory cues delineated safe waters from dangerous waters. The authority of these ‘common senses standards,’ historian Christopher Hamlin argues with respect to British water analysis, began to crumble in the late 1700s as chemists worked to claim authority over identifying the factors that made a water healthful or harmful (Hamlin, 1990, p. 90). However, as Hamlin shows, chemical analysis was not considered superior to personal experience 'until it was accepted as contradicting verdicts based on common sense' (1990, p. 89). This proved difficult. Indeed, the 'universality of olfaction and common sense' in nineteenth century practices of evaluating the environment in the U.S. complicated scientists' efforts to establish authority over the sense-able world (Kiechle, 2017, p. 139), especially as industrialization and urbanization added increasingly sense-able amounts of pollution to city water supplies (Smith, 2013). By the late 1800s the ascendance of the germ theory of disease, made possible in part by the theatre of proof linking typhoid and cholera with the microscopic life found in petri dishes (Goubert, 1986; Latour, 1993; Liboiron, 2013; Spackman, 2015a), helped undermine historical understandings of sensory cues as reliable indicators of potability.[iv] Microbial danger did not map neatly onto traditional sensorial methodologies for identifying safety. Microscopes revealed aesthetically acceptable waters as teeming with potentially dangerous life. In shifting reliance from sensory cues to analytical techniques in the effort to determine and mitigate danger, sanitarians' and scientists' began to set themselves, and their modes of sensing, apart from that of the everyday consumer.

Despite the widely held understanding by sanitarians and many water analysts at the end of the nineteenth and into the early twentieth centuries of sensory information as an unreliable indicator of quality, sensing continued to play a distinct role in the everyday practices of managing water supplies. For example, assistant engineer to the Philadelphia Water Department, Dana C. Barber, reported on February 28, 1885, that the city's water supply could be negatively affected by 'a decided odor and taste of brewery waste' (Bureau of Water, 1898). Odors and tastes facilitated water engineers' identification of pollution sources along the Schuylkill River and its tributaries. Cities with significant fiscal reach such as Philadelphia and New York implemented sanitary patrols of their watersheds, combining sensorial information with water sampling and chemical analysis ("Sanitary Patrol of the Watershed," 1903). Despite their reliance on embodied experience, the experts—engineers, chemists, bacteriologists, operators, and superintendents, many of whom wore multiple hats—shepherding water through newly-built municipal water systems in the U.S. at the end of nineteenth and into the early twentieth century sought methods that could address the pitfalls of sensory unevenness.

No uniformly accepted guide existed for developing water analyses, despite the widespread acceptance of chemistry as the primary mode of quantifying a water's qualities by physicians and public health experts (Hamlin, 1990; Spackman, 2015a; Weisz, 2001). William Pitt Mason, an early pioneer in water sanitation efforts from Rensselaer Polytechnic Institute who had trained at the Pasteur Institute, noted in an article in *Science* that unlike methods for analyzing ore quality, water analysis, "is really not an analysis at all ... but is a series of experiments undertaken with a view to assist the judgment in determining the potability of the supply" (1893, p. 258). For Mason, lack of methodological standardization meant that 'the numerical results of a water analysis are not only unintelligible to the general public but are not always capable of interpretation by a chemist' (1896, p. 3). Mason and others argued that the lack of standardized methods threatened water workers' ability to convincingly share knowledge and results amongst themselves and with the public (see also Whipple, 1899). This failure, they posited, implicitly undermined their ability to protect public health.

The range of analytical techniques needed for water analysis further complicated efforts to know water. 'To answer this question [of safety] there is needed a knowledge wider than a chemists' of the relation of decaying organic matter and of the germ-carrying power of water to outbreaks of disease,' noted the 1896 laboratory manual, penned by Ellen Swallow Richards, a pioneer in the field of sanitary chemistry.[v] An instructor of budding sanitary chemists at MIT, Richards argued that, 'To the chemists' knowledge must be added, therefore, that of the biologist, the engineer, and the sanitarian' (1896, p. 3). In part, differing water supplies complicated efforts to distinguish safe from unsafe waters: The 'clear' waters of New England called for treatments distinct from those used for the 'muddy' waters of South and Western regions of the U.S. (Whipple, 1907). Analyzing water was tricky business, further complicated by a growing public pressure to keep drinkers safe as individuals and institutions began to embrace the idea that water quality directly influenced public and economic health.

The opening of the twentieth century saw a variety of water workers, sanitarians, and economists calculating the values and costs of water. Lack of pure water, suggested George Whipple, a civil engineer who co-founded the Harvard School of Public Health, resulted in significant financial loss to individual and community. 'It so happens that persons are most susceptible to typhoid fever near the age when their life-value is considered greatest,' he argued, calculating that the average value of life lost to 'typhoid fever due to the public water-supply' was worth $4635 (1907: 8-9, 12). Unclean water threatened not only individual well-being, it also threatened the state by threatening the economy.

Whipple, like his sanitarian, economist, and public health counterparts, called for municipalities to make publically available 'pure and wholesome water.' For Whipple, this meant water that was 'free from all poisonous substances, from infection, and even from contamination, by which is meant pollution from fecal matter' (1907: 3). He acknowledged that pure and wholesome water may also contain 'a small degree of color, turbidity, odor, dissolved salts, etc., without throwing the water outside of the definition…' but considered such contaminants as 'minor matters' to be governed by 'local standards' established through analyst's expert judgment (Whipple, 1907: 3-4). A water's 'aesthetic deficiencies' could result in the financial depreciation of a water works value, but, Whipple noted, those deficiencies remained localized to individuals' gustatory preferences. Pure and wholesome water was not necessarily water one would seek out for its taste or texture as much as it was water declared safe from the range of possible dangerous pollutants.

The definition of pure and wholesome water put forth by Whipple and reflected in early twentieth-century conversations about standardizing water treatment, and thus water quality, reflect a model of toxicity grounded in flows. Sanitarians understood water as a potential carrier, not only of poison, but also of infection and of contamination. They framed both infection and contamination as flowing towards human bodies from microbial entities. In these models, protecting public health meant preventing disease-causing organisms, invisible to the naked eye, from reaching consumers' mouths.

Obtaining pure and wholesome water in line with these increasingly accepted definitions called for reproducible methodologies that could identify chemical and biological contaminants. Those reading Whipple's work after 1907 were in luck—unlike William Pitt Mason's 1893 complaint about lack of standardization in sampling and testing, by 1905 the first version of what would become the *Standard Methods for the Examination of Waters and Sewage* had been published, giving members of the nascent water works profession (officially organized as such in 1881) access to a central guiding methodological and analytical resource for the first time.[vi] Subsequent editions would become *the* handbook guiding water workers, due in part to American Water Works Association (AWWA) involvement in producing the handbook from 1932 onward (Wolman and Pirnie, 1932), and later, due to the 'quasilegal acceptance' of the standard methods in courts (Hinman, Jr., 1955). Yet a push for methodological consistency was considered inadequate against preventing flows of harm from microbes to the public: sanitarians such as Mason and professional groups such as the American Public Health Association and the AWWA sought the implementation of a standardized, albeit adaptable, approach to treating water. After all, perceiving the dangers found in water carried specific contours: how could one 'establish an exact line of demarcation between the two extremes of safe and unsafe water,' especially in the face of 'diverse sources,' differing storage conditions, and practicality (Monfort, 1915, p. 69)?

Regulating the knowable

For those concerned with establishing the lines between safety and danger, modes of disease communication were especially vexing. Bodily parts like lips, as well as community assets such as public drinking cups, became suspect; in 1912 public drinking cups were outlawed from common carriers in favor of alternatives like disposable paper cups (Sattar, 2016), a legal move grounded in the Interstate Quarantine Act of 1893 (Larson, 1989; Sullivan, 1924). On January 22, 1913 the Secretary of the U.S. Treasury appointed a commission to examine the problem of drinking water quality on interstate common carriers. The commission, composed of bacteriologists, sanitary engineers, research laboratory directors, physicians, and members of boards of health, recommended to the U.S. Surgeon General the adoption of a bacteriological standard not based on purity, but rather one based on 'limits of permissible impurity' for drinking water supplied on boats, trains, and other common carriers ("Bacteriological Standard," 1914). Any standard developed, the commission posited, should detail the 'furthest deviation from purity considered permissible'("Bacteriological Standard," 1914). Based on the Surgeon General's recommendation, the Treasury department adopted the commission's recommendations in October 1914. Establishing the line between safe and unsafe water, the commission lamented, had proved surprisingly difficult. As a result, the commission decided to primarily focus on the category of contaminant they best understood: bacteria. Posited as 'the most dangerous of all impurities,' the commission declared that bacteria could—and should—be tested for by following their proposed protocols and the standard methods of water analysis put forth in the 1912 volume of *Standard Methods.*

The newly formed 1914 interstate regulations sought to protect both the health of citizens and the economic health of interstate carriers—and by association, the nation (Cronon, 1991)—by making possible the identification of maximum permissible limits of bacteriological contaminants.[vii] Regulating danger called for quantitative monitoring of bacterial life through laboratory practices of culturing, and estimating microbial load.[viii] These standards, when combined with the increasing adoption of standardized testing methods used in disparate water production facilities, posited bacteriological dangers as the key threat to public health.

In contrast, other contaminants, specifically those 'physical and chemical properties which render water disagreeable to sight, taste, or smell without producing any concrete harmful effect,' presented the commissioners with a notable difficulty, as '… the degree of offensiveness is not accurately measurable, being largely dependent upon individual taste and habits' ("Bacteriological Standard," 1914, p. 2963). Unlike disease-producing bacteria, which had been shown to impact public health, taste-able and smell-able contaminants had no precise, scientific way of being known. Neither odor nor turbidity could indicate to consumers or analysts the presence of bacteria that caused typhoid or cholera. After all, 'a good water may be possessed of a slight marshy odor, while one of extremely dangerous character may be limpid, tasteless, and odorless' (Mason, 1896: 356). No matter how objectionable the odors caused by the presence of common non-pathogenic microorganisms may be, 'from an aesthetic standpoint, it has not been proven that they are productive of disease' (Mason, 1896: 18). Human senses, the commission intimated, building off the work of experts like Mason, were too grounded in individual experience to prove useful in accurately measuring water's safety. Although the commission identified the ideal water as one that neither offends eyes, noses, nor mouths, they nonetheless understood—and codified for the first time—gustatory contaminants as a matter of individual taste. Lacking the ability to accurately quantify and measure gustatory contaminants, the commission declined to even suggest regulatory limits: without a means of measurement, gustatory contaminants lacked regulatory credibility.

By framing gustatory contaminants as a matter of individual taste, the commission intrinsically resituated consumer detection of most sense-able contaminants out of the realm of safety and health and into the aesthetic realm where taste is intrinsically linked to judgment. In other words, they wrote out of regulation the 'common sense' standard of knowing water. For the commission, the beautiful and good in water was undoubtedly an inoffensive water. Yet in relegating measurements of inoffensivity to the subjective world of individual experience, and in focusing on bacteriological threat as that which could be known objectively, the commission set the stage for the creation of an institutional politics of sensory knowledge grounded in modes of perception.

Poisoning the Poisoner

It is clear from early editions of *Standard Methods* that by the twentieth century that those with the power to shape production approaches largely accepted the germ theory of disease, even if the politicians and municipalities funding infrastructure improvements did not always agree. In the U.S., efforts to deal with this new knowledge led to a range of spectacular legal and political skirmishes (McGuire, 2013). Some called for a reduction in population density, especially near waterways, and stricter protection of the watershed; others argued that such proposals were at best fanciful, and encouraged the search for technological solutions such as filtration or the novel technique of applying lime of chloride to water (Johnson, 1921; McGuire, 2013).

No matter the approach, for water workers protecting public health meant preventing disease-causing organisms, a danger invisible to the naked eye, from flowing through municipal systems to consumers' mouths. Boosters of chlorine treatment touted its ability to save human lives, often citing declines in cases of typhoid fever after chlorination (Longley et al., 1915; Melosi, 2008). The cost, they noted, was significantly less than that of installing expensive filtration plants or the even less politically feasible proposal to reduce the population living in watershed regions. 'Chlorine is comparatively cheap, much cheaper than human lives,' reported L.I. Birdsall, the superintendent of Water Filtration for Minneapolis in a paper submitted to the nascent AWWA (1920, p. 384). The reasoning was simple, grounded in the flow model of toxicity: pathogenic microbes caused illness or death, chlorine killed microbes, and thus chlorine saved lives.

Despite twenty-first century readers' familiarity with the concept of chlorination, adding chloride of lime to water was contested business in the early decades of the twentieth century. First widely used in the U.S. in 1908 in Jersey City, NJ, water chlorination took up the 'revolutionary idea' of adding chlorine to the public water supply in an effort to kill bacteria (McGuire, 2013: 2). Although the initial 1908 decision to chlorinate water was done without any public or regulatory approval, and subsequently, albeit unsuccessfully, challenged in court, by 1914 over half of the population who received municipal water in the U.S. received chlorinated municipal water (McGuire, 2013: 257-258). The simple solution of poisoning the poisoner offered producers and politicians a way around the problematic of unseen contamination often linked with human activity: after all, one could measure and quantify the death rate—not just through the absence of bacteria in a sample, but also through tracking the number of deaths from endemic typhoid before and after treatment (e.g. Longley et al., 1915).

Figure 1. Death rates from typhoid (Gorman and Wolman, 1939, p. 278). Reprinted with permission.

Sensory Politics

Water drinkers did not always agree that the ensuing chlorine, which they could smell and taste in their water, was harmless. Discussion of disinfection efforts across the U.S. and Canada in 1915 highlighted the challenges water workers faced in determining the best balance between appropriate disinfection and the danger of creating objectionable tastes and odors (Longley et al., 1915). 'Chlorine has been at once the operators' great benefactor and sore trial, as he has sought to preserve public health and avoid public condemnation through its use,' two chemists from the Grand Rapids Filtration plant cautioned water workers at the annual AWWA meeting in 1921 (Sperry and Billings, 1921, p. 603). Writing in response to a proposal at the annual meeting calling for constant chlorination of public water supplies, C.A. Emerson, the chief engineer from the Pennsylvania State Department of Health, warned fellow water workers that citizens often resisted efforts to chlorinate their water supply, especially when 'some public-spirited citizen has spread the gospel that chlorine is the "same stuff the German used to poison our boys during the war"' (Johnson, 1921, p. 313). C. Arthur Brown, a sanitary engineer from Lorain, Ohio who strongly opposed the proposed measure, noted that chlorination had made his and other water worker's jobs more difficult given the tendency of the 'nauseating gas' when found in water to 'render the water so objectionable that the average user cannot drink without gagging over each glassful' (Johnson, 1921: 315). Consumers literally sensed producers' uncertainty as water workers searched to understand the optimum treatment levels. By 1949, Philadelphia's water was widely known as a 'chlorine cocktail' ("Philadelphia," 1949). Chlorination at appropriate levels may have rendered water safe from the sanitarian's viewpoint, but it did not guarantee consumer acceptance.

Despite the occasional dissenting professional voice, most water workers publishing in the AWWA's journal shared Birdsall's view that, 'a chlorine taste in the water, even though it may be unpleasant, is less harmful to the water consumers than a tasteless water that contains typhoid bacilli' (1920, p. 384).[ix] For water workers, and the professional, local, and state institutions that shaped their views, professional processes of counting bacterial load in water ultimately trumped any consumers' sensory distaste over drinking chlorinated water.

Dividing Sensory Labor into Analytic and Aesthetic Modes

Perceiving and preventing bacteriological danger was the perception that mattered most for the U.S. water workers who voiced opinions at national meetings, in journals, or through development and refinement of standardized methods for examining the material qualities of water. Despite the Treasury Department Commission's view of sensory experience as unreliable, as consumer resistance to the odors and tastes of chlorination shows, the taste and odor of municipal water *mattered*. Water workers noted with exasperation the persistent problem of consumers detecting off odors in water that water workers themselves had declared free of sensory defects or considered safe (Baylis and Gullans, 1936, p. 508).

Even more frustrating than consumers detecting things professionals had missed were the claims that off-odors were giving rise to health problems. For example, water workers in

Philadelphia noted that after severe storms the water could carry disagreeable odors or tastes that aeration and sedimentation reduced, but did not entirely eliminate. ‘Naturally,’ they concluded, ‘many complaints from the consumers are registered and all sorts of alleged disorders from its effects are reported’ (Van Loan and Tolson, 1916, p. 119). Such episodes forced water workers to determine whether consumer complaints needed to be attended to or ignored; yet the standardized methods published in early manuals offered little distinction between lay and professional modes of sensing.

What water workers desired was a measurement system that could be evenly applied across all waters, reproducible by different people in different places and at different times; in other words, they sought an objective, rather than an aesthetic, way of sensing. The unevenness of human sensory data circumscribed its use within the demands of standardized measurement systems,[x] as well as placing water workers own expert authority at risk.

Finding an analytic, reproducible way of sensing water quality proved difficult. In fact, early efforts to develop sensory methods that differed from those used by the general public largely proved ineffective due to the difficulty of communicating about sensory experience. In 1899, Whipple proposed a standardized sensory method that sought to mitigate the ‘imperfect development’ of water workers’ sense of smell. His approach was codified in the 2nd (1912) through 7th (1933) editions of *Standard Methods*, which instructed water workers to identify the intensity of an odor by assigning it a numerical value from 0 to 5, a quality term describing the strength of the odor, and an approximate definition that related the intensity of the odor with potential consumer aesthetic responses (Table 1). As an analytical tool, the methodology outlined in these editions gestured towards a desire to separate professional practices of sensing from consumer practices. However, as the approximate definitions in the evaluation guide show, consumers could be *as sensitive* as experts to the presence of a taste or odor in water, even if they failed to use the language of standardized descriptors such as ‘vegetable’ or ‘peaty’ or ‘sweetish’ (American Public Health Association, Laboratory Section, 1912, p. 12). Evaluation of the odor at both ‘cold’ (room) and ‘hot’ (~65° C) temperatures offered to partially distinguish the professional from everyday user, as long as one ignored the legions of cooks boiling water for tea or soup. Given the unevenness of sensing within both consumer and professional circles, the methodology proffered ultimately left expert analyst and inexperienced observer with results rooted in the aesthetic realm of judgment where connoisseurship, rather than scientific methodology, ruled: the water either tasted and smelled off to an individual, no matter their role as expert or lay consumer, or it didn’t.

Table 1: Odor Evaluation Guide, adapted from 2nd – 7th editions

Early water workers were deeply aware of the difficulty of managing their product’s aesthetic characteristics. In the late 1920s two chemists in the Chicago Department of Public Works began experimenting with taste and odor removal. ‘For many years odor tests were conducted by such an unreliable method they were of little value,’ the chemists reported, noting that, ‘confidence in the ability of the chemist who makes the odor tests is lessened if he states the tests show no odor in the water yet some of the users of the water detect objectionable odors’ (Baylis and Gullans, 1936, p. 507). Convinced that the odor method outlined in the *Standard Methods* proved unreliable for comparison between odor mitigation methods, they recommended that utilities adopt their modified approach to determining the Threshold Odor Number (TON). Originally proposed by Charles H. Spaulding, a water technologist at the municipal water plant in Springfield, IL, TON was posited as a ‘quantitative yardstick’ that allowed operators to move beyond the ‘opinion of the observer based on a momentary impression that cannot be recorded and referred to for comparison’ (1931). Building on Spaulding’s method, Baylis and Gullans argued that, ‘It is essential that we have a test sensitive enough to detect odor in lesser amounts than can be detected by the consumers in any use of the water’ (1936, p. 507). Unlike the methodology presented in *Standard Methods* since its first publication, the TON required odor-free water, calibrated volumetric equipment, and training in proper smelling technique. For those looking to mitigate off odors, the numbers generated by sniffing serial dilutions of questionable waters were envisioned as more easily shared and reproduced between water workers in different locations; in other words, TON offered to mitigate the weaknesses of subjective sensory experiences and solidify, through a scientific way of knowing taste and odor, the divide between water worker and consumer.

Objectively perceiving tastes and odors, like other practices of instrumental or embodied sensing, is constrained not only by the techniques available, but also by the materiality of the thing being sensed. As detailed above, waters spatially differ in their material qualities—waters carry distinctive traces of the *terroirs* they pass through, from the underground aquifer to the reservoir and the laboratory. ‘Perception,’ Michelle Murphy argues, ‘always involves disengaging from a broader field of possibilities for the sake of focusing on, isolating, and rendering intelligible a more narrowly delineated set of qualities’ (2006: 24). For water workers, reproducibly perceiving a water’s sense-able qualities potentially opened the gate to identifying the chemical compounds causing objectionable tastes and odors. More importantly, through putting in place the trappings of objective sensing, TON offered water workers sensorial authority that trumped that of consumers.

The TON methodology was quickly adopted, making its first appearance as an “alternative” method in the 8th edition (1936) of *Standard Methods*; by the 9th edition (1946) the TON completely replaced the earlier method.[xi] Although the 10th edition briefly reintroduced Whipple’s methodology, it was only as a method for assisting water workers with understanding consumer complaints, and was subsequently abandoned (*Standard Methods*, 1955, pp. 202–206). Similarly, *Standard Methods* briefly adopted a scaling method for measuring intensity, but scientists found it, like earlier sensory methods, too dependent on the ‘subjective experience of the observer’ (Rosen, 1965, p. 701). TON replaced the complex yet ultimately ineffable sensory data produced by Whipple’s method, as well as consumer complaints, with a number that simply signified when water needed additional treatment or the success of a treatment effort. Water workers’ adaption and abandonment of Whipple’s method demonstrates their search to erase their own sensory unevenness, and in doing so, facilitate communication about mitigation of organoleptic defects.

Widespread adaption of TON solidified the separation between how water workers and consumers engaged with the tastes and smells of water. Scientific noses carefully attached to glass tubing plunged into beakers (Figure 2) carried more authority than that of the user-connoisseur's nose plunged into a glass. With the adoption and standardization of TON, water workers could more fully claim the ability to analyze the sensory aspects of water as scientific experts, and thus the authority of determining when sensorial episodes threatened health.

Consumers, in contrast, continued to be conceptualized as aesthetically judging water, perhaps as connoisseurs, but never as analysts. In fact, the 1974 passage of the Safe Drinking Water Act officially categorized contaminants that affect water's aesthetic characteristics under non-enforceable Secondary Maximum Contaminant Level guidelines, leaving enforcement up to individual states. This regulatory move officially framed sense-able gustatory contaminants as aesthetic contaminants.[xii] In doing so, the regulation further deepened the difference between consumer sensorial experience and that of water workers, even as many water workers, despite the regimes of perception that have foisted on them expertise, continue to find the labor of tasting and smelling water difficult. By making the work of sensing scientific, water workers rendered secondary the everyday 'sensory labor'—drawing on geographer Kathleen Stewart's (2011) turn of phrase—of looking at, smelling, and tasting water before drinking, and in doing so weakened consumers power to spur effective political action.

Figure 2: Apparatus for scientific smelling (Baylis and Gullans, 1936, p. 509). Reprinted with permission.

TON, and its more recent replacement, Flavor Profile Analysis—adapted in the early 1980s from the food industry, which itself had since the mid-1940s sought to replace connoisseurship with expert judgment (Lahne and Spackman, 2018)—furthered the gap between scientific analysis of aesthetic contaminants from consumer judgment by increasing the ability of water workers to find and eliminate the causes of undesirable tastes and odors (e.g. Bartels et al., 1986; Bruchet, 1999; Suffet et al., 1988). They did this through the creation of a shared technical language that finally linked expert sensory identification of off-odors and flavors with instrumental identification of the molecular causes of sense-able contaminants (Mallevialle and Suffet, 1987; Spackman, 2015a). In doing so, water workers sought to harness human senses in identifying the volatile chemicals, inorganic chemicals, and microbiological causes that affect water's taste and odor with the goal of then replacing human senses with standardized chemical and biological measurement methods.

Consumer Complaints in a Post-Miasmatic World

The complex and aging infrastructures of contemporary municipal systems offer multiple points where failure could occur. Customer complaints offer water producers a real-time, continuous information stream regarding the state of the water system (Burlingame and Mackey, 2007). As such, consumers are informally invited into practices of managing water quality. In fact, some utilities have included select groups of citizens in their scientific research, seeking to train citizens in analytical sensory techniques. This citizen science follows the U.S. Environmental Protection Agency's goal of improving public understanding of the environment. However, even these efforts reflect twentieth-century sensory politics by simply making small groups of citizens into experts who use similar techniques to water workers rather than drawing from everyday consumers' common sense perspectives to make judgments that provide additional, valuable information.

Even as customer complaints help water workers track problems in municipal systems, they continue to be differentiated from water worker practices of sensing. The view expressed in 1933 that, 'study of [complaint] records, showing the dates and times on which the complaints arose, the location, etc., often assists in the elucidation of the cause,' continues to be the foundation for current approaches to dealing with complaints (Thresh et al., 1933, p. 140). In fact, forward-thinking water utilities with adequate resources now consider these calls as work-orders demanding logging, investigation, and action through GIS tracking and statistical analysis (Dietrich et al., 2014). These institutional practices, which nonetheless continue to act within the regimes of perception developed during the twentieth century, allow consumer complaints to enter into the process of policing water quality, but only once they appear as part of an aggregate data stream. Yet even this approach, which requires significant investment and training of workers, fails to account not only for individual experiences of sensing, it also ignores new modes of complaint such as social media that suppliers have only recently begun to monitor.[xiii] These practices claim that only in combining consumer complaints can the unevenness of sensing be effaced. Although these techniques certainly have offered to rebuild bridges between utilities and consumers, they nonetheless contain blind spots endowed by their legacy of sensory politics.

Water workers' acceptance of aesthetic complaints as valid, actionable, warning systems is complicated by cases when populations fell ill after officials acquiesce to demands to not chlorinate water (Turgeon et al., 2004), or when customers reject analytically potable water due to aesthetic rather than health concerns (Farrimond et al., 1994). This is further complicated by the continued lack of concrete, quantifiable connections between disagreeable smells and bodily danger. As the AWWA's Water Quality Division Taste and Odor Committee reminded readers, 'Tap water taste and odor can be affected by a wide variety of chemical compounds that may appear without warning and often have no known health effects' (2002, p. 81). At the same time, current regimes of perception for determining toxicity struggle to account for analytically undetectable yet physiologically sense-able contaminants such as the crude MCHM found in Charleston, WV's water supply in 2014 (Spackman, 2015b). The unevenness of sensing thus extends in multiple directions: humans and instruments unevenly sense.

At times, complaints over aesthetic failures in municipal water do have the power to shape production practices. For example, continuing consumer dissatisfaction with off-odors in the water supply in Charleston, W.V. weeks after the 2015 chemical spill eventually resulted in political action when the governor funded a research program to analytically characterize consumers' aesthetic experiences (Spackman, 2015a). In contrast, customer complaints about off-odors, colors, and tastes in the water in Flint, MI in 2015 appear, based on news reports, to have been categorized as simply aesthetic. This categorization rendered their complaints insignificant until physicians and researchers using analytical methods highlighted the presence of non-sensible lead, revealing extensive degradation of the municipal system (Egan, 2015; Hanna-Attisha et al., 2016). Consumer's aesthetic experiences, while considered unreliable for the toxicity of water, can nonetheless trigger public outrage, economic loss, and break trust not only in water providers, but also in regulatory structures and the political process—potentially much slower disasters. Although the root of these and many other drinking water disasters lies in the decay caused by late industrialism, the failure to value consumer's aesthetic knowledge compounds the problem. As these disasters highlight, water utilities, regulators, and politicians may discount aesthetic concerns until consumer complaints and news coverage reach a tipping point where further inaction threatens civic stability.

Conclusion

As government officials and sanitarians in the early twentieth century came to understand microbiological contamination of the water supply as the ultimate danger to public health, they wrote out traditional sensorial modes for determining potability from the analytical procedures and regulatory practices governing municipal water production. The implementation of techniques such as chlorination, statistical tracking of disease, and the development of standardized methods for testing drinking water, shaped the development of a new regime of perception for understanding safety and danger in municipal water production. Through technological intervention rooted in scientific practices of measurement, water workers became experts designated by their cities and states as the entities tasked with controlling the making of safe water.

Along with the regimes of perception focused on protecting public health came new regimes of imperception. The newfound ability to demonstrably improve health outcomes via chlorination clashed with consumer's distrust of the smell of chlorine. This discord between water workers' and consumers' understandings coupled with the inability to quantify and measure gustatory contaminants in a scientifically robust manner before the 1930s, as revealed in *Standard Methods* and early regulatory efforts, show that regulators and water workers began to frame sensory experiences as aesthetic. Once conceptualized as aesthetic, flavors and odors became largely a matter of individual taste rather than scientific judgment, and as such were written out of early regulations of water quality. The development of expert, standardized methods of sensing such as TON in the 1930s, that significantly differed from how the lay population sensed, further divided the potency of sensory labor. Scientific sensory labor, performed first by coupling a nose with specialized glassware, and then later by coupling the scientist with a cohort of flavor panelists and analytical instruments, became the primary method of defining and knowing a water's quality and establishing maximum permissible limits. In contrast lay sensory labor, performed in the everyday act of turning on a tap or drinking out of a glass became officially codified (at least on a national scale) as secondary by the 1974 classification of aesthetic contaminants under the SCMLs.[xiv] Thus, although water workers and consumers equally use their bodies in evaluating the sensory qualities of water, twentieth-century regulations restricted consumer practices of sensing from the networks of power that spur action. In contrast, when compiled, consumer complaints re-enter the realm of political activity: as composite instead of individual taste-judgment experiences, complaints become credible and enter into the regime of perceptibility. They can be analyzed, quantified, compared, shared, and used to argue for institutional and regulatory changes. Flavors and odors, detected by consumers, became less perceptible through regulation.[xv]

In a system where the stated goal of regulators and professionals is no *significant* health risk, consumers' sensory aesthetic knowledge remains circumscribed in its ability to act. It is accepted as a sentinel indicating problems. But it does not demand action the way that analytical measurements have for most of the twentieth century. However, laboratory tests can make general process checks but *cannot* provide complete coverage of an entire system. Contamination and illness still occur. The human body, and unfortunately, its hospitalization, mark instances of toxicity in ways that even the most robust of testing programs cannot. The unevenness of sensing thus extends in multiple directions: humans and instruments unevenly sense. Political practice that acknowledges this reality will, instead of dividing sensory knowledge about toxicity into categories of objective vs. aesthetic, try to engage the human body and its sensory knowledge in regulatory efforts to monitor and protect the environment.

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[i] We are indebted to Liboiron (2012, pp. 112–124) for alerting us to Murphy's work on regimes of perception and the analytical possibilities opened up through this framing.
[ii] Although we parallel Masco's (2004, p. 356) argument that 'mechanical measurement has displaced embodied experience,' our mobilization of sensory politics rather focuses on how such practices of measurement and definition exclude embodied experience from political action.
[iii] Definitions based off of the French definition appear in U.S. publications such as Hinman (1920, 823).
[iv] However, as Snowden (1995) shows with regards to early twentieth-century cholera epidemics in Naples, the equation between bacteria and danger was not always straightforward, especially when mixed with politics.
[v] Richards was the first woman educated at MIT, and worked there until her death. Despite her extensive work in sanitary engineering, she is more commonly remembered as the progenitor of home economics.
[vi] The first edition, published as "Report of Committee on Standard Methods of Water Analysis to the Laboratory Section of the American Public Health Association," was presented in 1905 at the Havana meeting, and then printed in the *Journal of Infectious Diseases Supplement* 1 (May 1905).
[vii] Until the 1970s such regulations on public health and the environment were largely considered a state matter; as such the federal government limited its regulatory powers to federal jurisdiction.
[viii] This resulted in an intensive project of certification bringing together the Public Health Service and state workers; by 1923 railroad companies were reported to have requested certification of 3,129 water supplies (Sullivan, 1924, p. 1624).
[ix] Melosi (2008, p. 95) notes that an operator in Milwaukee in 1916 shut off the chlorine one evening due to complaints, a step that was reported to cause '50,000 to 60,000 cases of gastroenteritis and between 400 and 500 cases of typhoid resulting in forty to fifty deaths.'
[x] We are indebted here to Daston and Galison's (2010) arguments.
[xi] For a historical overview of odor analysis, see chapter one in Dietrich et al. (2004).
[xii] It is worth nothing that in recognizing disinfection by-products from chlorine as potentially hazardous to human health, and thus limiting the level of chlorine used during water treatment, the Safe Drinking Water Act inadvertently reduced levels of aesthetic contaminants produced by chlorination. However, the regulation continues to frame aesthetic concerns as secondary.
[xiii] The 2006 Community Water System Survey by the EPA reported that 82% of water systems serve 3,300 or fewer people. AWWA conversations about social media in the journal primarily

focus on using social media for outreach, rather than as a core method of tracking consumer complaints.

[xiv] Regulations vary by state, so some states more thoroughly police aesthetic contaminants than others.

[xv] Water workers have an ongoing discussion examining ways to gather more actionable information from consumers, such as in providing them with a list of sensory terms to use in reporting off flavors (e.g. Burlingame et al., 2017).