Risk Perception and Institutional Complexity in the 2014 West Virginia Chemical Spill

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Summary
On January 9th, 2014, the chemical MCHM (4-Methylcyclohexanemethanol) spilled into West Virginia's Elk River and contaminated the drinking water of over 300,000 people. In the weeks that followed, the public uncovered a series of institutional failures--among the private sector, local utilities, and government agencies, and both preceding and following the spill. This case study will introduce students to the institutional complexities and ecological vulnerabilities that slowed effective response to the disaster due to an unclear chain of responsibility across sectors. The case also assesses how West Virginia residents and agencies perceived environmental risk severity and the responsibility of different institutional actors, and how these perceptions added to the complexity and uncertainty surrounding response to the spill. This case aims to teach students about different theories of risk perception and environmental governance. It also provides a basic introduction to water quality data, monitoring, drinking water systems, and source water protection. The course's main modules will take approximately 3 class periods of 1.5 hours each. We also provide optional modules on environmental risk perception, which will grant several more class periods' worth of material.

Topical Areas
Environmental governance, Water resources management, Environmental decision-making and risk perception

Proposed Educational Level
Upper level undergraduates and graduates, from environmental studies/sciences and environmental engineering.

Type/Approach
This case uses a discussion-based approach.

SES Learning Goals

1. Understand the structure and behavior of socio-environmental systems. (*Relates to learning outcomes 1, 4, 5, 10, 12, 14)*
2. Consider the importance of scale and context in addressing socio-environmental problems. (*Relates to learning outcomes 2, 5, 11, 15)*
3. Co-develop research questions and conceptual models in inter- or trans-disciplinary teams. (*Relates to learning outcomes 7, 8, 9)*
4. Find, analyze, and synthesize existing data, ideas (e.g., frameworks or models), or methods. (*Relates to learning outcomes 4, 6, 13, 15)*

Student Learning Outcomes

Overall
After completing this case, students will be able to

1. Understand the hydrological, social, political, and technical systems surrounding the West Virginia chemical spill.
2. Articulate the effect of temporal scale on the framing of the problem and its solution.
3. Articulate multiple causes of the chemical spill.
4. Evaluate available sources of evidence to explore the social, political, and technical dimensions of evaluating safe drinking water.
5. Articulate the social and environmental vulnerabilities in a drinking water management system.
6. Persuasively communicate a stance on the management of drinking water.

Risk Assessment and Perception
After completing this case, students will be able to

7. Understand the influence of subjective judgment calls on risk assessment measures.
8. Understand the influence of institutional complexity in facilitating “normal accidents.”
9. Understand tensions between layperson versus expert ways of knowing in environmental issues.

Institutional Governance
After completing this case, students will be able to

10. Identify key laws, agencies, and stakeholder groups (1) responsible for and (2) affected by the spill.
11. Discuss the pros and cons of managing at different geographic and political scales, and understand the rationales for and limitations of decentralization.

Water Quality
After completing this case, students will be able to

12. Identify potential sources and sinks of pollutants in a drinking water distribution system.
13. Understand the importance (and limitations) of analytical water quality monitoring techniques.
14. Recognize that drinking water quality depends on a complex socio-environmental system.
15. Evaluate potential solutions to lessen uncertainties related to the safety of drinking water (such as monitoring improvements, source water protection, distribution system leak repair, and secondary/backup drinking water sources).

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INTRODUCTION

This case evaluates the causes and consequences of the January 2014 MCHM spill in West Virginia's Elk River. The case material is divided into three "Classes," which are designed to fit a 1.5 hour session.

Class One introduces students to the spill and to the various ways different actors calculated and perceived the risks associated with drinking the contaminated water.

Class Two delves into the legal and regulatory frameworks that were in place to prevent spills from happening, and asks students to consider why this framework was not effective at controlling the West Virginia spill.

Class Three discusses the continued uncertainty of the spill's causes and consequences, considers potential contaminant sources, and synthesizes the overall political, environmental, and social aspects of the spill.

Additionally, several **optional Risk Perception modules** are provided for instructors who wish to delve more deeply into the risk-related implications of the case: how risks are assessed by the public and private sectors, tensions between communities and experts, and how individuals interpret and respond to risk data.

While relevant background material is provided throughout the class descriptions, instructors can find **additional information** at the following websites:

Denison, R. (2014, January 13). West Virginia officials trust shaky science in rush to restore water service: One-part-per-million "safe" threshold has questionable basis. Retrieved from http://blogs.edf.org/health/2014/01/13/west-virginia-officials-trust-shaky-science-in-rush-to-restore-water-service-one-part-per-million-safe-threshold-has-questionable-basis/?s_src=ggad&s_subsrc=wvh2o&gclid=CJ2Qvo7p07wCFc1hfgodEj4Ayg

Drajem, M. (2014, February 13). West Virginia Chemical Spill Spurs Long-Term Health Study. Retrieved from http://www.bloomberg.com/news/2014-02-13/west-virginia-chemical-spill-prompts-review-of-longterm-exposure.html

Ginty, M. M. (2014, June 4). Why the West Virginia Spill Wasn't a Freak Occurrence. Retrieved from http://billmoyers.com/2014/06/04/why-the-west-virginia-spill-wasnt-a-freak-occurrence

Sass, J. (2014, January 19). WV Chemical Spill of MCHM - doing the math on drinking water safety | Jennifer Sass's Blog | Switchboard, from NRDC. Retrieved from http://switchboard.nrdc.org/blogs/jsass/doing_the_math_on_the_west_vir.html

Walsh, B. (2014, January 14). Officials Don't Really Know How Dangerous the Chemical Spilled in West Virginia Is. *Time*. Retrieved from http://science.time.com/2014/01/14/how-dangerous-is-chemical-spilled-in-west-virginia

CLASSROOM MANAGEMENT

Class One Teaching Notes

Summary

Day One introduces students to the particulars of the chemical spill—what happened and who the actors were—and highlights how risks were handled throughout the event.

Schedule overview

Approximate time: Parts 1-4, ~45 minutes; Parts 5-6, ~45 minutes

1. Setting the stage: the immediate spill
2. Lecture to introduce the actors
3. Students discuss the perception of water safety (Think Pair Share)
4. Students create concept maps, showing the part each actor played in the spill
5. Lecture/discussion elaborating a timeline through the first 2 weeks
6. Discussion of risk assessment
    a. Grandfathering of risks by Toxic Substances Control Act
    b. How risk of MCHM was evaluated
7. *Optional risk modules (require between 30 min and 5 hours of extra class time, depending on desire to explore risk perception issues; these would add extra days to the course)*
    a. *Alternatives assessment and the Precautionary Principle*
    b. *Informational asymmetry, trust, and experts*
    c. *Probabilistic versus ambiguous risks*
8. Homework: Students revisit concept maps, now including "failure points" where measures were insufficient and/or prone to failure

Introduction

Introduce the students to the spill, using either of the following stories.

Story/Hook Option 1

A journalistic overview of the spill

(Source: Ginty, M. M. (2014, June 4). Why the West Virginia Spill Wasn't a Freak Occurrence. Retrieved from http://billmoyers.com/2014/06/04/why-the-west-virginia-spill-wasnt-a-freak-occurrence)

"MCHM seeped into Charleston's water supply [on January 9, 2014] in the depths of a long, bleak winter. Along the banks of the frozen Elk River, at the Freedom Industries facility on the northeast side of town, stood a 76-year-old storage tank with a cracked containment wall that had been slated for repairs since some time in 2013. Two holes in the tank began releasing a trickle of mining chemicals. These toxins oozed into the ground and eventually into the river, flowing a mile-and-a-half south toward the largest water treatment plant in West Virginia and tainting the water supply of 300,000 Charleston residents. The spill contained not just MCHM, but also PPH (odorless polyglycol ethers, solvents that reduce other chemicals' viscosity, that accounted for 5 percent of the leak by volume…)

"Those of us living nearby smelled the leak for days before authorities found it," says Kevin Kidd, a local musician. "It smelled like a Jäger bomb — a cocktail of Jägermeister and beer or Red Bull energy drink. It was a sickly, awful licorice smell. And it was powerful." Responding to residents' complaints, state inspectors drove out to Freedom Industries around 11 a.m. on Thursday, January 9. An hour later, facility employees called a hotline to officially report the leak. But it wasn't until 6 p.m. that West Virginia Gov. Earl Ray Tomblin, a Democrat, announced a local ban on the use of tap water for drinking, cooking and bathing.

The next day, President Barack Obama declared a federal state of emergency. National Guard troops sped into Charleston bearing bottled water by the truckload. Authorities shut down local schools, businesses and restaurants. The FBI launched a criminal investigation. And more than 4,000 calls from Charleston residents started flooding the lines of the Kanawha-Charleston Board of Health.

Glued to their televisions, radios and laptops, affected locals listened, watched and worried as recovery took a few steps forward, then just as many steps back."

Story/Hook Option 2

Written by a local resident affect by the spill

On January 9, 2014, the governor of West Virginia declared a state of emergency and issued a "do not use" notice to residents of across a nine county area. As residents watched the evening news, they were told not to use their tap water for drinking, cooking, washing, or bathing. Fumes of toxic licorice hung in the air in Charleston as restaurants closed before dinnertime, bottled water supplies ran out, some residents left to stay with relatives in unaffected areas, and hundreds began asking questions on social media. Local news sources revealed the culprit – MCHM – a chemical used in the coal cleaning process. The chemical leaked from a storage facility into the Elk River less than one mile upstream of the drinking water intake for the regional drinking water system. My Facebook account lit up with speculation about this chemical and its potential risks. What is MCHM? How dangerous is it? Why can we not even wash our clothes in it? Who is responsible? Are my children going to be okay? One of the WV senators called for a full investigation from the Chemical Safety Review board, the Center for Disease Control, and others. As speculation on social media persisted, I asked myself – would this chemical spill have long-term consequences for the health of local residents or government policy related to drinking water? Or would we awake the morning of January 10, 2014 to find that the smell had gone away and be told the chemical was not toxic and we could safely drink our water again. The interesting part of this case study to me is that there is still so much that is unresolved about this case and also the long-term safety of drinking water in the United States.

The Actors

Next, briefly introduce students to the key players in the spill. For reference on both the introduction and the key actors, see either the "Timeline" provided or the comprehensive one found at:

Kroh, K. (2014, February 9). The Complete Guide To Everything That's Happened Since The Massive Chemical Spill In West Virginia. Retrieved from http://thinkprogress.org/climate/2014/02/09/3196981/chemical-spill-timeline

You may want to write this timeline out on the board, perhaps during real-time discussion with the students. A useful approach may be to discuss openly with students, what kind of actors would be involved? Then walk through the progression of the spill – from the storage site, through the water supply, into communities, where its impact required governmental response. Then students can be asked about potential influential actors before the spill – who might have been responsible for establishing safety prior to the spill? For investigating the chemical?

Major actors initially are:

- Freedom Industries – The storage company for the crude MCHM, which spilled 10,000+ gallons into the Elk River. Filed for bankruptcy by January 17th. As evidenced in the timelines provided, responsible for numerous safety lapses that led to this incident (e.g., slow response time to initial spill, nondisclosure of a second leaked chemical for ~12 days, move of stored chemicals to an unsafe secondary site).
- West Virginia American Water – The private water utility in charge of damage control for the tainted water supply.
- Governor Earl Ray Tomblin – The governor of West Virginia; declared a state of emergency on January 9th. On January 20th he asserted that it was up to residents to determine whether they felt comfortable drinking the water, and if not they should remain on bottled water. He set the standard acceptable MCHM level from the CDC's initial 1 ppm to a more stringent 2 parts per billion. Tomblin's administration also called for federal aid in testing MCHM's safety, but federal officials rejected the appeal for animal studies.
- The Center for Disease Control (CDC) – established the baseline acceptable level of MCHM with minimal information or safety studies, guided largely by its status as a grandfathered chemical of the Toxic Substances Control Act.

<u>Discussion of Water Safety</u>

Have students break up into small groups for a "Think, Pair, Share" discussion. First, have students think, answering the questions individually and taking notes. Second, have students break into pairs and discuss their answers with a partner. Encourage them to revise their answers based on the conversation. Finally, have pairs volunteer their answers in a full group discussion, and facilitate a conversation around the variation in student answers and how one might determine safety, as in the questions below.

The discussion should center on the following questions: *Do students think the water is safe? If they were residents of WV, would they drink it themselves/give it to their family? If they were in charge of deciding if it was safe for others (e.g., if they worked for the water utility), what would they advise and why? What would they require in order to determine safety?*

Examples of potential responses and follow-up questions:
Student: If I was working for the water utility I'd probably base public advice on whatever the accepted safety levels of the chemical were, since that's pretty defensible from a litigation standpoint. But I would keep my family on bottled water privately.
Teacher: How do you segregate the two in your mind? What do you feel is your responsibility in translating the inherent risks of the spill to the public, since your advice affects the decisions of other families?

Student: I'd need to see study data for myself in order to determine the acceptable levels of risk.
Teacher: Would they need to be animal or human studies? What size of population? Do you think it should factor in potential interactions with common medications or other environmentally-pervasive chemicals?

Concept Maps

On their own, have students spend ~10 minutes drawing concept maps diagraming the various actors involved in the MCHM spill. Explain that a map viewer should be able to identify (1) what caused the spill, (2) who was responsible for the spill, and (3) who was affected by the spill. Maps can be basic for now, as they will be revisited throughout the course. See "Concept Map Resources" for guidance on making concept maps.

Major Risk Assessment Issues

Next, introduce how risk was handled before, during and after the spill. The students have already engaged from a layperson's perspective with what they would require to feel "safe", and this is an excellent transition into discussing how risks are assessed, and the elements that are often unaccounted for in official assessments.
Each of the discussion prompts are short (max 5 min), meant to get students thinking about how the complexities and implications of risk perception.

In the early days of the spill, it became clear that there were many unknown factors as to what was leaking into the water and how dangerous it was:

- Crude MCHM has 6 chemicals; only the main one (4-MCHM) was safety-tested initially, and may not be the most damaging
- On January 21st, Freedom Industries admitted to a 2nd chemical having leaked as well, PPH, which is deemed "proprietary," allowing them to restrict information about its nature. The CDC noted that information on both chemicals is "very limited." Freedom Industries had known about PPH's concurrent spill from day 1 according to internal emails.
- On January 29th, a Marshall University environmental scientist found the known carcinogen formaldehyde in the water.

Discussion (~5 minutes) about how they define a problem when it may have a wealth of unknowns: Is focusing on MCHM potentially myopic, given that there may be other (and more problematic) chemicals in the mix? How do we decide what is an acceptable level of investigation when assessing risks, when we do not understand how widespread and complex the spill is?

The CDC's stance on MCHM was defensive:

- MCHM was not well-studied because:
    - It was grandfathered in by the Toxic Substances Control Act (TSCA), which meant that no safety data was required. MCHM was just one of approximately 84,000 chemicals registered since 1976 and exempted in this manner. The law makes it difficult for the EPA to critique any of these substances, because serious adverse effects essentially need to be conclusively indicated in order to fuel an investigation. Thus, risk assessments to these TSCA-grandfathered chemicals,

under the current status quo, are made in response to spills and other damaging events, rather than prior to them – hamstringing the ability to respond appropriately to their impacts.

- The Freedom Industries site was for chemical *storage*, not for chemical processing or use. MCHM was not supposed to get into the drinking water and the available Materials Safety Data Sheets (MSDS) were for worker exposure not drinking water. In fact the MSDS sheets say "not for human consumption." See the image in the "Timeline" below to understand how the site was an accident waiting to happen, with storage tanks built right above the banks of the river.

Discussion: Where would you draw the line with respect to how fully potential chemical risks should be assessed – would you commit resources to testing these 84,000 grandfathered chemicals? What would be your argument if there was a backlog of new and wholly untested chemicals, which had no past use history, needing evaluation as well?

- The CDC said that 1 ppm is considered "acceptable for use". CDC information including a "Summary Report of Short-term Screening Level Calculation and Analysis of Available Animal Studies for MCHM" is at available at CDC (2014)[1]. According to Gupta from Kanawha County Health Department, the CDC later said this was only a "short-term" standard, for less than 14 days of exposure. Also, CDC defended the 1 ppm standard even when a more recent expert panel recommends 120ppb (8 times lower).[2]

Discussion: Why is absence of evidence not the same as evidence of absence when it comes to public health? This is a crucial point of understanding for science literacy. Safety cannot be assumed due to a dearth of available information. Having evidence on hand that a given chemical is absent is very different from having a lack of evidence that that chemical exists.

A summary of how the lone pre-existing study on MCHM's safety was likely calculated (details in Denison 2014[3]). Teachers should emphasize the steps at which assumptions were made in the risk calculations, and ask students about their views on the adequacy of animal studies for extrapolating human safety measurements:

- In 1990, the chemical's producer, Eastman Chemical Company, calculated the oral toxicity LD50 of MCHM in rats.
- LD50 (median lethal dose) is the crudest measure: feed rats the chemical until 50% of them die in a short time period (usually 24 hrs).
- This is already troubling because standard practice is to use No Observable Adverse Event Levels (NOAEL), very far from LD50.
- This was reported an 825 mg/kg lethal dose. Mg/kg is equivalent to parts per million (ppm).
- Because humans may be more sensitive than rats, there's a 10-fold reduction because of an "interspecies extrapolation" uncertainty factor (reduces to 82.5 ppm).

[1] Centers for Disease Control and Prevention. (2014, February 5). Information about MCHM: 2014 West Virginia Chemical Release. Retrieved from http://www.bt.cdc.gov/chemical/MCHM/westvirginia2014/mchm.asp
[2] CDC stands by 1ppm "standard," misrepresents WVTAP findings. (2014, May 24). Retrieved from http://ourwaterwv.org/cdc-stands-by-1ppm-standard-misrepresents-wvtap-findings/
[3] Denison, R. (2014, January 13). West Virginia officials trust shaky science in rush to restore water service: One-part-per-million "safe" threshold has questionable basis. Retrieved from http://blogs.edf.org/health/2014/01/13/west-virginia-officials-trust-shaky-science-in-rush-to-restore-water-service-one-part-per-million-safe-threshold-has-questionable-basis/?s_src=ggad&s_subsrc=wvh2o&gclid=CJ2Qvo7p07wCFc1hfgodEj4Ayg

- Because individuals differ in their sensitivity (the young and elderly, pregnant women, allergic) another 10-fold reduction for "intraspecies extrapolation" is applied (reduces to 8.25 ppm).
- A third uncertainty factor was applied because the chemical would likely have adverse effects short of lethality; this was 8.25x, to bring the safe level to 1 ppm. This was not justified and does not have a prior basis in the literature.

Discussion: Should there be requirements for transparency in risk calculation methods? Who should regulate/enforce this?

<u>Class 1 Homework: Continue Building Concept Maps, Add Failure Nodes</u>

At home, have students add to their concept maps: any additional actors discussed after the first map was built (e.g., Eastman Chemical Company), as well as points of failure that may have precipitated the MCHM spill (for instance, the grandfathering by TSCA and the flawed risk assessment). Specifically, ask them to label points of responsibility:

Optional: have students mark their concept maps with:

1) *Who should be responsible for studying the health effects of MCHM and other grandfathered chemicals?*
2) *Who should be responsible for enforcing safety based on the findings, and who should be culpable in the event of a problem?*

<u>Optional Risk Assessment Modules</u>

If desired, teachers may utilize the risk assessment modules found in "Suggested Modifications" to supplement the information and approach provided in the first classroom session. In the first, students learn about the Precautionary Principle, the subjective judgments involved in risk assessments, and Mary O'Brien's concept of "alternatives assessments" – essentially, seeking solutions where risks are completely sidestepped rather than evaluated in a flawed fashion. In the second, students learn about the tension between expert opinion and laypeople in communities, and the asymmetries in information, trust, and objectives between both, as well as between communities and firms which operate within those communities with environmental impacts. In the third and final module, students understand how we assess and engage with both probabilistic risks, where we know the parameters of the system in question, and ambiguous risks, where the problem is not well-defined and we may be missing critical knowledge.

Class Two Teaching Notes

<u>Summary</u>
Class Two focuses on institutional governance leading up to and following the chemical spill. It introduces students to the key regulations that govern management of drinking water supplies and hazardous materials, as well as to concepts of governance, decentralization, regulatory fragmentation, and normal accidents.

<u>Schedule overview</u>

1. Students share concept maps (15 minutes)
2. Discussion on whether the water is safe (15 minutes)
3. Lecture about relevant laws (30 minutes)
    a. Optional student presentations
4. Lecture with discussion about key concepts for understanding the laws (30 minutes)
5. Homework: Students revise concept maps with added detail from the day; complete Water Quality Assignment

<u>Detailed notes</u>
To open, have students share their concept maps with a partner and ask them to share their thought process in developing the maps. Then ask for a few examples from the class, and use these examples to explain what you're looking for in the concept maps. More details on assessing the concept maps are available in "Formative Assessment".

Next, bring a bottle of water to class, fill up a few glasses, and tell students that it is water from Charleston, WV, bottled on January 15, 2014. Have the students write 1-2 sentences about whether they would drink the water, given what they learned in the previous class. Start a discussion as to whether the water is safe enough to drink and why. Then ask them to step into the shoes of the water provider, and ask whether they would tell others that the water is safe to drink. Why? If their answers changed, why do they have a different safety threshold as an individual or a water provider?

Next, introduce the primary regulations that were in place to (1) reduce the likelihood of a chemical spill and (2) protect the drinking water supply from contamination. First, ask students to brainstorm ways they think the resource could be regulated. Examples might be to know where hazardous materials are stored, to monitor drinking water intakes for dangerous chemicals, etc. Then introduce the laws that were in place: the Safe Water Drinking Act, the Emergency Planning and Community Right-to-Know Act, the Clean Water Act, and the Toxic Substances Control Act. Summaries of each of these laws, the components that directly relate to the Elk River spill, and discussion of how the laws worked/did not work to prevent the spill are provided in "Summary of Relevant Laws and Regulations."

Note: for a smaller class groups of students could be asked to familiarize themselves with one of the laws prior to class. Each student group could give an in-class presentation on the key *components of the law and how it related to the Elk River case. This is an example of the jigsaw approach.*[4]

Next, guide students through a discussion reflecting on why these laws failed to prevent the spill. We consider key theoretical drivers of the failure to be decentralization and fragmentation of regulation, which led to a so-called "normal accident". Summaries of each of these concepts, as well as potential discussion questions and background readings, are in "Theoretical Background for Class 2."

Class 2 Homework: Concept Maps and Water Quality
Before Class Three, students should (1) continue to update their concept maps with the laws, regulations, and failure points introduced in Class Two; and (2) complete the "

[4] For a more in depth description of the Jig-Saw approach and other teaching methods, the National Center for Case Study Teaching in Science (NCSTS) is a great reference. NCSTS (2014) Case Types & Teaching Methods: A Classification Scheme. Retrieved from: http://sciencecases.lib.buffalo.edu/cs/collection/method.asp

Water Quality Homework."

Class Three Teaching Notes

Summary

Day Three focuses on the continued uncertainty regarding the safety of water quality in the months following the Freedom Industries chemical spill. More than one month after the spill, the governor of West Virginia told residents that they should decide for themselves whether the water was safe to drink. What are potential sources of MCHM in the system one month after the spill? How do water utilities manage risks associated with drinking water quality? This section considers the technical and environmental system in addition to the social and institutional systems considered in previous lessons.

Schedule overview

1. Describe/discuss prolonged uncertainty due to chemical spill (20 minutes)
    a. Show short PowerPoint presentation including video clip of school cook and WV American Water responding to questions of water safety.
    b. Student reflections on their homework assignments: “Would you drink the water? What would you need to know about the system?” (Write responses on the board)
2. What are the risks associated with MCHM in the water? What are potential sources of MCHM? (30 minutes)
    a. Instructor breaks students into small groups and provides news article that discusses preliminary results from the WVTAP study. Each group is asked to consider the following potential sources of MCHM and other pollutants in the drinking water:
        i. Source Water: The Elk River
        ii. Water Treatment Plant: Filters releasing MCHM
        iii. Water Distribution System: MCHM reservoirs (e.g. storage tanks)
    b. Discussion of importance and limitations of analytical water quality monitoring techniques such as detection limits
3. Social-Environmental Synthesis (20 minutes)
    a. Individual journaling: Students list everything components of technical/environmental system, and connections to the social/political.
    b. Handout final assignment and answer questions related to it
    c. Introduce solutions that have been proposed at state, federal, and local community scales
4. Homework: Final Take-Home Essay

Detailed notes

1. Describe/discuss prolonged uncertainty due to chemical spill

a. Begin this class by showing a short series of PowerPoint slides to orient and engage students in the continued uncertainty following the chemical spill in West Virginia. Powerpoint presentation provided separately. Please note that these slides are meant as an optional guide and review of the chemical spill. Instructors should move through these quickly (~5-7 minutes including video clips). <**Show Slides 1 through 7**>

b. Draw linkages between the monitoring data students downloaded for their homework and the video clip of the school cook with the following question: Why were schools closed when no MCHM was detected in the water in the schools? This is a good "think/pair/share" exercise and entry point to discuss student responses to their homework questions: What do some of the expert sources we have reviewed advise with regards to the drinking water? What is surprising about the data that you downloaded? What is confusing? **<Show Slide 8>**

c. Group Discussion: *Would you drink the water? What would you need to know about the system to determine if the water is safe?* **<Show Slide 9>**

The many possible responses could be written on the board as students mention them. It might be helpful to distinguish the following (these are potential student responses):

- *Personal experience* – Has the water made me sick in the past? Can I smell or taste MCHM? Do I feel dizzy, nauseous, or have other symptoms related to MCHM?
- *Air/water exposure route* – To what extent and how is the chemical making other people sick? I want more information about whether MCHM in the air or in the water is responsible for reported illnesses.
- *Location of water quality samples taken* – I would want water quality samples taken directly from my household tap – not from a fire hydrant or a treatment facility.
- *Social acceptability* – Are my neighbors/colleagues/friends drinking the water?
- *Trust in authorities*– Do I trust the water provider/CDC/WVDEP?
- *Alternative water sources* – Do I have any other (affordable) options for safe water?
- *Vulnerable population* – Are particular populations more susceptible to illnesses caused by MCHM? Such as pregnant women, babies, the elderly, etc.
- *Other responses not already listed?*

2. What are the risks associated MCHM still in the water? What are the potential sources of MCHM? As of October 2014, the answers to these questions are still unclear. The homework assignment demonstrated that low-levels of MCHM were detected in the distribution system of West Virginia American Water for months after the spill. The PowerPoint included a map of the school closures due to MCHM exposure more than a month after the spill (Slide 6). In Table 1, we combine information from the EPA's publication "Considering the Source: A Pocket Guide to Protecting Your Drinking Water"[5] with information about the chemical spill in West Virginia to explore potential sources of MCHM in the system. We include a series of slides in the PowerPoint presentation to help illustrate the connection between drinking water system components and risk barriers. **<Slides 10 through 18>**

The summary of this part of the lesson: Drinking water systems are susceptible to pollution. If the water utility understands how each component of the system is susceptible, then they can mitigate risks associated with each component of the system.

[5] Environmental Protection Agency. (2002). *Consider the Source: A Pocket Guide to Protecting Your Drinking Water. (No. EPA 816-K-02-002).* EPA Office of Ground Water and Drinking Water. Retrieved from: http://www.epa.gov/safewater/sourcewater/pubs/guide_swppocket_2002.pdf

Table 1: Multiple-Barrier Approach to Safe Drinking Water & Potential Sources of MCHM

Drinking Water System Component	Type of Barrier	Potential Source of MCHM
A. Source Water & Collection System	Risk Prevention Barrier	The Elk River (from Freedom Industries or other locations)
B. Treatment Plant	Risk Management Barrier	Filters in water treatment system adsorb MCHM (thus adding it to the system)
C. Distribution System	Risk Monitoring and Compliance Barrier	MCHM from initial spill stored in distribution system (water storage tanks, household water heaters, etc)
D. Consumer	Individual Action Barrier	

Activity: First, go through the PowerPoint slides and introduce the four components of the drinking water system and the "Multiple Barrier Approach to Safe Drinking Water" (See Table 1 and slides). We provide a very basic background so that this can be covered quickly and no technical background is required. **<Show slides 10 through 18>**

Next, break students into small groups and provide each group a copy of this news article: Ward, K. (2014, March 25).”‘Trace amounts’ of MCHM found in Elk plant water.”[6] Each group is asked to work together to develop an argument for or against three potential sources of MCHM in the system. In this section, we provide commentary for the instructor related to potential student responses. **<Slide 19>**

A. Source Water: The Elk River
   The only source of water for the West Virginia American Water drinking water system is the Elk River in West Virginia. The source water assessment conducted by the West Virginia Bureau for Public Health (2002) ranked WV American Treatment plan to be highly susceptible to potential contamination.[7] Hansen, Gilmer, and Varrato (2014)'s provide an excellent review of potential industrial, commercial, and other potential sources of pollution on the Elk River upstream of the West Virginia American Water Charleston Intake.[8] The primary source of MCHM in the drinking water system originated at the Freedom Industries storage tanks on the banks of the Elk River during the spill in January 2014. The storage tanks leaked into the river and entered into the drinking water intake. Yet, in the months that followed, little or no MCHM was detected in the Elk River above the drinking water intake.

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[6] Ward, K. (2014, March 25).‘Trace amounts’ of MCHM found in Elk plant water. Charleston Gazette. Retrieved from http://www.wvgazette.com/News/201403250093

[7] West Virginia Bureau for Public Health. (2014). *State of West Virginia Source Water Assessment and Protection Program, Source Water Assessment Report, WVAWC – Kanawha Valley, Kanawha County, PWSID: WV330216.* Retrieved from http://www.wvdhhr.org/oehs/eed/swap/get.cfm?id=3302016

[8] Hansen, E., Gilmer, B., Varrato, A., & Rosser, A. (2014). *Potential Significant Contaminant Sources above West Virginia American Water's Charleston Intake: A Preliminary Assessment.* Morgantown, WV: Downstream Strategies. Retrieved from http://downstreamstrategies.com/documents/reports_publication/pscs-above-charleston-intake_final_2-23-2014.pdf

Therefore, it is unlikely that the Elk River was the source of MCHM in the drinking water system.

B. Treatment Plant: Filters in water treatment system released MCHM
The West Virginia American Water treatment plant was not designed to remove chemicals such as MCHM. Typical treatment plants consist of several different components or steps: coagulation, sedimentation, filtration, disinfection, and storage. (We include a slide in the PowerPoint a typical treatment plant. This may also be a good student handout for students unfamiliar with water treatment.[9]) 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.[10] The filters that had processed large amounts of MCHM following had not been replaced and were likely releasing trace amounts of the chemical into the system.

C. Distribution System: MCHM from initial spill stored in distribution system (water storage tanks, household water heaters, etc)
In the days and weeks that followed the chemical spill in West Virginia, residents continually questioned the monitoring strategy of regulators and West Virginia American Water. In short, residents wondered if MCHM was trapped in their water heaters, in the filters inside their homes, in the plumbing neighbors' vacant homes, in WV American Water's storage facilities or in other places within 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 led by Andrew Whelton to conduct water quality testing inside people's homes.[11] The WVTAP study read by students as part of the Water Quality Homework is the outcome of this initial funding for household testing.

Monitoring: Use discussion of potential sources of MCHM as a starting point to teach the importance (and limitations) of analytical water quality monitoring techniques. Key principles to teach include detection limits, error, precision, and representative sampling. A good reference for definitions of these terms is Chapter 3 of the Environmental Protection Agency's "The Volunteer Monitor's Guide to Quality Assurance Project Plans."[12]

3. Social-environmental synthesis

Drinking water systems rely on complex social and ecological systems. This case on the 2014 West Virginia Chemical Spill considers the questions: Is the water safe to drink? Would you

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[9] Environmental Protection Agency. (2009). Water on Tap: What You Need to Know. (No: EPA 816-K-09-002, Page 8). EPA Office of Water. Retrieved from http://www.epa.gov/ogwdw/wot/pdfs/book_waterontap_full.pdf

[10] Ward, K. (2014, March 25). *'Trace amounts' of MCHM found in Elk plant water.* The Charleston Gazette. Retrieved from http://www.wvgazette.com/News/201403250093

[11] Ward, K. (2014, February 11) *Study to test home plumbing for MCHM.* The Charleston Gazette. Retrieved from http://www.wvgazette.com/News/201402110073

[12] United States Environmental Protection Agency. (1996). *The Volunteer Monitor's Guide To Quality Assurance Project Plans* (No. EPA 841-B-96-003). EPA Office of Wetlands, Oceans and Watersheds. Retrieved from http://water.epa.gov/type/rsl/monitoring/upload/2002_08_02_monitoring_volunteer_qapp_vol_qapp-2.pdf

drink the water? By this point in the overall case study, students should have a good grasp of the how three different perspectives of risk perception, environmental governance, and drinking water systems relate to each other and questions of water safety. The end of the last class provides an opportunity to talk holistically about the social and human aspects of these environmental hazard cases, and how these interact with, and can create vulnerabilities in, technological and environmental systems. This provides an opportunity to talk in a direct way about social-environmental synthesis, both through the analysis of students' concept maps and potential solutions.

a. Individual journaling: Ask students to list key components of the technical/environmental system related to the 2014 West Virginia chemical spill. Ask students to write down (brainstorm through writing) different ways the technical/environmental system connects to the social/political system (from concept maps developed in a previous class). Discuss the students' ideas about how the different systems interact. See "Formative Assessment" for further ideas on how to draw out students' ideas of linkages.

b. Handout a copy of the "Final Take-home Essay" homework and answer questions related to assignment

c. Introduce a few solutions that have been proposed at different political levels as a way to end on a positive note:
   - State: WV Senate Bill 373 - "spill bill" - passed March 8, 2014 (improves inventory of chemical storage tanks, requires water utilities to create source water protection plans)
   - Federal: Bills introduced by WV politicians in both Senate and the House in response to the spill with no traction, health advocates pushing for the passage of the Safe Chemicals Act of 2013 to reform the 1976 (Toxic Substance Control Act)
   - Local community: Advocates for a Safe Water System (local citizen action group formed in response to the spill)

<u>Class 3 Homework: Final Essay</u>
After the class, students should make any remaining changes to their concept maps and complete the "Final Take-home Essay."

BACKGROUND MATERIAL

Timeline

The timeline below follows the events for one month after the spill. An excellent timeline can also be found at Kroh, K. (2014). The Complete Guide To Everything That's Happened Since The Massive Chemical Spill In West Virginia. Retrieved from http://thinkprogress.org/climate/2014/02/09/3196981/chemical-spill-timeline

January 9th – Approx. 10,000 gallons of crude MHCM dumped into the Elk River. Gov. Earl Ray Tomblin declares state of emergency. Over 300,000 people ordered not to use the water for more than flushing the toilet in 9 counties. Residents notice smell 8:15 AM, but no one at plant notices the leak until 10:30 AM. Freedom Industries claim they contained the spill and removed the remaining MHCM in the tank. By the time DEP inspectors arrive, there is only 1 cinder block and 1 50-lb bag of absorbent powder set up to stem the 400 ft^2 pool of liquid coming out of the broken tank. DEP officials said there were "no spill containment measures" before the inspectors came on site, after receiving 2 separate odor complaints from residents.

Symptoms of exposure include "severe burning in throat, severe eye irritation, non-stop vomiting, trouble breathing, or severe skin irritation such as skin blistering" according to West Virginia Department of Health and Human Resources.

January 10th - Press conference by West Virginia American Water (a private utility) concedes that the company has little concrete knowledge of the compound's health effects. FEMA is called in to deliver water.

January 13th – "Do not use" ban lifted by WVAW

January 15th – Freedom Industries cited a second time by DEP, for moving the chemical to an unsafe secondary site

January 17th – Freedom Industries files for bankruptcy

January 18th – "All clear" sounded by West Virginia American Water; hospital admissions increase as soon as people begin using water again.

January 21st – Freedom Industries admits to a second chemical having leaked as well, PPH, which is deemed "proprietary"; CDC notes that information on both chemicals is "very limited." Freedom Industries had known about the second chemical from day 1 of the spill

January 29th –formaldehyde (a known carcinogen) also found in the water by a Marshall University environmental scientist

February 4th – 2 schools closed for the persistent MCHM smell

February 5th – 14 schools complain of persistent MCHM scent even after it is not detected via testing.

Concept Map Resources

Novak, J. D., & Cañas, A. J. (2008). *The Theory Underlying Concept Maps and How to Construct and Use Them* (No. Technical Report IHMC CmapTools 2006-01 Rev 01-2008). Florida Institute for Human and Machine Cognition (IHMC). Retrieved from http://cmap.ihmc.us/Publications/ResearchPapers/TheoryUnderlyingConceptMaps.pdf

Dr. Douglas Luckie at Michigan State University summarizes much of the above theory in Luckie, D. (n.d.). Concept Maps: What the heck is this? Retrieved from https://www.msu.edu/~luckie/ctools/

A detailed tutorial is available on the Florida Institute for Human & Machine Cognition website: Cañas, A. J., & Novak, J. D. (2009, August 28). Constructing your First Concept Map. Retrieved from http://cmap.ihmc.us/docs/ConstructingAConceptMap.html

Trochim, W. M. K. (2006). Concept Mapping. Retrieved from http://www.socialresearchmethods.net/kb/conmap.htm

Summary of Relevant Laws and Regulations

Note: these summaries reflect the authors' best knowledge of how the laws were applied in the case of the West Virginia spill. We have tried to focus on the letter of the law and how they were implemented, with minimal editorializing.

The EPA website is a great resource for information about the following laws. Links to the EPA's summaries of each law are included at the close of each section. Another great resource is a report by Downstream Strategies entitled "The Freedom Industries Spill: Lessons Learned and Needed Reforms,"[13] published shortly after the spill.

1. *Safe Drinking Water Act*, 42 U.S.C. §300f et seq. (1974, amended in 1986 and 1996)

The SDWA authorizes the EPA to set national drinking water standards and to oversee "public water systems." (The law does not apply to bottled water, nor to private wells that serve less than 25 households.) Under the SDWA, EPA sets Maximum Contaminant Levels (MCLs), the legally allowed upper concentration of a chemical in drinking water; anything above the MCL requires treatment. However, this list only covers 90 contaminants, and there was no MCL in place for MCHM.

The process for listing a new chemical is lengthy, highly politicized and often lawsuit riddled. The EPA maintains a list of unregulated chemicals that may require regulation, available at http://water.epa.gov/scitech/drinkingwater/dws/ccl/index.cfm, including timelines of reviews and monitoring. The EPA also periodically monitors a subset of chemicals to determine whether they should be listed; the current list is available at http://water.epa.gov/lawsregs/rulesregs/sdwa/ucmr/ucmr3/index.cfm. When a new contaminant is proposed, the EPA considers both the health impacts and a cost-benefit analysis of changes necessary to comply with the new rule. Each of these steps is also open for public comment. (For an example of the listing process, including public comments, expert reviews, and congressional hearings, the arsenic rulemaking is available at http://water.epa.gov/lawsregs/rulesregs/sdwa/arsenic/history.cfm.)

Under the SDWA, states are responsible for enforcing the drinking water standards. How this works in practice is that the individual water suppliers self-monitor by testing for contaminants and reporting the results to relevant enforcement agencies (in West Virginia, to the Department of Health and Human Resources, Bureau for Public Health, and Office of Environmental Health Services). Remember, though, that this only pertains to the 90 listed chemicals, not to MCHM.

The 1996 Amendment also requires states to undertake source water assessments, which involves "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

[13] Hansen, E., Glass, M., Gilmer, B., & Rosser, A. (2014). *The Freedom Industries Spill: Lessons Learned and Needed Reforms*. Morgantown, WV: Downstream Strategies. Retrieved from http://www.downstreamstrategies.com/documents/reports_publication/freedom-spill-report_1-20-14.pdf

public"[14]. Many states, including West Virginia, delegate this responsibility to individual water providers. WVAWC completed their source water assessment and protection report in 2002. The report found the system to be highly susceptible to contamination. However, the Freedom Industries site was not among those listed as a potential problem.[15]

Because there was not a national standard for MCHM under the SDWA, the Center for Disease Control chose to step in after the spill to decide whether the water was safe to drink.

EPA summary:
US EPA, O. (n.d.). Summary of the Safe Drinking Water Act [Overviews and Factsheets]. Retrieved from http://www2.epa.gov/laws-regulations/summary-safe-drinking-water-act

Another nice resource describing the Safe Drinking Water Act as it relates to the Elk River spill is Schnoor, J. L. (2014). Re-Emergence of Emerging Contaminants. *Environmental Science & Technology*, *48*(19), 11019–11020. doi:10.1021/es504256j

2. *Emergency Planning and Community Right-to-Know Act* 42 U.S.C. §11001 et seq. (1986)

The EPCRA requires facilities to report (by providing a "hazardous chemical inventory form" or Tier Two report) any hazardous chemicals stored on their property to the state emergency response commission, local emergency planning committees, and local fire department. The idea is that communities can then use that information to develop emergency response plans in the event of a spill. Freedom Industries filed its Tier Two form in February 2013 (and every year since at least 2008).

Under EPCRA, West Virginia has a state emergency response commission under the Division of Homeland Security and Emergency Response, comprised of heads of relevant agencies, and currently has vacant seats (from a local fire department and the chemical industry). Drinking water interests on the commission are represented through the Public Service Commission. Local emergency planning committees also exist at county scale. For example, the Kanawha-Putnam committee has a 2006 emergency response plan, including planned responses for hazards and spills. According its website (http://www.kpepc.org/), the committee meets monthly, although no one from WVAWC is on the board).

EPA Summary:
US EPA, O. (n.d.). Summary of the Emergency Planning & Community Right-to-Know Act [Overviews and Factsheets]. Retrieved from http://www2.epa.gov/laws-regulations/summary-emergency-planning-community-right-know-act

[14] United States Environmental Protection Agency. (n.d.). Protecting Drinking Water Sources. Retrieved from http://water.epa.gov/lawsregs/guidance/sdwa/upload/2009_08_28_sdwa_fs_30ann_swp_web.pdf
[15] West Virginia Department of Heath and Human Resources. (2002). *State of West Virginia Source Water Assessment and Protection Program Source Water Assessment Report*. Retrieved from http://www.wvdhhr.org/oehs/eed/swap/get.cfm?id=3302016J

3. *Clean Water Act,* 33 U.S.C. §1251 et seq. (1972):

The CWA requires that entities discharging waste or other materials into "waters of the United States" obtain permits for point source pollution under the National Pollutant Discharge Elimination System (NPDES). The Freedom Industries facility had a NPDES permit that focused on preventing contamination by stormwater runoff. The permit was issued under a statewide "general" permit, meant to streamline activities assumed to have minimal environmental impact. General permits are pre-written by the WVDEP and under go public comment and review when they are written. Companies then register under a general permit. Because there is no public notice comment during this registration, general permits do not take into account site-specific factors or allow people who live near the site to comment.

Freedom Industry's permit focuses on developing Best Management Practices (BMPs) to prevent stormwater runoff. The permit also requires that runoff not violate applicable water quality standards. While there was no standard in place for MCHM (and thus no permit violation), the spill would still violate narrative standards regarding odor and toxicity.

The permit requires that spills be reported immediately, but Freedom did not report the spill to WVDEP until four hours after the first odor complaint was filed. The spill was not reported to the US Coast Guard's National Response Center, which catalogues oil and HAZMAT spills nationwide, until 7:42pm. However, the fault may not lie entirely on Freedom Industries: "Press reports indicate that WVDEP did not recognize this permit requirement to immediately report noncompliance. According to a January 13 [2014] article from CNN, WVDEP Cabinet Secretary Randy Huffman stated: 'Basically they had to monitor the runoff from the rain and send us the results every quarter. Those were the only regulatory requirements,' Huffman said. 'The materials they were storing there is not a hazardous material.' (Field et al., 2014)."[16]

WVDEP is responsible for issuing and enforcing NPDES 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. 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, Randy Huffman, the head of the West Virginia Department of Environmental Protection, said, "We went out on site and didn't find anything that would cause concern, no leaks or anything like that."[17] Moreover, most of these impromptu inspections focused on air quality, rather than water.[18]

EPA summary:

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[16] Hansen, E., Glass, M., Gilmer, B., & Rosser, A. (2014). *The Freedom Industries Spill: Lessons Learned and Needed Reforms*. Morgantown, WV: Downstream Strategies. Retrieved from http://www.downstreamstrategies.com/documents/reports_publication/freedom-spill-report_1-20-14.pdf

[17] Field, A., Edwards, M., & Sholchet, C. E. (2014, January 13). West Virginia chemical spill shines spotlight on loose regulation. Retrieved from http://www.cnn.com/2014/01/13/us/west-virigina-chemical-contamination/index.html

[18] Hansen, E., Glass, M., Gilmer, B., & Rosser, A. (2014). *The Freedom Industries Spill: Lessons Learned and Needed Reforms*. Morgantown, WV: Downstream Strategies. Retrieved from http://www.downstreamstrategies.com/documents/reports_publication/freedom-spill-report_1-20-14.pdf

US EPA, O. (n.d.). Summary of the Clean Water Act [Overviews and Factsheets]. Retrieved from http://www2.epa.gov/laws-regulations/summary-clean-water-act

4. *Toxic Substances Control Act,* 15 U.S.C. §2601 et seq. (1976)

The TSCA (pronounced "Tosca") governs the production and use of hazardous chemicals. Mostly designed as an information-based policy instrument, it requires companies to keep records and report what chemicals they use in processing and manufacturing. For new chemicals where potential health risks are identified, the law also enables the EPA to require chemical importers, manufacturers, and processors to conduct tests.

TSCA's goal is to develop new standards for use and disposal as new chemicals are created. In practice, however, listing new chemicals under the law is quite difficult. First, when the law was created, approximately 62,000 chemicals were grandfathered in, assumed to be safe because they were already in use. Additionally, as new chemicals come into use, they are often subject to lawsuits. Thus, as Scruggs and Ortolano[19] note, of the 84,000 chemicals listed in TSCA's Chemical Substance Inventory, "the EPA has been able to use its authority under TSCA to regulate only five chemicals or chemical classes and require industry testing of only about 200 existing chemicals and a small fraction of new chemicals since the law's enactment." MCHM was not one of those chemicals, so there was very little known about the potential health impacts of contact or ingestion.

EPA summary:
US EPA, O. (n.d.). Summary of the Toxic Substances Control Act [Overviews and Factsheets]. Retrieved from http://www2.epa.gov/laws-regulations/summary-toxic-substances-control-act

Discussion note: While the precautionary principle was likely raised on Day 1, the SDWA and TSCA provide great discussion points about burden of proof. Is absence of evidence of harmful effects equivalent to evidence of absence? In the European Union, companies that use chemicals must prove that the chemical is safe for use. In the US, government is responsible for determining the safety of chemicals. What are the pros and cons of both approaches? How did we see the US's approach failing in this case?

[19] Scruggs, C. E., & Ortolano, L. (2011). Creating safer consumer products: the information challenges companies face. *Environmental Science & Policy*, *14*(6), 605–614. doi:10.1016/j.envsci.2011.05.010

Theoretical Background for Class Two

The following are theoretical concepts that we see relating to the institutional complexity governing the Elk River spill. There are many others, and instructors are encouraged to add to this list. If you do introduce another concept, please let us know how it went!

Decentralization

One common theme influencing how the regulations affected the spill is decentralization: the shifting of political power away from centralized governments. In this case, the EPA delegated implementation authority to states for every regulation. (In fact, while it doesn't apply to this case, some actual decision-making authority is delegated under the CWA, as states set their own contaminant standards). Further decentralization occurred when West Virginia authorized individual drinking water providers to monitor their own contaminant levels.

Some of the rationales for decentralization include efficiency, because it can avoid the bureaucratic bottlenecks of a central government; effectiveness, because people closer to a problem (states or counties, in this instance) are thought to have a better understanding of the local context; and democratic accountability, because it can allow for increased public participation (it's easier for a West Virginian to attend a meeting in Charleston, WV than in Washington, DC).

Discuss: Do you see any of these benefits from decentralization in the West Virginia spill? Why? Why not?

One challenge of decentralization is that the nodes implementing the laws may not have the same priorities as the centralized body. In this case, the EPA is authorized to protect human health and the environment. West Virginia has a very different stance on the environmental protection, and actually sued the EPA in 2010 over coal mining regulations[20].

Discuss: If the goal is to protect the environment and human health, do you think EPA should delegate authority to states? Why do you think West Virginia might not have the same goal? Is there a better balance between these goals?

Who should have authority over managing the environment? What are benefits of local governance? What are benefits of centralized governance? How can we find a good balance?

Reading ideas:

A great overview of decentralization in the US is Laskowski, S., Morgenstern, R., & Blackman, A. (2005). *Environmental Decentralization in the United States: Seeking the Proper Balance between National and State Authority* (Discussion Paper No. RFF DP 05-42). Washington, DC: Resources for the Future. Retrieved from http://ageconsearch.umn.edu/bitstream/10779/1/dp050042.pdf

For a slightly more theoretical take, refer to the introduction and literature theoretical

[20] Greenwire, P. R. O. (2010, October 6). W.Va. Sues Obama, EPA Over Mining Coal Regulations. *The New York Times*. Retrieved from http://www.nytimes.com/gwire/2010/10/06/06greenwire-wva-sues-obama-epa-over-mining-coal-regulation-48964.html

background provided in Larson, A. M., & Soto, F. (2008). Decentralization of Natural Resource Governance Regimes. *Annual Review of Environment and Resources*, *33*(1), 213–239.

Fragmentation

Another characteristic of environmental regulation is its patchwork quality. In the US, the environmental regime arose out of centuries of court decisions, congressional laws, and cultural norms. In the global environmental governance literature, this is referred to as "fragmentation": the "patchwork of … institutions that are different in their character (organizations, regimes, and implicit norms), their constituencies (public and private), their spatial scope (from bilateral to global), and their subject matter."[21] While fragmentation is most commonly discussed regarding global environmental governance, it applies very well to the West Virginia case. There was no centralized party responsible for monitoring drinking water quality or preventing spills, so no one was fully responsible. Moreover, despite the many laws and regulations in place, there were enough loopholes that MCHM was not fully governed, yet no one realized it in advance.

Discussion: Given the fragmented nature of US environmental regulation, who do you think is responsible for the spill? How would you manage or enforce the system differently? How might we identity where there are gaps in a governance system?

Reading idea:

While its topical focus is global environmental governance, a decent theoretical overview of fragmentation is available from Zelli, F., & van Asselt, H. (2013). Introduction: The Institutional Fragmentation of Global Environmental Governance: Causes, Consequences, and Responses. *Global Environmental Politics*, *13*(3), 1–13.

Normal Accidents

Charles Perrow developed the concept of Normal Accidents specifically about nuclear disasters but his concepts are broadly applicable. He provides three main points as the basis for large-scale environmental disasters: that individuals are fallible, that big accidents build from small beginnings, and disasters are often a result of institutional failures rather than mechanical ones. This gives rise to "normal accidents" or "system accidents", which Perrow views as inevitable in complex systems. The complex interactions of a number of systemic vulnerabilities can generate unanticipated large-scale events.

A treatment of the WV chemical spill that permits easy analogies to the normal accidents framework is Ginty, M. M. (2014, June 4). Why the West Virginia Spill Wasn't a Freak Occurrence. Retrieved from http://billmoyers.com/2014/06/04/why-the-west-virginia-spill-wasnt-a-freak-occurrence

Discussion ideas: How did institutional failures compound to essentially predispose the WV storage facility to a normal accident?
If a discussion of Mary O'Brien's framework has preceded this, then:
How could alternatives assessment create more parsimonious systems, thus reducing likelihood of natural accidents?

[21] Biermann, F., Pattberg, P., Asselt, H. van, & Zelli, F. (2009). The Fragmentation of Global Governance Architectures: A Framework for Analysis. *Global Environmental Politics*, *9*(4), 14–40, p. 16.

<u>Reading ideas:</u>

Perrow, C. (1999). *Normal Accidents: Living With High-Risk Technologies*. Princeton University Press.
Introduction and Ch. 3 – "Complexity, Coupling, and Catastrophe." Ch. 7 – "Earthbound Systems: Dams, Quakes, Mines, and Lakes" and Ch. 9 – "Living with High Risk Systems" are also highly relevant.

Perrow, C. (2008). Complexity, Catastrophe, and Modularity. *Sociological Inquiry*, 8(2), 162-173. Available from: http://onlinelibrary.wiley.com/doi/10.1111/j.1475-682X.2008.00231.x/pdf

ASSIGNMENTS AND ASSESSMENT

Formative Assessment

In this case, students' learning is assessed by their capacity to answer discussion prompts by integrating not only the facts provided in lecture, but also their own views and perspectives (e.g., on how environmental risks should be managed and where responsibility should fall, both in prevention and response). Discussion questions will serve as measures of their ability to do so. Most questions are presented in a way to facilitate the expression of students' opinions about handling of the spill, safety concerns, etc.; students who overly rely on regurgitating the case's facts without integrating their own views should be drawn out with follow-up questions to ensure that they are thinking critically about the many complex elements of the case and the actors involved.

Providing repeated feedback on student concept maps is another key opportunity for formative assessment. Students are asked to develop and refine concept maps throughout the course, but will only be graded on the final product. Therefore, the maps are a great tool to understand student learning throughout the course and to clarify misunderstandings about the case study material. In introducing and revisiting students' maps each day, the teacher should highlight stronger and weaker examples of the following concept map components:

1. hierarchical structure: more general concepts (like "laws and regulations") are located more centrally than more specific concepts (like "Clean Water Act"),
2. organization: maps group around logical subsystems, such as the political system and the technical system subsystems,
3. feedbacks: arrows are used to show which concepts/actors affect the others), and
4. interactions: maps should describe cross linkages between concepts in words or with sketches.

Teachers should also take the opportunity to highlight any surprising or novel (but still correct) representations of the case.

Formal Evaluation

In-class Participation	50%
Concept Map	10%
Water Quality Homework	10%
Final Take-home Essay	30%

In-class participation focuses on whether students are engaged in discussion and individual reflection (e.g., during journaling) throughout the course. In-class Participation can be assessed using an established rubric such as the one developed by John Immerwahr,[22] available from http://www46.homepage.villanova.edu/john.immerwahr/TP101/EvDay/discussion%20rubric.pdf.

The Concept Maps are graded on the following scale:

[22] John Immerwahr, Copyright License: http://creativecommons.org/licenses/by-sa/3.0/us/

10 points: Concept map is detailed and identifies many potential actors, their linkages, and potential sources of failure
5 points: Concept map identifies only some of the potential actors and/or does not clearly articulate linkages or sources of failure
0 points: Student does not produce a concept m

Water Quality Homework

Students should complete the Water Quality Homework before Class Three.

IS THE WATER SAFE?
CONSIDERING WATER QUALITY AND OBJECTIONABLE ODOR DATA

1. Create a list of the (1) drinking water level suggested by the Centers for Disease Control and Prevention (CDC) as "acceptable for use," (2) health-based standard recommended by West Virginia Testing Assessment Program (WV TAP), (3) objectionable odor concentration (WVTAP), and (4) odor recognition concentration (WVTAP). Please report all answers in ppb (equivalent to ug/L).

   1000 ppb (or ug/L microgram per liter) = 1 ppm (or mg/L milligram per liter).

   CDC recommendations are outlined at:
   Centers for Disease Control and Prevention. (2014, February 5). Information about MCHM: 2014 West Virginia Chemical Release. Retrieved from http://www.bt.cdc.gov/chemical/MCHM/westvirginia2014/mchm.asp

   WV TAP recommendations are available:
   Rosen, J. S., Whelton, A. J., McGuire, M. J., Clancy, J. L., Bartrand, T., Eaton, A., … Adams, C. (2014). *WV TAP Final Report*. Scituate, MA: Corona Environmental Consulting. Retrieved from http://www.dhsem.wv.gov/WVTAP/News/Pages/Final-WV-TAP-Report-Posted.aspx

2. What are the similarities and differences between the methods used by the CDC and the WVTAP to reach the MCHM recommendations for drinking water consumption in Question 1? Please use your own words.

3. Follow the instructions below to download 2-3 different files of water quality data submitted by West Virginia American Water to the Public Service Commission. Each file represents one day of sampling. What is surprising about the data that you downloaded? What is confusing? ***Please note the dates of the sample files you downloaded and bring these sample files to class.***
   Go to http://www.psc.state.wv.us/WebDocket/default.htm
   Click on Search: Case
   Case Number: 14-0872-W-GI
   When short description of case appears, click on "Activities"
   There are 57 separate downloadable files from West Virginia American Water Company (e.g. "Continued filing - Part 39 Sample Data February 25, 2014")

4. Based on the water quality data provided, would you drink the water? What threshold would you use to determine whether the water is safe? Why? Please draw on your responses to questions 1-3 in this response. Then reflect on your response with respect to our discussions of risk perception – what individual experiences or cultural factors may be influencing your personal decision?

Assessment:
Students can earn a total of 10 points on this assignment.

Q1.
CDC recommendation – 1000 ppb
WVTAP recommendation – 120 ppm
Odor Objection Concentration (WVTAP) – 4.0 ppb
Odor Recognition Concentration (WVTAP) - 2.2 ppb

1 point for all standards listed in ppb
0 points otherwise

Q2.
Page 8 of the WVTAP Final Report summarizes the similarities and differences between the CDC and the WVTAP recommendations:
"The [WVTAP] panel reviewed the available data on crude and pure MCHM and recognized that there were limited toxicology data for MCHM. They agreed with the judgment of CDC that the 4-week oral study in rats with pure MCHM (Eastman, 1990), and the 100 mg/kg-day no observed effect level (NOEL), was the most appropriate available study and end point to establish a short-term health advisory for MCHM. However, the expert panel chose to adjust this 100 mg/kg-day experimental dose to account for the dosing regimen of five days per week. In addition, the expert panel determined that without information on what life stage is most sensitive to the effects of MCHM, the health advisory should be designed to protect the most exposed life stage that consumes the most water on a body weight basis, that is, a formula-fed infant of 1- 3 months."

2 points – student adequately describes differences and similarities between WV TAP and CDC recommendations
1 point – student description only partially discusses differences and similarities
0 points – limited description or does not adequately paraphrase descriptions by CDC

Q3.
2 points if student describes what is surprising about the data AND what he/she finds confusing about the data

Q4.
5 points if student answers all parts of this question:

- Based on the water quality data provided, would you drink the water? (0.5 point)
- What threshold would you use to determine whether the water is safe? (0.5 point)
- Why? (2 point)
- What individual experiences or cultural factors may be influencing your personal decision? (2 point)

Final Take-home Essay

Reflect on what you've learned about the Elk River chemical spill, environmental governance, risk perception, and environmental engineering to answer the following prompt.

Imagine that you have been hired to direct a special task force convened by the Obama administration, which 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.

1. *How would you reform the regulation or implementation of regulations? Why?*
2. *What technical or environmental solutions would you recommend to lessen uncertainties related to the safety of drinking water? Why? Potential ideas include monitoring improvements, source water protection, distribution system leak repair, and secondary/backup drinking water source.*
3. *Why should the administration attend to both regulatory and environmental solutions, given the socio-environmental nature of the system?*

After the administration receives your report, they follow up with questions about the costs necessary to impose these reforms; after all, the Elk River spill was an abnormal occurrence. Given what you've learned about risk perception and the precautionary principle, respond to the following:

4. *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?*

The 1000-1500 word essay should reference any relevant sources.

<u>Assessment:</u>

For each criterion, first decide whether the student's essay clearly matches either extremity (0 points or 3 points). If yes, assign that many points for that criterion. If no, decide whether it is closest to 0 (assign 1 point) or to 3 (assign 2 points).

Criterion	0	1	2	3
Demonstrated understanding of the case	Essay has many factual errors.			Essay shows comprehensive understanding of the West Virginia spill, including key actors and failure points.
Demonstrated understanding of the theory	Essay does not reference relevant theory.			Essay shows comprehensive understanding of theoretical

				concepts introduced in class and the readings.
Argument	Essay lacks a clear argument or rationale for the recommendations.			Student builds on the facts and theory to provide an argument for why their choices are justified.
Clarity	Essay is difficult to read and/or contains numerous grammatical errors.			Prose is clear, effective, and error-free.
Completeness	Essay does not answer any prompt in full.			Student responds to each item in full.

The summed score is doubled, for a final grade out of 30 points.

SUGGESTED MODIFICATIONS

Optional Risk Module 1: Alternatives Assessment and the Precautionary Principle

Module Goals:

- Students will start thinking about "alternatives assessment" when dealing with environmental risks: instead of accepting a risk scenario as "given" and spending time quantifying its level of risk more precisely, trying to find new ways of designing risky human-environmental activities from the start.
- Students will have a basic understanding of the Precautionary Principle, which takes a "better safe than sorry" approach to environmental risks and puts the burden of proof of safety on those who would introduce such risks into the public commons.
- Students will understand cultural differences between countries and cultural groups within the US in level of engagement with the Precautionary Principle.

Estimated Time:
This module could take a full 2 hours of class time to discuss; more if a larger amount of O'Brien's book is explored. However, it could also be pared down to a half-hour discussion.

<u>Preparation</u>
Students should read the following before class:

O'Brien, M. (2000). *Making Better Environmental Decisions: An Alternative to Risk Assessment*. The MIT Press.
Ch. 1 – "Goal: Replace risk assessment"
Ch. 2 – "How does risk assessment actually work?"
Ch. 3 – "What are we defending with risk assessment?"
Ch. 13 – "The essential features of an alternatives assessment"

Precautionary Principle
The Precautionary Principle - World Commission on the Ethics of Scientific Knowledge and Technology: ***ONLY Introduction (p. 7-16)***
http://unesdoc.unesco.org/images/0013/001395/139578e.pdf

Kriebel, D., Tickner, J., Epstein, P., Lemons, J., Levins, R., Loechler, E. L., Quinn, M., et al. (2001).
The Precautionary Principle in Environmental Science, *109*(9), 871–876.
http://www.ncbi.nlm.nih.gov/pmc/articles/PMC1240435/pdf/ehp0109-000871.pdf

If the time spent on this module is on the shorter side, do not assign Kriebel. If longer, consider assigning Chs. 4, 5, 10-12 of O'Brien as well.

<u>Assignment</u>
Before class, student should prepare a 1 page response to one of the following:

1) How does alternatives assessment complement the Precautionary Principle? What are some concrete examples of alternatives to specific risks in the case of the MCHM spill? How would application of the Precautionary Principle have changed the response around the West Virginia MCHM case post-spill?
   Grading Criteria: 1 point for discussion of alternatives assessment and PP. 1 point for at least 2 concrete examples of alternatives to specific risks in the MCHM case. 1 point for discussion of how PP would alter the response post-spill.

2) Discuss O'Brien's example of shifting risk assessment for dacthal in the groundwater in eastern Oregon, and compare to the risk assessment for MCHM's safety. Describe the flaws and subjective judgment calls in each. Discuss the case for alternatives assessment with regards to these two examples of risk assessment.
   Grading Criteria: 1 point for discussion of both risk assessments' methodological flaws. 1 point for discussing the room for subjectivity in each. 1 point for convincing argument around the use (or non-use) of alternatives assessment given these two cases.

Talking Points/Discussion Walkthrough

Mary O'Brien's advocacy for "alternatives assessment" is especially relevant to the chemical spill. O'Brien says that instead of trying to assign probabilities to risks, one should attempt to completely eliminate the opportunity for them. In this instance, preventing storage tanks of unstudied chemicals from being placed accessibly upstream of a major water source.

Discussion: *What are some examples of complete alternatives to specific risks we have identified in the WV MCHM spill?* (using examples from their homework, e.g., storage site relocation or spill barriers such that spilled chemicals did not have access to the river)

Discussion: *Kriebel et al. raise the issue of Type III errors, where the problem is bounded inappropriately to make it more tractable (e.g., looking under the streetlight for one's keys because the light is better there). How does this relate to traditional methods of risk assessment?*

The level of detail on the Precautionary Principle (PP) (and the extent to which they read the UNESCO link) can be tailored to the class. Discussion questions can be wide-ranging, but samples are below:

Discussion: Is the Precautionary Principle a useful approach to address potential environmental risks? Opponents to the precautionary principle assert that an excess of caution could create a regulatory nightmare and inhibit development. Should the principle be given teeth, and if so, how many? At what financial cost? Before this disaster, would you have advocated for testing of all the TSCA chemicals? Do you advocate for this position now?

Discussion: PP is more prevalent in Europe than the US. Why might this be the case? If cultural views devalue environmental risks or oppose regulation, how might this create a climate inhospitable to the adoption of PP?

Discussion: Is the PP suitably open-ended in order to be as far-reaching as is necessary to cover a wide array of risk scenarios? Or is it too vague in its prescriptions of risk assessment? Is O'Brien's alternatives assessment a meaningful way of navigating "how" precaution should be exercised?

Optional Risk Module 2: Informational Asymmetry, Trust, and Experts

Module Goals:

- Students will understand informational asymmetries between a firm and the surrounding community, as well as asymmetries within a community.
- Students will understand how knowledge gaps can cause trust issues between experts and laypeople.
- Through Robert Wynne's case of Cumbrian sheep farmers, students will understand how laypeople's experiential knowledge can be useful in ensuring the real-world validity of risk assessments, and can in some cases trump "expert" knowledge.

Estimated Time:
This module will likely take 1.5 hours of additional class time.

Preparation
Students should read the following before class:

Kulkarni, S. P. (2000). Environmental ethics and information asymmetry among organizational stakeholders. *Journal of Business Ethics*, *27*(3), 215–228. doi:10.1023/A:1006340624326
http://link.springer.com/article/10.1023/A:1006340624326#page-1

Slovic, P. (1999). Trust, emotion, sex, politics, and science: surveying the risk-assessment battlefield. *Risk analysis : an official publication of the Society for Risk Analysis*, *19*(4), 689–701. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/10765431

Wynne, B. (1996). May the Sheep Safely Graze? In S Lash, B. Szerszynski, & B. Wynne (Eds.), *Risk*, *Environment, and Modernity*. Sage Publications Ltd.

Assignment
One page response paper on the following prompt, before class:

Discuss how experts and laypeople can differ in terms of: 1) access to information, 2) interpretability of information, 3) what motivates their risk assessments, and 4) how they bound problems (how much are circumstances controlled, how much are interactions with the environment and inherent uncertainties taken into account).

Grading basis: 1 point for each of the 4 elements of the dialogue.

Talking Points/Discussion Walkthrough

Slovic argues that cultural heavily impacts the subjective severity of a risk (for example, a "white male effect" where white males systematically view risks as less severe than other demographic groups). He ties this to Dake's orienting dispositions, which include people's locus of control (how much they feel in-control of their own lives), desire for equity, and belief in the value (and independence) of individual achievements. For more information on these cultural factors that influence risk perception, interested teachers should investigate Douglas and Wildavsky's Cultural Theory of Risk, which places individuals on a 2-axis cultural group-grid which maps strongly with their risk perceptions on different issues. This has been used to study how both liberals and conservatives polarize as they achieve greater education in their attitudes toward climate change (an example of *confirmation bias*) by Dan Kahan:

> Kahan, D. M., Peters, E., Braman, D., Slovic, P., Wittlin, M., Ouellette, L. L., & Mandel, G. (2011). The Tragedy of the Risk-Perception Commons : Culture Conflict , Rationality Conflict , and Climate Change. *Cultural Cognition Project working paper*, (89). http://papers.ssrn.com/sol3/papers.cfm?abstract_id=1871503

Through Slovic's paper, teachers can lead a discussion of how these differing worldviews influenced people's openness to having the environmental risk of a nuclear power plant in their backyard, and how worldview can create polarizing responses based on how risk information is framed and the affective (emotional) response it elicits.

Discussion: *How might these cultural frameworks create disparities in risk perception between the individuals in different communities (especially those at risk for environmentally- and medically-risky developments) and individuals coming from firms in charge of the development?*

Discussion: How much do you think these biases influence scientists? How much are they impacted by their conflicts of interest, and how much by more implicit forces (e.g., cultural factors)?

Discussion: How are informational asymmetries between different communities exploited when choosing hazardous site development?

Discussion: What informational asymmetries can you list in our MCHM spill case?

Wynne's case of the Cumbrian sheep farmers sends a powerful message. Because the farmers knew the soil types that their sheep grazed on, as well as the behavior of the sheep if they were confined at length, they had relevant information that should have been factored in by the scientists. Ignoring these details meant that their field experiments were not ecologically valid and had severe confounds from the outset. This is an example of informational asymmetry, but also one where experiential layperson knowledge was very relevant to the work of "experts", who ended up making a Type III error (bounding the problem incorrectly, as discussed in the Precautionary Principle module).

Discussion: What does Wynne's case say about "layperson" knowledge? What does this suggest about communication between the scientists and the community?

Discussion: In the MCHM spill, when was experiential layperson knowledge useful? How could it be better mobilized and utilized if a similar spill occurred?

Optional Risk Module 3: Probabilistic versus Ambiguous Risk

Module Goals:

- Students obtain an understanding of differences between our processing of risks which can be quantified and those which remain ambiguous.

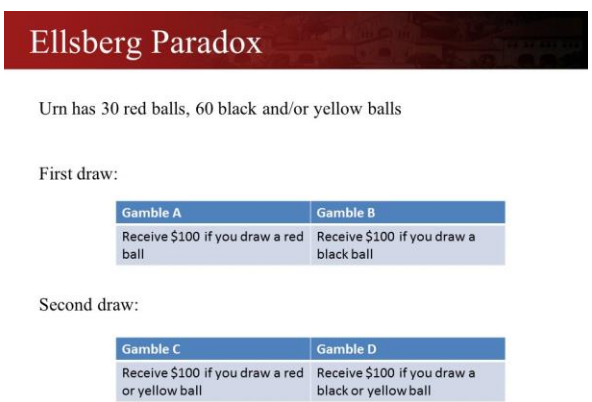
Estimated Time:
This module likely will take 30 minutes of additional class time.

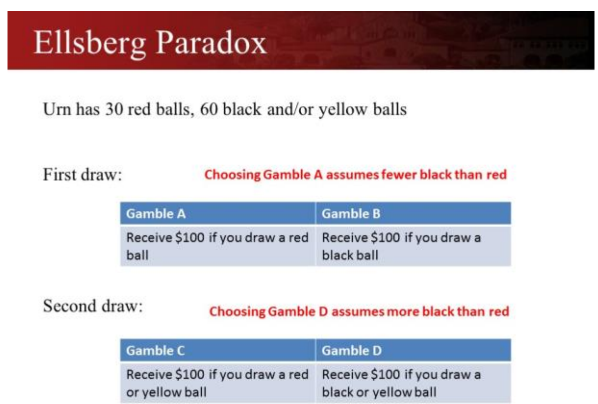
<u>Preparation</u>
No preparation is necessary by students in order to teach this module.

<u>Talking Points</u>

"Ambiguity is uncertainty about probability, created by missing information that is relevant and could be known." – Frisch and Baron, 1988

Individuals have radically different approaches to risks where they know the probabilities (probabilistic risk), versus those where they don't (ambiguous risk). Environmental risks, due to their complexity, often fall within the ambiguous risks category. An easy way to show our innate bias against ambiguous risk is to explore the Ellsberg Paradox with students - in our experience every class will heavily display predictably irrational preferences in this task. Essentially, there are 2 choices between 2 gambles (as below, with replacement of the drawn ball between draws), and individuals prefer the gamble with less uncertainty - even though these preferences reveal a contradiction in their beliefs about the distribution of colors in the urn. For a full treatment see Ellsberg (1961).[23]





[23] Ellsberg, Daniel (1961), "Risk, Ambiguity, and the Savage Axioms," The Quarterly Journal of Economics, vol. 75 no. 4 (November 1961)

In the brain, ambiguous circumstances activate the amygdala, which handles fear and anxiety response, and deactivate the ventral striatum (reward pathway), making rewarding stimuli in uncertain circumstances less attractive. More information in Hsu et al.[24]

Many systems have inherent ambiguity due to their complexity (think of climate change interactions). However, when evaluating risks, we perceive ambiguity from a variety of sources:

- If people question the credibility of information sources, or see expert disagreement, they may perceive greater ambiguity in the system. Thus media coverage which people do not trust, or which creates an atmosphere which implies expert controversy over an issue, will create a more ambiguous context for risk evaluation.
- Similarly, even if the probabilistic risks in a system can be well-articulated, uncertainty about how to weight each piece of the puzzle can create ambiguity in risk analysis. In the MCHM spill for example, when quantifying the risks, how much do you weight the likelihood that the tanks will become structurally compromised? That the MCHM will persist through the water supply? How long do you anticipate it staying in the water supply once there? All of these pieces interact and often in risk assessments, some subjective weighting comes into play.
- Heath and Tversky (1991)[25] propose that competence (knowledge, skill, comprehension) creates a gap between belief and decision weight. If the issue is in a domain where you feel more informed, your perception of ambiguity is less.
- Much of the discomfort with ambiguity is the belief that others have privileged information: "Avoid betting when you lack information others might have."
- People prefer betting on future events to past ones, because not knowing what happened in the past (when someone else might) undermines competence.
- In summary, people depend not only on the *degree of uncertainty* (subjective probability) but also on its *source.*

Because ambiguity aversion is amplified in situations where others possess the information you're missing, informational asymmetry in environmental risk situations will amplify ambiguity's influence on individuals' fear and anxiety.

[24] Hsu, M., Bhatt, M., Adolphus, R., Tranel, D. & Camerer, C. F. Neural Systems Responding to Degrees of Uncertainty in Human Decision-Making. *Science (80-.).* **310,** 1680–1683 (2005)
[25] Heath, C. & Tversky, A. Preference and belief: Ambiguity and competence in choice under uncertainty. *J. Risk Uncertain.* **4,** 5–28 (1991)