ARTICLE CASE

Risk, Uncertainty, and Institutional Failure in the 2014 West Virginia Chemical Spill

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ABSTRACT On January 9, 2014, 4-methylcyclohexanemethanol (MCHM), a chemical used to process coal, spilled into West Virginia's Elk River and contaminated the drinking water of over 300,000 people. In the following weeks, the public uncovered a series of institutional failures—among the private sector, local utilities, and government agencies—preceding and following the spill. This case study introduces students to the institutional complexities and ecological vulnerabilities that slowed and confounded response to the disaster due to an unclear chain of responsibility across sectors. This case study also assesses how West Virginia residents and agencies perceived the environmental risk and the responsibility of different institutional agencies and how these perceptions added to the complexity and uncertainty surrounding response to the spill. This case study aims to teach students how risk assessment and perception interact with environmental governance.

KEY MESSAGE

Through West Virginia's 2014 MCHM chemical spill, students will learn about the complexities engaged in managing and assessing environmental hazards. Students will gain an understanding of the roles of empirical data, extrapolation, and uncertainty in risk assessments, and the factors influencing the public's risk perception and response. Students will also learn about the interactions between different environmental laws and regulations in maintaining and enforcing water quality and hazardous chemical safety, and potential vulnerabilities in the interactions between private sectors and government agencies.

INTRODUCTION

On January 9, 2014, approximately 10,000 gallons of crude 4-methylcyclohexanemethanol (MCHM), a chemical used to process coal, spilled into West Virginia's (WV) Elk River. The spill came from a storage facility owned by Freedom Industries. Nearby residents noticed a strange smell at 7:30am, but no one at the water treatment plant reported the leak until 10:30am. WV Department of Environmental Protection (WVDEP) inspectors arrived after 11am, after receiving two separate odor complaints from residents; WVDEP officials reported that there were "no spill containment measures" before the inspectors came on-site. However, later that day, Freedom Industries claimed that they had contained the spill and removed the remaining MHCM in the tank [1].[1] Figure 1 shows an overview of the spill site.

The Elk River was the only source of water for a drinking water system serving nine counties in WV including Charleston, the state capital. Figure 2 maps the location of the spill and the affected counties. At 5:30pm on the day of the spill, WV Governor Earl Ray Tomblin declared a state of emergency, and over 300,000 people and businesses throughout the service area were ordered to not

1. For a comprehensive timeline of the spill, see the online supplement for Ref. [2].

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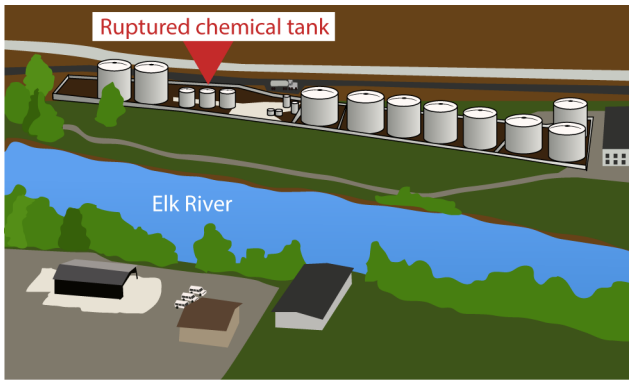

FIGURE 1. A diagram of the Freedom Industries site. Note the proximity of the storage tanks to the Elk River.

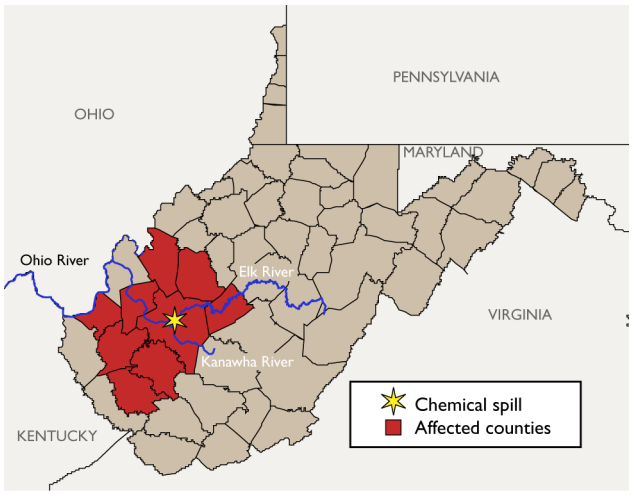

FIGURE 2. West Virginia counties affected by the MCHM spill. The star indicates the location of the Freedom Industries site.

use their tap water for more than flushing the toilet [2]. According to WV Department of Health and Human Resources, symptoms of exposure to MCHM included "severe burning in throat, severe eye irritation, nonstop vomiting, trouble breathing, or severe skin irritation such as skin blistering" [3].

The following day, West Virginia American Water (WVAW), the private water utility supplying the region's water held a press conference and conceded that they had little knowledge about the health effects of MCHM. This uncertainty would compound, and in the following weeks, it became clear that little was known about the chemical, its sources, and its potential health and environmental impacts.

CASE EXAMINATION

What Was in the Water, and Where Was It Coming From?

In the early days of the spill, it became clear that responsible parties—Freedom Industries, WVAW, and WVDEP—were not sure precisely what was leaking into the water and how dangerous it was. First, crude MCHM has six component chemicals. Only the main component (4-MCHM) had been safety tested for workplace exposure, and therefore, a lack of evidence made it unclear whether it posed the greatest health concern of the six components. Second, on January 21, Freedom Industries admitted to the concurrent leakage of a second chemical, PPh glycol ether. Freedom Industries deemed this chemical "proprietary," allowing them to restrict information about its nature. The Center for Disease Control (CDC) noted that information on both chemicals was "very limited." According to internal emails, Freedom Industries had known about the PPh spill from the outset. Finally, on January 29, an environmental scientist from Marshall University found the known carcinogen formaldehyde in the water [4].

An additional complication was that MCHM appeared to persist in the water system much longer than anyone anticipated. The drinking ban was lifted on January 18, nine days after the spill occurred [2]. However, hospital admissions increased as soon as people began using the water again [4]. And over a month after the spill, several schools in the area remained closed because of the persistent MCHM smell, even though the chemical was not detected via water sampling [2].

Because of the persistent health impacts and smell, residents questioned the monitoring strategy of regulators and WVAW, and wondered if they were missing MCHM trapped in residents' water heaters, plumbing, filters inside their homes, in neighbors' vacant homes, in WVAW's storage facilities, or in other places throughout the distribution system. In response to these and other concerns, on February 10, 2014, the State of West Virginia announced that they would provide funding to an independent academic research team to conduct water quality testing inside people's homes. Although the study found MCHM in every home sampled, none were above the study's recommended screening level, 10 parts per billion (ppb) [5].

So where was the persistent MCHM coming from, since the initial spill was stopped within a day? One potential source was the WVAW treatment plant, which was not designed to remove chemicals like MCHM.

Water treatment plants consist of several different processes that include coagulation, sedimentation, filtration, disinfection, and storage. Independent water quality sampling in March 2014 found low concentrations of MCHM in the outflow from the water treatment plant on days when there was no detectable MCHM at the intake [6], suggesting that the water treatment plant was a source of MCHM. The filters, which had processed large amounts of MCHM following the spill, had not yet been replaced and were likely releasing trace amounts of the chemical into the system.

What Is a Safe Level of Chemical Exposure?

An additional difficulty was determining the safe level of exposure to crude MCHM. At the time of the spill, the nature and effects of MCHM were not well studied because the chemical was grandfathered in when the Toxic Substances Control Act (TSCA) was created in 1976. MCHM is one of approximately 84,000 chemicals exempted in this manner. For these chemicals, no safety data are required for their production or use unless serious adverse effects are conclusively indicated. Under this status quo, risk assessments for these TSCA-grandfathered chemicals are most often made in response to spills and other damaging events, rather than prior to them, hamstringing the ability to respond quickly and appropriately to minimize their impacts.

In addition to not being regulated by TSCA, there was no safe drinking water standard in place for MCHM. Although the Safe Drinking Water Act authorizes the U.S. Environmental Protection Agency (EPA) to set national drinking water standards to protect public health, MCHM is not among the approximately 90 contaminants regulated. Because MCHM was not regulated, there were also no standard methods in place for measuring MCHM in water or for understanding health effects of consuming MCHM-contaminated water. Following the spill, WVAW stated that they were meeting all state and federal drinking water standards. This was true only because there was no drinking water standard for MCHM.

The lone preexisting study on MCHM's safety was conducted on rats in 1990 by Eastman Chemical Company, the chemical's producer (detailed in Ref. [7]). They calculated the median lethal dose ($LD50$)[2] of MCHM by feeding it to rats until 50% of them died in a short time period (usually 24 h). The $LD50$ for rats was reported at 825 parts per million (ppm).

Following the spill, the CDC issued an emergency advisory level of 1 ppm for MCHM based on very limited data. On January 14, 2014, WVAW started announcing that sections of their service area where "water is safe" according to the 1 ppm advisory level developed by CDC. Yet, some, including Environmental Defense Fund's Senior Scientist Richard Denison, questioned the CDC's methods [7].

The CDC used these general rules of thumb. Because humans may be more sensitive than rats, a 10-fold "interspecies extrapolation" uncertainty factor reduced the $LD50$ to 82.5 ppm. Further, because individuals differ in their sensitivity (e.g., the young and elderly, pregnant women), another 10-fold reduction for "intraspecies extrapolation" was applied, reducing the $LD50$ to 8.25 ppm. A third uncertainty factor was applied because the chemical would likely have adverse effects short of lethality; this was 8.25 times, to bring the safe level to 1 ppm. Yet, according to Denison, this final multiplier was not justified methodologically in press reports of state and federal officials' details on the calculations used. Denison argued that this multiplier is likely an underestimation when extrapolating from lethal to nonlethal effects and is an argument for greater transparency in the process to derive risk assessments [7]. The CDC defended the 1 ppm standard even when a more recent expert panel recommends 120 ppb (8 times lower) [8].

Finally, on January 20, after the drinking water ban was lifted, WV Governor Earl Ray Tomblin was asked in a press conference "Should we be drinking the water?" by a local resident. He responded: "*It's your decision*. If you do not feel comfortable drinking or cooking with this water then use bottled water. I'm not going to say absolutely, 100 percent that everything is safe. But what I can say is if you do not feel comfortable, don't use it" [2,9, emphasis added].

Who Was Responsible for Providing Safe Drinking Water, and What Went Wrong?

The final challenge in responding quickly to the spill and preventing future spills is that multiple organizations held some responsibilities for the accident, but no single organization was entirely responsible.

2. The standard practice is to use No Observable Adverse Event Levels (NOAEL), a much more stringent test than $LD50$.

Freedom Industries is the company that was storing the crude MCHM and spilled over 10,000 gallons into the Elk River. They were responsible for numerous safety lapses that led to this incident, including a slow response time to the initial spill, not disclosing for almost 12 days that a second chemical had leaked, and moving the stored chemicals to an unsafe secondary site. However, because the Freedom Industries site was for chemical storage, not for chemical processing or use, it had less stringent requirements for reporting about chemicals and safety. Because MCHM was not supposed to get into the drinking water, the available Materials Safety Data Sheets (MSDS) detailed safety concerns for worker exposure rather than drinking water; first aid guidance for ingestion was "not relevant, due to the form of the product" [10].

Moreover, because the Freedom Industries site was for chemical storage and not for chemical discharge, the Clean Water Act requires only a storm water permit and not a discharge permit for the site. Without a discharge permit, there were no discharge permit limits for MCHM at the Freedom Industries site. Under the storm water permit, Freedom Industries was required to develop Best Management Practices to prevent storm water runoff and to avoid violating applicable water quality standards. Although there was no statewide in-stream water quality standard in place for crude MCHM (and thus no permit violation), the spill still violated narrative standards regarding odor and toxicity [11]. Moreover, the permit required that spills be reported immediately, but Freedom Industries did not report the spill to WVDEP until 4 h after the first odor complaint was filed. The spill was not reported to the U.S. Coast Guard's National Response Center, which catalogues oil and HAZMAT spills nationwide, until 7:42pm.

WVDEP is responsible for issuing and enforcing Clean Water Act permits. They are required to inspect "major" facilities annually, but have discretion over how frequently they inspect smaller sites like Freedom Industries. Evidence suggests that WVDEP conducted irregular, unsystematic inspections. No routine inspections were conducted at the Freedom Industries site since 1991 [11,12]. During that time, there were several short inspections in response to public complaints about odors, but no violations were reported. As reported on a 2010 site visit, the head of the WVDEP said, "We went out on site and didn't find anything that would cause concern, no leaks or anything like that" [12]. Moreover, most of these impromptu inspections focused on air quality, rather than water.

WVAW was the private water utility in charge of damage control when their water supply became tainted with crude MCHM. The Safe Water Drinking Act requires states to undertake source water assessments, which involve "delineating (or mapping) the source water protection areas; conducting an inventory of potential sources of contamination in those areas; determining the susceptibility of public water systems to those contamination sources; [and] releasing the results of the determinations to the public" [13]. Many states, including WV, delegate this responsibility to individual water providers. WVAW completed their source water assessment and protection report in 2002. The report found the system to be highly susceptible to contamination, but the Freedom Industries site was not among those listed as a potential contamination source [14].

Finally, under the Emergency Planning and Community Right to Know Act, Freedom Industries was required to file a "hazardous chemical inventory form" with the state emergency response commission, local emergency planning committees, and local fire department. Although Freedom Industries had filed its report in February 2013, it was unclear whether WVAW had received a copy prior to the spill [14]. Moreover, although the local Kanawha–Putman emergency planning committee met monthly, no one from WVAW was on its board [15].

Underlying this discussion of responsibility is that many laws regulating each organization individually and jointly failed to prevent the spill and the uncertainty it created. These laws are summarized in Table 1. Despite having multiple laws to prevent spills, plan for hazards, and protect drinking water, institutional failures meant thousands of people were left without safe drinking water.

How Has West Virginia Responded to the Spill?

Since the spill, there were a few reform efforts to prevent a similar spill from happening again.

- The state passed a bill on March 8, 2014, that improves the inventory of chemical storage tanks and requires large water utilities that rely on surface water to create source water protection plans [2]. However, the bill was rolled back substantially in March 2015 [16].

TABLE 1. Environmental governance failures.

Environmental law	Institutional failure that resulted in WV chemical spill
Toxic Substances Control Act	• MCHM not regulated under TSCA (grandfathered), little information on health risk available
Safe Drinking Water Act	• No drinking water standard for MCHM • Freedom Industries site not included in inventory for source water assessment
Clean Water Act	• Freedom Industries site was for chemical storage, only storm water permit required (so no permit limits for MCHM) • No routine inspections conducted by WVDEP
Emergency Planning and Community Right to Know Act	• Unclear if WVAW had a copy of Freedom Industries' hazardous waste chemical inventory report prior to spill • WVAW had not completed a risk assessment for MCHM prior to spill • Local emergency planning committee meets monthly, but WVAW was not included

- At the federal level, bills were introduced by WV politicians in both the Senate and the House in response to the spill; these gained limited traction. Health advocates also pushed, without success, for the passage of the Safe Chemicals Act of 2013 to reform the 1976 Toxic Substance Control Act.
- At the local level, a citizen action group called Advocates for a Safe Water System (now called Our Water) formed in response to the spill. Their action resulted in a settlement in which WV American Water committed to numerous water system improvements [17]. They continue to advocate for public ownership of the WVAW water system.

CONCLUSION

While the MCHM spill is unique in its particulars, its implications for drinking water management are far reaching, extending across geographic boundaries and chemical compositions. Thousands of potential contaminants are unregulated, including the 84,000 grandfathered in under TSCA and numerous new compounds coming into use as technologies develop. Drinking water quality standards for these compounds often do not exist either. Without regulation, companies have little incentive to research health and environmental impacts, so when a spill happens, both the responsible parties and the public lack guidance on what is safe and how to respond effectively.

CASE STUDY QUESTIONS

1. If you lived in West Virginia in February 2014 (a month after the spill), would you drink the water or serve it to your family members? What information would you draw on to make your decision? Now, step into the shoes of the water provider. Would you tell your customers that the water is safe to drink? Why? If your answers changed, why do you have a different safety threshold as an individual versus as a water provider? Would you have a different safety threshold for yourself than for a child under your care?

2. The case discusses several laws that were designed to prevent a chemical spill and/or reduce impacts to human health, including the Toxic Substances Control Act, the Clean Water Act, the Safe Drinking Water Act, and the Emergency Planning and

Community Right to Know Act. Why did these laws—individually and as a group—fail to prevent the disaster?

3. Imagine that you have been hired to direct a special task force that seeks to ensure that this type of accident never happens again. You have been asked to recommend a series of technical and regulatory reforms and discuss how those reforms would have helped prevent the Elk River spill or lessen its consequences. What would you recommend to reform the regulation or implementation of regulations? Why? Of the reforms you recommended, which do you think are reasonable precautionary steps? Why? In the absence of a severe disaster, how would you justify the costs?

AUTHOR CONTRIBUTIONS

Conceptualization	HAL, NS, NU
Methodology	HAL, NS, NU
Validation	HAL, NS, NU
Formal analysis	HAL, NS, NU
Investigation	HAL, NS, NU
Resources	HAL, NS, NU
Data curation	HAL, NS, NU
Writing—Original draft	HAL, NS, NU
Writing—Reviewing and editing	HAL, NS, NU
Visualization	HAL, NS, NU
Supervision	HAL, NS, NU
Project administration	HAL, NS, NU
Funding acquisition	HAL, NS, NU

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COMPETING INTERESTS

The authors have declared that no competing interests exist.

SUPPORTING INFORMATION

Slides: Risk, uncertainty, and institutional failure in the 2014 West Virginia chemical spill. Slides for use in a classroom setting. PDF.

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