Inevitably Toxic

Sarathy, Brinda, Hamilton, Vivien, Brodie, Janet Farrell

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Epilogue

Containment

DISCUSSING NUCLEAR WASTE WITH PETER GALISON

Interview by Vivien Hamilton and Brinda Sarathy

The rich and nuanced stories in this volume deepen our understanding of the multiple ways in which toxic environments have been created and continue to be sustained. You may feel, as we do, overwhelmed by all that remains debated, unknown, and uncertain. However, simply acknowledging that uncertainty seems to be an important first step in confronting our toxic present. As so many of our cases have shown, the creation and regulation of contaminated places has historically favored economic growth and military-industrial interests. Uncertainties around toxicity have either been ignored or used to justify action rather than caution. But in recognizing that pattern, we can imagine acting otherwise in the future: we might move ahead with greater caution, anticipating and planning for toxic substances rather than reacting to an environmental or health crisis already under way.

The histories in this collection also help us to imagine a more active partnership between citizens and scientific experts. These cases show how an easy reliance on expert opinion is complicated when experts from different disciplines, or even within the same discipline, disagree about the nature and safety of toxic spaces. Even when there has been clear consensus, expert knowledge has often been suppressed due to structures of military or industrial secrecy. This prompts us to have a more critical and deliberate

political conversation about what is known and by whom, and to do a better job of acknowledging the voices of those harmed by toxic exposures so that we can incorporate that knowledge into policies and decision making around toxic substances.[1]

As we begin to envision ways to minimize and better regulate toxics moving forward, we also need to confront the reality of the toxic landscapes we already inhabit. This volume has shown how the invisible nature of toxic agents can lead to appearances of normalcy or innocuousness, which contribute to a lack of urgency around risks of exposure. Whether it is urban drilling sites that have been artfully masked by landscape beatification schemes, the silent seep of chemicals into underground aquifers, or the sheer insensibility of radiation, the imperceptibility of toxicity has obscured a clear path to action.

This collection is one attempt to make the all-pervasive reach of toxic spaces more visible, but it is clear that there is no silver bullet for the problem of toxic contamination. The very nature of nuclear and industrial waste, and the entanglement of petrochemical products in almost every facet of life, renders the issue of toxic pollution a "wicked problem." Such problems are large scale and constitute "long-term policy dilemmas in which multiple and compounding risks and uncertainties combine with sharply divergent public values to generate contentious political stalemates."[2] Yet, stalemates or not, it is incumbent on society to do something about toxic contamination. As historian of science Peter Galison states in the interview that follows: "There is no way of avoiding these questions. We have to figure out what's the best among alternatives, none of which are perfect."

We have chosen to end this collection with a consideration of one of the most urgent challenges currently confronting us: the problem of how to store nuclear waste safely and communicate the dangerous nature of that waste to civilizations that will exist millennia from now. In the remaining pages, we engage in conversation with Peter Galison, whose recent film with Robb Moss, *Containment* (2015), explores the fraught problem of long-term nuclear waste storage. The film takes us to radioactive wilderness in Fukushima, Japan, to nuclear weapons plants and a waste storage facility deep underground in the United States, and to a distant future in which generations will need to be warned about the presence of this almost timeless danger. We encourage readers to engage with this interview as a companion to the film and also to this book. Our conversation with Galison connects with many of the themes covered in this volume (scientific expertise, toxic

contamination, and political contestation) with a focus on the most terrifying example of toxicity we have considered yet—that of nuclear waste.

SPACE AND TIME

Vivien: One of the big questions that emerges from the case studies in our book is one of responsibility. Who feels responsible for managing toxic spaces and for communicating risk? Who do we feel responsible to protect? Whose danger gets acknowledged?

Peter: Hard questions of responsibility arise when we look at how to dispose of uranium, plutonium, and all of the by-products of fission up and down the periodic table. What is impressive to me is that such a concrete issue of waste throws into question fundamental aspects of how we think about the politics of space and time.

For instance, if you ask the people who are living right near the Carlsbad, New Mexico, salt mine (the Waste Isolation Pilot Plant, WIPP) that is being used as a deep ecological repository for nuclear waste, many favor it—the work has launched a significant economic boom. As former Carlsbad, New Mexico, mayor Bob Forrest says in the documentary, it provides a thousand jobs that, with benefits, pay $100,000 apiece in a part of the world that is not filled with high-paying jobs. So, if you think of families of four, in a town of 25,000, you have got four thousand people, or 17 percent of the city directly affected. Then there are all those businesses that support or are supported by the effort: in total, the waste industry is a big part of the local economy. The WIPP is a powerful part of the economic life of Carlsbad.

But what about the rest of the state? The northern part of New Mexico frequently votes Democrat; the southeast is distinctly Republican. There are differences in people's relationship to the federal government as well as different patterns of ethnic and political composition. In the south, it is not uncommon to hear people talking about how great it has been to have the WIPP, and in the north people have often been quite opposed—I am generalizing to be sure—but that is an overall feeling. This split goes back decades. So, then, the question is, who should decide? Is this an issue for the proximate neighbors of the plant in Carlsbad and a few surrounding towns? Does New Mexico as a whole get to make

the decision? What about the states around New Mexico? The waste is transported through other states on its way to WIPP. Do citizens in those other states have a vote? What about the country of Mexico? Mexico is closer to the WIPP site than the WIPP site is to the biggest city in New Mexico—Albuquerque. In all the research I have done over the past decade, I never saw a single document that raised the idea that Mexico might have a view about this. Energy policy has rarely been able to transcend national boundaries, even if nuclear accidents do. Chernobyl's plume did not stop at the Ukrainian border.

In addition to spatial questions, there are the temporal ones. As we make decisions today, we can ask: To which generation are we responsible? Are we only obligated to people living now? To the generation of our children? To that of our grandchildren? Five generations? A hundred generations? Four hundred generations? In order to open the WIPP site in New Mexico, Congress had the Environmental Protection Agency (EPA) determine the period during which people should be adequately warned against inadvertent intrusion into the waste. Taking into account the half-lives of the radioactive materials (e.g., plutonium-339 has a half-life of 24,100 years), balancing that against the age of our civilization since writing, the EPA set the era of immediate responsibility at ten thousand years. After protest from various quarters, and reckoning with some of the much-longer half-lives involved, the National Academy of Sciences urged the Yucca Mountain site in Nevada to follow a *million*-year period in protecting and warning the future. A million years from now, we may not even be the us of our species self. I mean that literally: "we," as homo sapiens, emerged from homo erectus around 200,000 to 300,000 years ago; we homo sapiens were surely not in existence in our anatomically modern form a million years ago. There is no reason to expect that "we" (in that sense) would be around a million years from now. Does this mean giving up on the far future altogether?

I do not see a conflict between the future and the present: you cannot safeguard the future without taking care of the present. Indeed, to think about the future can reinforce our care in taking action now; to care for the present is to make a first and needed step toward safeguarding the far future. However, it is sobering to think how difficult it is to contemplate hundreds or thousands of years down the line. We may be ill-equipped to address the future, but we have created a world with nuclear materials that makes thinking about that future mandatory.

Brinda: In the documentary, it was striking to see so much thought and resources put into conveying dangers to future generations that we will not even know. By contrast, there was little warning or explanation for communities in the present. I am thinking of the scene in Burke County near the Savannah River Site, a vast nuclear complex owned by the Department of Energy. There is a "no trespassing" sign but not much else in the way of explanations about danger.

Peter: That is true. The young woman driving the boat on the Savannah River says, "It says 'no fishing,' but it doesn't say *why* no fishing." And she adds, "People think it's a territory thing, not a radioactive fish thing." Burke County (Georgia) is right across the river, just fifty feet from the Savannah River Site (SRS is in South Carolina). An SRS advisory urges people to eat just one meal a week of mudfish or largemouth bass from the river because of the cesium-137, Strontium-90, and mercury.[3] On the Georgia side, they report that there are no consumption guides for the cesium and strontium issued.[4] I read an article once warning people against eating more than twenty-five kilos (about fifty-five pounds) of fish a year caught near the weapons facility. The article had an asterisk, and in the footnote it said that, in fact, many African Americans in this area eat more than that. It turns out that many people in Burke County rely on fishing for food; a lot of their protein is from fish from the Savannah River. It is a matter of pride for some in the county that they are not on a public handout program—and they have been fishing for generations. These are old communities that go back to the time of slavery. These people are more than an asterisk. It is indeed important that contemporary fish consumption warnings be clearer and more widely distributed as well as consistently presented across state lines.

So, no doubt the present is important, urgent, a matter of health and justice. That said, I do not think that the resources spent on warning the future are pointless or a distraction. By forcing us to think about future dangers and communication with the future, we can find better ways to assess contemporary dangers, mitigation, and warnings. I do not see it as a choice that *either* you warn the future *or* you warn the present. We must understand the reality that subsistence fishing in this area is an integral part of some residents' food supply. To be effective, warnings must intersect with the lives people lead.

COMMUNICATING RISK

Vivien: How should we most effectively communicate risk and danger when we are thinking about many, many generations in the future? In the film, you raise the possibility that myths and stories containing some kind of archetypal character might be the most effective. And yet if we are thinking about the SRS and what we have just been talking about, it seems so important to situate any communication in the particular local experiences of a community. It seems that those two modes of communication are very different from each other. How do we balance talking to a particular culturally, temporally situated group with trying to talk to an imagined future where we have no idea, culturally or socially, what it is going to look like?

Peter: Thinking about the culture surrounding the messenger, message, and recipient is crucial. We do not do a good job with that. If you go on YouTube, you can see people cheerfully, proudly breaking into the old atomic airplane research station (Georgia Nuclear Aircraft Laboratory), where much radioactive material lies buried; people have cut the chain-link fence, squeezed underground, clambered onto the structures for the frisson of penetrating the secret and the dangerous. Once something is no longer in use, it is hard for companies or governments to find the motivation to guard them with the utmost vigilance. Almost instantly, abandoned sites get transformed for reasons ranging from the recreational to the economic. As Adriana Petryna has documented in her work, local scavengers regularly go into Chernobyl to dig up radioactively hot copper piping and sell it on the black market.[5] No mystery here: they are poor, and they need the money. People break into other places as a kind of dark tourism, curiosity, or adventure.

As long as the WIPP site is in use, no one is going to bust into it. Private security guards provided with trucks and automatic weapons guard the facility day and night. I was filming there with Robb Moss one day after we had detailed discussions with the head of the WIPP site about filming after the plant was closed for the evening. I said, "I want to make sure that nobody thinks we're illegally there." The plant director said, "No, no, don't worry, we'll take care of it." We set up the camera, we started to shoot, and a militarized vehicle pulled up with armed guards not at

all happy to see us. I'm glad the site is well guarded. That is now. A very different situation will surely exist thirty years after the site is closed.

Judging by our experience with ancient sites, the more types of warning we establish, the better our chance of being understood now and in the future: inscribed text, multiple languages, easily understood images—even stories. Questions of preventing exposure obviously are particularly salient in the nuclear case, but there are similar issues with myriad other substances, from e-waste and mining slag to chemical effluents. Thinking about communication is crucial, and if we could learn something about the difficulty of warning the distant future, perhaps it could help us in the here and now.

SECRECY, EXPERTISE, COMMUNITY

Brinda: Could you speak a little bit about the nature of secrecy while you were making the film? It was interesting to hear one of the interviewees saying, "There are problems with nuclear storage, but I can't talk about that." It seems that secrecy poses limits to communication and sharing specific information.

Peter: That comment was from Allison Macfarlane, the former chair of the Nuclear Regulatory Commission (NRC), where she served from 2012 to 2014. She started to talk about things that could go wrong, and she said that she could not speak about certain classified dangers, dangers presumably having to do with a potential terrorist attack at some of the nuclear power sites. The problem occurs in any discussion about risky technologies: How can we discuss dangers—to prepare for them—without also giving an instruction manual to people who would want to do us harm? It is clear, for instance, that any cutoff of water to the waste fuel pools would be a very bad thing. In Fukushima, you recall, the plant lost outside power because of the earthquake, and then the tsunami flooded and destroyed the backup diesel-powered pumps. Without cooling, the stored fuel rods overheated, and the pools started to boil off. The then prime minister of Japan, Naoto Kan, says in *Containment* that if this stored hot fuel had caught fire, the airborne contaminants could have been a threat to greater Tokyo. According to Naoto Kan, some fifty million people might have had to be evacuated, a calamity that would have

endangered the very existence of the modern state of Japan. No one has any idea how to evacuate so many people in one urgent go. It has never been done: the vast evacuation in Britain at the outset of World War II saw some three million people moved to the countryside. Because nuclear disasters are thinkable at such a scale, secrecy matters, not just for military nuclear capacities but for the civilian sector as well.

I think there are ways that secrecy can actually make things more dangerous. Secrecy is complicated. We do not want to see on the web detailed instructions for how to make nerve gas. I am really happy that that is not on the web (or I hope it isn't). At the same time, there are cases where secrecy can cover up bad or shoddy practices and lead to things being much more dangerous than they would have been otherwise.

Vivien: One of the things we have grappled with in this book is understanding the role that scientific experts have played in making decisions about safe levels of exposure for different toxic agents. It feels as though there is a continuum between things that are deliberately kept secret and issues that come into play when you have scientific experts with a special kind of knowledge. This makes some of the assessment of risk inaccessible simply because of a particular specialized vocabulary. Communities then react to scientific pronouncements with trust or suspicion, without necessarily being able to follow or understand all the decisions that are being made by experts.

Peter: Some people living in a technical bubble simply do not think about communicating with people beyond that world. Such outward address seems unimportant, not their job, not interesting, or not rewarding. That is one problem. Some companies keep things secret because they want to protect proprietary information, save money, resist public criticism, and negotiate from a position of strength with employees, unions, and regulators. Sometimes secrecy is just a prosaic cover over cost savings: with the Bhopal disaster in India, one of the significant problems was that the company that ran the plant had cut back on safety procedures to save money and speed up production.

Then there is the secrecy around the specifics of nuclear power and nuclear weapons, which have been shrouded since the beginning of the nuclear age in the 1940s; that has gotten us into trouble over many decades. Just think back on the U.S. Atomic Energy Commission's experiments.

Pregnant women, prisoners, soldiers, and "downwinders" were exposed to some very high doses of radioisotopes. It was only after 1994, under Department of Energy chair Hazel O'Leary in the Clinton administration, that much of this information (some 1.6 million pages of documentation) was released. Unsurprisingly, that decades-long period of secrecy and misrepresentation exacerbated mistrust toward things atomic and made it harder for the Department of Energy to persuade people even when their science and intentions would have benefited the civilian population. All over the world, nuclear technologies and secrecy have been intertwined.

In some ways, we live in a more open world now. In other ways, secrecy has *increased* as more and more of the nuclear establishment has become corporate and the big weapons labs and other labs have shifted from government to private control. You might think, "Oh, well, that's better. The government is the most secret entity." I do not think that is true. There is no Freedom of Information Act for corporations. My big worry, actually, in many of these cases is about corporate secrecy more than it is about government secrecy. If you go to a private chemical plant and say, "I'd like to see documents surrounding your founding and safety records," they will simply say "no." That is the end of the discussion. If you go to a government plant that does the same things, they often say, "Well, here are the things we can release, and here are the things we cannot. You can then apply for those documents through the Freedom of Information Act, and if that fails, you can move it up the chain to the appeals process. In the event of an appeal, the request goes all the way up to the highest-level group that deliberates about what can and cannot be disclosed. Even then, at that ultimate level of adjudication, they release a significant fraction of the materials. There is no such analog process in the private sphere, and I think this kind of secrecy is often not discussed. The more restrictive element is often now lodged in the private sphere—this was indeed my experience with Robb Moss in making *Containment*.

Brinda: And in addition, in the corporate sector, research is often done by corporate scientists to deem whether something is indeed safe or not. For example, how do we actually regulate practices like hydraulic fracking, which may lead to contamination?

Peter: In Josh Fox's film *Gasland* (2010), he talks to the companies that inject the liquids into the ground, which often contaminate the ground-

water, but those processes are proprietary. What these companies do is held back but not for some national security reason. No, the secrecy is about protecting their particular mix of chemicals used under pressure to release the gas from the matrix of rocks. So they say, "No, we absolutely are not going to tell you what is in it." It has been a long-running legal battle to get companies to disclose the chemical mix being used, to standardize their practices, and to conform to EPA standards for keeping the water supply safe.

In disposing of waste, both government and the private sector need to consult the community. The tendency toward secrecy has, over and over again, led to confrontation. I was reading recently about an experimental borehole proposed by the Battelle Memorial Institute, three-mile-deep holes that might be prototypes for a means of burying nuclear waste—an alternative to the deep-mine repository, like the one in Carlsbad. A first recent attempt was in North Dakota. The local rural community found out about it in February 2016 and then only by reading the local newspapers. They were furious. No one had told them what these holes were for or what was going to happen if the tests were successful, or even that this was preliminary to the burial of nuclear waste.[6]

Several hundred people came to a meeting (not a trivial fraction of the community), and they blocked it. Then the project leaders moved their experiment to South Dakota, where local rural resistance stopped it again. This reluctance to be open about nuclear matters runs long and deep—and the scientific-technical planning was for naught. There was nothing inherently secret about digging a three-mile-deep hole in the ground, and the company did not even plan to put nuclear materials in it. However, they were not up front with the community, and two communities, infuriated, struck back. This cycle repeats itself over and over with toxic materials. When corporations or government agencies do not communicate with the community, when they pull wool over the eyes of the public, when they think they will reduce conflict by squelching disclosure, they often discover that secrecy makes things much worse.

Vivien: I wonder about what is really being communicated and what the community is hearing. At the WIPP site, people were told that science had proven that nuclear storage was going to be safe because salt beds at the site had not dissolved over many millions of years, and so the nuclear waste was going to be perfectly stable. Did local residents consciously

embrace risk in order to get the economic benefit from the waste site? Or was it more of a blind trust in the idea that there are scientific experts out there who have deemed something to be safe?

Peter: Think about manned spaceflight. You cannot make launching rockets perfectly safe. You are dealing with extremely high temperatures, and you have people sitting on top of a vast tank of exceedingly explosive material. We do not *have* to send manned missions into space; if we do, we need to understand the risks. We must, however, deal with nuclear waste because it is already among us, left over from almost seventy-five years of Cold War weapons and a half century of nuclear power production. Bad planning, national security pressure, and economic demands join forces: together they have left us with a vast legacy of waste.

We cannot leave the nuclear waste untouched in its unstable pools, tanks, and canisters, but there are no perfect solutions. The worst of all the solutions is to leave the 80 percent or so of fuel rods that now sit in cooling pools packed to the gills with both new, hot fuel and older cool fuel. Many of these pools are high aboveground, high in the air to facilitate transfer from the reactors. If a storage pool loses the cooling water, the hot fuel can catch fire and ignite the older, cold fuel. Among other measures, it seems clear that we must minimize the used reactor rods contained in these pools—that is, take out the old, cold rods that have been there three, four, or five years or more, reducing the consequences of a loss-of-cooling event. Then the question is, What are you going to do with that waste? It is not a choice between the one true, perfect solution and other bad solutions. It is a choice among imperfect solutions, each with risks, some more risky than others. When I talk about transparency, I mean not pretending that these things are risk-free, but instead I am urging that we talk soberly and realistically about the alternatives.

Containment judges that, ultimately, the waste is safer underground than it is on the surface. That does not mean that putting it underground is going to be absolutely safe. Indeed, one of the buried underground drums had the wrong mix of chemicals in it, leading to a fire and a leak. Former chair of the NRC Allison Macfarlane is clear that there is "no magic," as she puts it—the waste will not go away. Her point is reinforced by the accident: the underground is not perfect.[7] Still, had that same accident occurred aboveground it would have been far worse. A crucial part

of communication is giving people an understanding of the real risks and the tools they need to assess realistic alternatives.

(IN)VISIBILITY AND MATERIALIZATION

Brinda: This raises the larger question of what is visible and what is not. Nuclear weapons were out of sight of the public for so long, but in this book we are also talking about everyday waste and thinking critically about the processes of production. The United States is always talking about growth, naturalizing economic growth, and waste is the invisible outcome of that. There is justifiably so much fear around the issue of nuclear waste, but toxic waste is also the invisible by-product of consumer society.

Peter: Radioactivity is not apparent to us through sight, taste, or touch. It is not like a river turned to green suds or the carcass of a freighter being disassembled in Bangladesh. We use instruments to try to make radioactivity visible. Then there is the waste itself. As soon as something is dubbed waste, we want to avert our eyes. We do not want to look at sewage and sludge. We react with disdain, even disgust. There is a remark attributed to various famous physicists that put it directly: "No one will win a Nobel Prize for solving the nuclear waste problem." If you are a physicist, chemist, or metallurgist, prestige goes to new theories, novel instruments, and innovative experiments, not to sludge treatment.

A large part of the work I do both in print and film is designed to make things concrete. I want to see abstractions through their concrete manifestations: seeing the size of a million-gallon tank, or peering into those tanks; looking at the x-rays of waste material as it is being brought to WIPP; and seeing the trucks, staging areas, cooling pools, salt mines, the SRS, and Fukushima accident video records. Understanding means recognizing that these things have, as Bertolt Brecht might have said, a name and an address. Because waste is often hidden—or set in sparsely populated or impoverished counties—it is crucial to make the problem visible. As long as these issues remain cloudy abstractions, they remain both out of sight and out of mind.

It is worth underscoring that waste is often invisible not because of physics or our reluctance to think about the discarded, but because it is

put into communities that are racially or economically marginalized. Most Americans probably do not know that a big part of the uranium for the American nuclear arsenal came from the Navajo Nation. Indeed, the Navajo Nation has had a thousand uranium mines on it, and those mines operated with poor safety oversight. Accidents keep happening even after the mines are closed. Houses have had to be torn down, and there are always worries about groundwater contamination. A particularly bad accident occurred on July 16, 1979, when United Nuclear Corporation's Church Rock uranium mill (northeast of Gallup, New Mexico) had a catastrophic failure of its retaining pool for radioactive sludge. Some thousand tons of solid radioactive detritus and ninety-three million gallons of acidic sludge broke its pool and ran into the Puerco River. When that pool broke, the sludge came in a flash flood down the hills—children were playing in it, and animals drank from it. It was a disaster, but the general public, away from what is now a Superfund site, is largely unfamiliar with the incident. More generally, many people may not even be aware of the crucial part the Navajo Nation played in providing uranium for the Cold War weapons complex. We need to make things visible in order to confront their materiality and their location, and to make it both understandable and politically addressable.

Brinda: There are often harmful yet innocuous-looking landscapes in highly populated areas. Superfund sites are a good example of this. You might see injection wells in the ground not far from residential communities but have no meaningful understanding of what you are seeing or the history of a particular site. We live a mile away from freeways where populations are exposed to fine particulate matter that is known to be carcinogenic. All this is visible but also invisible because it is normalized. How, then, can we mobilize against such ubiquitous toxicity?

Peter: To me, an essential first step is materializing things. If you do not have an idea of where toxicities are or what they are like, it is hard to address them. We barely grasp what we cannot picture. That is why when I look at the history of physics I am interested in laboratories, equipment, and the procedures of image making. Learning from the materialization of things often tells us about how to understand the abstract. And if we do not have a sense of where toxic things are, what they are like, and whom they affect, it is hard to mobilize any kind of action.

There are different strategies for materializing (or perhaps rematerializing) toxic environments. We can write with the kind of evocative, human, spatial specificity we need. I think many of the authors in this volume are doing just that. It is crucial, I think, that other forms of visibility—film, photography, exhibits—complement the written word. There are also other ways of making things visible: for example, new forms of maps that show the distribution of plastics or organic compounds or nuclear materials. These maps let people know more about the dimensions and shapes of things such as the radon prong that goes up through Pennsylvania, which has affected lots of people. This kind of information can alert people about installing the right kind of equipment so that the presence of radioactive dust can be known.

Vivien: I understand what you are saying about the need to make something that is invisible visible by emphasizing its materiality. Yet, as the case studies in this book have shown, some of the effects of toxicity on the body are complex and difficult to establish epidemiologically. When we reduce toxic effects on the body to material tumors, for example, are we perhaps ignoring more holistic understandings of mental and emotional health and well-being?

Peter: By materialization, I do not just mean of the contaminants. I mean we have to make visible the real lives of people who live in and among toxic environments. When we look, really look, it is clear that lives are not run only on doses and dose-response curves. Mr. Sasaki, the older man in *Containment* who goes back to his house in Fukushima every other day, shows us a great deal. He would like to move back permanently but cannot: put aside the cesium-137, and there are no stores, no nurses, no doctors, no hospitals; he cannot bring back family since there are neither jobs nor schools.

Second, there is, as your question suggests, fear. Too often we read or hear experts say that fear is not real, that their calculations suggest that people could move back to the areas around Chernobyl or Fukushima or some Pacific islands without a large increase in cancer rates. Here the various themes we have been discussing intersect. Secrecy and the concomitant minimization of risk by authorities in many countries have left people without faith in nuclear reassurance. Couple that with a casual dismissal of trauma and anxiety, and you have a recipe for never understanding the lives people actually live. You can tell people that

their children would only suffer a 1 percent chance of contracting cancer due to exposure near the Fukushima plant, but is it then really a surprise that people say: "Thanks, but I'll live elsewhere." In recent years, at long last, PTSD has gotten better traction, at least for returning soldiers, as a "real" disorder. We can only hope that our societal stance toward acute anxiety, depression, and other difficulties will come to be treated with the seriousness with which we treat cardiac arrest or staph infections.

Third, there are challenging technical questions. What dose did people get? This is often *very* hard to determine. Unless you are near the explosion of an atomic bomb, where simple geometry can tell you how much gamma radiation you received, it is more or less impossible to calculate a dose of radiation accurately, even if you know a worker was in a certain plant over a period of, say, ten years. Exposure could be entirely different on one side of a hallway than on the other and depend on whether the worker was laboring where radioactive dust was present, or whether the worker had a mask or a breathing apparatus, or whether he or she was typically standing behind a protective vent, next to a milling machine, or outside a glove box. Exposure depends on a great range of details, and, historically, there was very little monitoring, so people do not really know what the doses were. I am speaking here about radioactive doses, but analogous questions arise with myriad industrial chemicals, including asbestos, heavy metals, organic compounds, and other contaminants.

Then there is the question of the relationship between the dose and resulting cancer. That, too, requires statistics, and even the most basic data are debated. At very high levels of radiological exposure, you get immediately sick and can die. Acute radiation poisoning is tragically clear. At low levels, it is still hugely debated. There are even people who say low levels of radiation are good for you. That claim is widely deprecated as bad science, but it is a view that one hears among some pronuclear activists. So, there are confounded levels of uncertainty: if you develop cancer, you can never prove in a particular case what the origin of that cancer was. That is, even if you know your exposure, and even if you know the statistical correlation between exposure and cancer rates, you still cannot know that *your particular* eye cancer, liver cancer, breast cancer, or testicular cancer came from a specific source.

There are many kinds of anxieties that are associated with living in a contaminated area. What does such acute anxiety about exposure do to people as they worry about their future health, or the future health of

their children? No doubt that living in the midst of a radioactive area can be very psychologically damaging, even if these psychological impacts are hard to prove. In Adriana Petryna's *Life Exposed* (2002), the work I referenced earlier, she talks about how people struggled to try to make a claim for psychological damage beyond the physiological damage to activate compensations or housing or schooling or whatever it was that they needed in that all-too-turbulent period of Ukrainian history. Very few paths led to help for people with often debilitating anxiety from having to live in a region of constant radioactivity.

Sometimes people will say, "Well, why did people leave Fukushima? It's really damaging to them to be nuclear refugees." But could you really have stayed there? During the accident sequence itself, no one knew how bad it would get; no one knew if fuel pool 4 would collapse; no one knew whether the reactor meltdowns would result in a far worse loss of containment. It was uncertain for months, by which time the problem of reinhabitation was truly acute, not to mention the ordinary, nonnuclear damage to houses from moisture, mold, and fauna. When experts and politicians ask with surprise why people do not head back, they ignore the trauma that those 150,000 people have undergone.

NUCLEAR LESSONS

Peter: There is a remark at the beginning of Kant's *First Critique* that states that there are some problems we face that we cannot avoid and cannot solve. Some nuclear issues are like that. We cannot turn away and say we do not have to deal with this. You could say we do not have to go to Mars. We could choose not go to Mars or decide not go to Mars for fifty or a hundred or five hundred years. That is a choice. But we cannot leave the waste in these big swimming pools. It is not an option. People say, "Just bury it and don't mark it." Well, oil companies cannot wait to dig underneath the WIPP site because of the staggering amount of oil and gas there. You *cannot not* mark such sites; ethically, it would be wrong and people recognize that. So then you mark the site, but the various marking techniques each present great challenges. Do you make a nuclear Rosetta Stone, do you use pictures, do you use cartoons, do you bury samples, do you make stories up, or do you try to do a little of columns A, B, C, and D?

I do not think there is any way of avoiding these questions. We have to figure out what the best among the alternatives is, none of which are perfect. The larger lesson, it seems to me, is that we need to think about the consequences of producing the waste as part of the production process itself. If you want to make aluminum or you want to make electronics, you should have to bear responsibility for the cost of that socially, politically, financially, and environmentally. We have to think of waste not as something that we can avert our eyes from but as part of the process. That is a big change because people offload those things: "Oh, the mountaintop's unstable in West Virginia because we strip mined it, but that's a problem for the government, for some other generation." We want to get that coal out now, and we have immediate needs. Or we want to make iPhones cheaply in China, and we will deal with the acid effluents some other time. But it is always more expensive to deal with it once it is decontained. It will require a real political and economic change to think about waste as part of the process of production itself. Nobody wants to do that.

Brinda: Do you see links between concerns about climate change, which is a slow-moving crisis of planetary proportions, and concerns about nuclear catastrophe? Is there hope in the face of such monumental problems?

Peter: In a way, as big an issue as nuclear waste is, it is a model, maybe, for the even bigger issue of global warming, where we have done a terrible job of imagining the future. Even though the water is bubbling up in Miami through the waste grates on the ground, you can still have a state government banning discussion or use of the phrase "global warming." If thinking about nuclear waste gets us to reason beyond the political periods of election cycles or the economic periods of fiscal quarters, that would be a great thing.

Is *Containment* pessimistic? I think the fact that in this one solitary instance it actually came to pass that several dozen people with backing from the government produced some thought about how to mark nuclear waste for the distant future is actually a very optimistic turn of events. Mostly, we think in super-short time frames that are not even remotely close to a human lifetime. True, each of the schemes for marking seem to pale before the vast expanse of ten thousand years. Yet there is something very moving, inspiring even, about the government moving beyond the demands of a fiscal quarter to put the ethics of ten millennia on its agenda.

If the ten-thousand-year ambition inspires us to think a little bit more about lead and mercury and organic compounds, if it prompted questioning about the long-term effects of fracking fluids in the water supply and plastics in the ocean, that would be good. To think a little bit beyond the immediate: to think up to parents and grandparents or great-grandparents and down to children and grandchildren and great-grandchildren. Maybe we think that far, but, relative to the long half-life of plutonium, that is a pretty narrow horizon. Thinking spatially and thinking temporally about these issues is really important. As difficult as it is to get at, the nuclear is still a finite thing. There are four hundred nuclear power plants in the world. There are maybe fifteen thousand nuclear weapons. It is not an infinite task, and so grappling with this, and the mining from the beginning of the cycle to the burial, is something that we could at least get our heads around. Perhaps this view beyond our immediate temporal horizon could inform these other issues of prevalent waste, contamination, and, at the largest scale, global warming.

NOTES

1. For a careful consideration of what it might mean to include citizens in environmental policy decisions, see Bäckstrand, "Civic Science for Sustainability."

2. Balint, *Wicked Environmental Problems*. Book description, https://islandpress.org/book/wicked-environmental-problems.

3. South Carolina Department of Health and Environmental Control, "Eating Fish from the Savannah River."

4. Georgia Department of Natural Resources, "Guidelines for Eating Fish from Georgia Waters," 40.

5. Petryna, *Life Exposed*.

6. North Dakota residents of Spink County first heard about the borehole project from local newspapers, greatly worsening the controversy. See, for example, Vossen, "Protests Spur Rethink on Deep Borehole Test for Nuclear Waste."

7. U.S. Department of Energy, "What Happened at WIPP in February 2014."

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