This is an Accepted Manuscript of an article published by Taylor & Francis in *Bulletin of the Atomic Scientists* on September 3, 2018, available online: https://doi.org/10.1080/00963402.2018.1507792.

Chronic long-term risk of low-level radiation exposure: Bridging the lay/expert divide

François Diaz-Maurin [1,2]

[1] Center for International Security and Cooperation, Stanford University, Stanford, CA 94305, USA
[2] Amphos 21 Consulting SL, C/ Venezuela 103, 08019 Barcelona, Spain

Abstract
The failure of experts and lay people to understand each other has been fueling conflict around the environmental clean-up of the many sites in the United States that are contaminated by the nuclear weapons program. This mutual distrust was exacerbated by the culture of secrecy surrounding the atomic weapons program during World War II, and later by the innate culture of bureaucracy in the federal agencies that have sprung up since then. A prime example of this problem can be found in the regulation of chronic long-term risk from low-level radiation exposure affecting communities in Missouri's North St. Louis County. This case study illuminates this divide, and illustrates opportunities to close it.

Keywords
radioactive waste, nuclear weapons production, Superfund site, environmental clean-up, mill tailings, radiotoxic

When Enrico Fermi and his colleagues achieved the first controlled, self-sustaining nuclear chain reaction at their atomic pile underneath the University of Chicago's football stands in 1942, the event was a great scientific achievement. It gave prominence to nuclear physics and paved the way for the production of fuel for nuclear bombs—and later, the production of electricity in nuclear power reactors. But at the time, no one thought about the fate of the radioactive materials being generated. Even when, six years later, some researchers realized a nuclear waste problem existed, it was simply dismissed as "unimportant" by leading scientists such as former Manhattan Project head Robert Oppenheimer (Alley and Alley 2012).

Today, however, the reality is far different. Not only has the generation of weapons-related nuclear waste proved to be a difficult problem to solve, but the sheer volume of material is on a massive scale.

Across the United States, 64 environmental management sites, spread over 25 states, were contaminated by radioactive waste from nuclear weapons production during World War II and the Cold War. To put these numbers in perspective, the US Energy Department annually spends $6 billion on environmental clean-up of nuclear weapons program waste, or one-third of the

entire budget of a department that is supposed to develop future energy technologies, improve energy efficiency, and more. Put another way, this huge overhead almost equals the annual budget of the entire National Science Foundation ($7.4 billion in 2018), which supports public research in the United States.

These costs are important considerations in light of the current administration's Nuclear Posture Review (https://thebulletin.org/experts-new-nuclear-posture-review11480) (US Defense Department 2018) which calls for a complete upgrade of the US nuclear arsenal. Yet the Trump administration is unlikely to give proper management of the back-end of the nuclear fuel cycle a political and scientific priority anytime soon, because its focus is nearly all upon recapitalizing US nuclear forces over the next 30 years.

This situation is not new. The United States has suffered for decades from a stalemate regarding its nuclear waste management program—largely due to the systemic inability of government agencies to highlight the risks posed by not safely managing and permanently disposing of radioactive waste. This denial of both the size and the importance of the legacy of nuclear weapons production has its origins in the historic culture of secrecy of the nuclear program and today's culture of bureaucracy; both have contributed to create a divide between agency experts and affected communities. This can be seen by looking at just one reactor: Enrico Fermi's Chicago Pile–1, the radioactive waste it generated, and the toxic legacy it left behind.

A historic culture of secrecy

Over its lifetime, this one reactor consumed about 45 metric tons of uranium dioxide—essentially all produced at the Mallinckrodt Chemical Works plant in downtown St. Louis, Missouri. When production stopped at the plant in 1947, most of the processing by-products that contained radioactive residuals were trucked away and stored on open ground now known as the St. Louis Airport Site, or SLAPS (US Army Corps of Engineers of the St. Louis District). During transportation, radioactive materials were spilled at various locations along the 12 miles separating the plant from the airport. Over the course of about 12 years, SLAPS stored a total of about 380,000 cubic meters of radioactive material, making it one of the largest sites by volume of solid radioactive waste from nuclear weapons production in the United States (US Energy Department 1997).

In the 1960s, the Atomic Energy Commission sold approximately 121,000 tons of uranium refinery residues and contaminated wastes from SLAPS to the Cotter Corporation, a private company. Once purchased, the residues and wastes were moved to another location in Hazelwood, Missouri, only one mile away from the airport, and stored in two-story, open-air piles. But a series of mismanaged efforts by the company for storing, handling, and transporting the radioactive waste caused about 150,000 cubic meters of these materials to be spread onto several nearby properties. Some of this waste was spilled along the routes that vehicles used to haul the material, while others—such as the open-air piles stored at Hazelwood and left in place there for several decades—were washed by rainwater to nearby Coldwater Creek resulting in radionuclides leaching into the surrounding environment. As if that were not bad enough, approximately 47,000 tons of the same legacy radioactive waste was moved again from Hazelwood in 1973, and illegally dumped nearby at the West Lake Landfill. This radioactive

waste contains mainly uranium 238, thorium 230, and radium 226—all long-lived daughter products of the uranium decay chain. These particles, potentially harmful to humans when inhaled, have been found by the US Army Corps of Engineers in soil samples from public parks and private houses adjacent to Coldwater Creek.

Today's culture of bureaucracy

Since the illegal dump of radioactive materials happened in their backyard, the communities of North St. Louis County are fighting for the clean-up of the West Lake Landfill and remediation of the contamination spread around Coldwater Creek. But in their fight, community members must deal with the culture of bureaucracy in federal agencies.
The word "bureaucracy" literally means rule by desks, combining the French word *bureau*—meaning desk or office—with the Greek word *Kratos*, meaning rule or political power. The word was first coined satirically by an 18th-century French economist, and has since become a synonym for an overadherence to fixed rules, often in disregard to reality; Webster's Dictionary describes bureaucracy as "a system of administration marked by officialism, red tape, and proliferation." Meanwhile, the radioactive waste problems grew worse.

For example, at the West Lake Landfill, an underground fire—known in bureaucratese as a subsurface smoldering event—has been going on for years, slowly getting closer to the part of West Lake where the radioactive materials are located. Any contact between the fire and radioactive waste would lead to the widespread release of radionuclides into the air, causing an even worse environmental and health disaster. In the fall of 2014, the fire was located in the south quarry area of the landfill.

But there was no agreement about whether it was progressing north towards the radioactive waste. Republic Services, the private company that owns and operates the landfill (and is the second-largest waste disposal company in the United States) claimed that the landfill was safe and actively monitored, that the fire was limited to about half the south quarry area, and that it would eventually extinguish itself before getting to the radioactive materials. But an analysis conducted by the state of Missouri found that the fire was already spread over the entire south quarry area and about 1,000 feet from the West Lake side. Complicating matters, the underground fire can only be monitored indirectly, through measurements of temperatures and carbon dioxide emissions from the landfill. According to a former division head at the Missouri Department of Natural Resources—the state regulator in charge of monitoring the area of the burning landfill—evidence of an underground fire had existed since September 2010, when elevated temperatures and CO2 emissions as well as the presence of particles of radium 226 on the surface were first measured at the landfill. The head of unit eventually resigned soon after, saying the department was withholding critical information about the site. Yet, relying on the data provided by Republic Services and without conducting its own monitoring, the US Environmental Protection Agency said in 2014 that there was no conclusive evidence that the fire was progressing towards the radioactive waste.

The situation crystalized the attention of the community living around the landfill. Based on the Missouri Department of Natural Resources' findings, the community living close to the landfill pressed the EPA to remove all the radioactive materials. Instead, the EPA proposed a

contingency plan consisting of the installation of an "isolation barrier" —an underground wall that would protect the radioactive waste if the fire reached it. Inadvertently, the agency thus acknowledged that the fire was indeed progressing and not self-extinguishing as previously claimed. But it was only by early 2016 that the EPA officially acknowledged that the fire was already occupying all the south quarry area of the landfill and announced that it would install the isolation barrier at the West Lake landfill. The EPA's remedial project manager at the time explained: "We are going to take action. … We are going to issue an order. This year. Not next year. This year."

And when first announced, the design of the wall was expected to take 12-to-18 months, but no barrier was ever constructed. Later the EPA reversed its strategy, saying that the wall was technically impossible to build in due time. In another public meeting in March 2018, the EPA announced its intention to remove 70 percent of the site's radioactive waste within five years.

But this proposed partial removal—was not considered acceptable at this point by the neighboring communities, given that the underground fire had already been active for eight years and continued to progress towards the radioactive waste materials. As of the writing of this article, no final decision has been made by the EPA about the clean-up of the West Lake Landfill, although the public comment period of public comments on its proposed plan ended nearly four months ago.

At the same time that the fight against the landfill was going on, the community of Coldwater Creek launched in 2015 a campaign to self-report cases of cancers and other autoimmune illnesses affecting those living in the area (see http://www.coldwatercreekfacts.com/2015-health-maps/). The community claims that former high-school students now in their 40s have developed all 21 of the types of cancers associated with exposure to ionizing radiation by the US Department of Veteran Affairs. The maps showing the self-reported cases of cancers and diseases seem to give solid evidence that those health problems are more likely to occur in the population living next to the Coldwater Creek flood plain. The maps generated by the Coldwater Creek community are aimed at putting pressure on the federal agencies to study those cases. But these reported cases are not considered as evidence by the EPA—which has run across cases of spontaneously occurring, unrelated, and purely coincidental "cancer clusters" in the past, and consequently prefers to rely on statistical models to explain the link between the landfill as causative agent and cases of cancer. Yet, by not conducting an anecdotal study (at least, none has been conducted so far), federal agencies have contributed to a sense of frustration among the population, generating the suspicion that the situation is a case of deliberate inaction to maintain ignorance. In other words, locals accuse the feds of trying to say "If we don't see it, then it must not exist."

One legitimate objection to these self-reporting cases is that they cannot be used as evidence to calculate the health effects of radiation levels measured at Coldwater Creek. There is indeed an inherent difficulty in providing evidence of any association, because the self-reporting cases cannot discriminate between those cases of cancers caused by the radiation and those due to other causes. Association is not causation, after all. The apparently higher number of cancers around Coldwater Creek could be an over-representation, as the population is more alert to the risks of cancer and consequently more likely to report a known case of cancer. The West Lake

landfill ultimately poses the challenge of how to regulate a chronic long-term risk of low-level radiation exposure to a widespread population. However, such objection should not serve as a justification for claiming that no association could ever be established in absolute terms.

Experts' models vs. lay people's evidence

In fighting for the clean-up of the West Lake Landfill and the Coldwater Creek, community members are facing the discourses of experts and their so-called objective models. But the way in which this expertise is presented to the public, often in incomprehensible form such as a "simplified equation of how risk is calculated to evaluate how much an individual can possibly inhale in a day"—is something that is not consistent with their daily life experience. In the absence of good data on low-level exposure in the local area, health physicists rely on risk models that are based on other samples such as atomic bombings survivors, exposed populations from nuclear reactor accidents, and so forth. But the communities are pressing for getting a clear answer to one simple question: If they build their home on nuclear weapons waste, what happens to their kids three decades later? The divide resides in that risk assessment cannot provide such clear-cut answer because it is only based on probability that people could have an increased risk of getting cancer when exposed to a certain level and type of radiation.

Unsurprisingly, these statistical assessments of risk do not convince members of the communities. And there is a good reason for that: The models shown by the experts contradict the lay people's evidence of an increased number of early-age cancers experienced in their communities. Scientists believe people don't trust them simply because they don't blindly listen to scientific discourse by experts. But trust and credibility are defined through social interactions; they are not some intrinsic feature to either the actors concerned nor to the information said to be transmitted between them. Studies such as those conducted by Brian Wynne in his article 'Misunderstood Misunderstanding' essentially tell us that in the public mind, who says a thing, how they phrase it, and where they lie on the social scale count for just as much as what they say (Wynne 1992). Context matters as much as content. Therefore, the inability of scientists to take seriously the anecdotal evidence provided by the local community can only exacerbate public distrust. And this distrust is more likely to form when experts are recognized as outsiders to the community affected by an environmental and health problem.

For their part, experts also tend to distrust the lay people's ability to make rational choices, which may sound strange given it is the sacred principle in the field of classical economics. For instance, I often experience this distrust myself when, at scientific meetings, I explain the importance of long-term, trust-building efforts in the management of radioactive waste and get the immediate objection by established scientists that people cannot be trusted to make decisions. With such a divide, no wonder the US nuclear waste management program has been stalled for decades. What is missing is the mutual understanding that what is considered "rational" is always the result of a mixture of subjective values and preferences shared among members of a specific social group. Experts and lay people belong to two distinct social groups in this regard, with inconsistent views and priorities about the role to give to scientific expertise in democracy.

Two colliding worlds

Today, two worlds are in collision with each other. On one side is a world which considers that democracy—where people collectively determine their social contract—takes precedence over epistocracy, or rule by experts. In the other world view—increasingly shared among scientists and politicians—the idea reigns that "experts ought to be in charge of public policy and should manipulate, or contain, the policy preferences of the ignorant masses" (Tampio 2017). In short, it is a case of the elites against the people, where the two groups are engaged in a mutually distrustful relationship.

The case of the illegal dump at the West Lake Landfill and contamination around Coldwater Creek is only one of many instances of systemic lack of public trust in the EPA across America (Robinson, Stoutenborough, and Vedlitz 2017). The regulatory agency has long been unable to negotiate with communities on environmental conflicts, a problem that is broadly affecting other federal agencies in the United States as well (Porter 1995). These conflicts highlight the distance that exists between the federal bureaucracy and people's daily lives. Such distance can only further fuel the distrust of a public that perceives a lack of commitment from institutions, and an apparent lack of "skin in the game" from the personnel overseeing the issues. But at the same time, the EPA clearly faces many constraints in its ability to remediate complex environmental problems such as the West Lake Landfill and Coldwater Creek. The federal government is engaged in the clean-up of dozens of other sites in the United States and in the broader issue of the management and disposal of radioactive waste nation-wide.

What needs to be done

The environmental conflict around the West Lake Landfill and Coldwater Creek poses the challenge of how to regulate long-term risks from low-level radiation exposure, in the context of opposing views about what rule should prevail: statistical probabilities or anecdotal evidence.

Until this year, no risk factor other than age could be clearly established in the incidence of appendix cancer in the population of North St. Louis County. But in June 2018, the Agency for Toxic Substances and Disease Registry (ATSDR), the federal public health agency of the US Department of Health and Human Services, published a report evaluating the exposures to people living near the Coldwater Creek (https://www.atsdr.cdc.gov/sites/coldwater_creek/docs/ColdwaterCreek-508.pdf).

It concluded that the radiological contamination in and around the Coldwater Creek, prior to remediation activities, could have increased the risk of some types of cancer in people who played or lived there. The federal agency also concluded that because no sampling data are currently available, it was unable to evaluate other exposure pathways of concern to the community, such as inhaling dust blown from historical radiological waste storage piles. For this reason, the agency recommends that public health agencies seek further environmental sampling data to continue evaluating community concerns in addition to the clean-up efforts around the Coldwater Creek.

This report clearly represents a first step in the right direction by better integrating local evidence into the scientific basis used for regulating the environmental problem. If followed by concrete actions of remediation by the EPA, it could help to re-establish public trust in the federal

agencies in charge. But this would require expanding the boundaries of the clean-up zone—known under EPA's Superfund Program as the SLAPS Vicinity Properties—because as radioactive materials spread, radiotoxic particles have been found in backyards and basements of homes located outside the current zone and have been traced as coming from the West Lake Landfill.

To remedy the absence of sufficient evidence, a campaign of radiation dose reconstruction should be conducted in the population of North St. Louis County for developed diseases in which latent, chronic, low-level ionizing radiation exposure has been shown as a potential risk factor by the ATSDR. Such a campaign may prove costly to establish a correlation for every individual, considering the incidence of health problems and the radioactive contamination of the area surrounding the Coldwater Creek. An alternative therefore could be to have Congress pass a bill for compensating those developing a cancer in the area.

And there is precedent for this. For instance, the Radiation Exposure Compensation Act enacted in 1990 provides monetary compensation to veterans and federal civilians who have developed cancers or other specified diseases after being exposed to radiation from atomic weapons testing or uranium mining, milling, or transporting (Szymendera 2017). Such a compensation scheme could also be applied to citizens who were exposed to radiation from the nuclear weapons' production sites and who are concerned by EPA's environmental clean-up program.

How to close the divide

Resolving the lay/expert divide will require moving away from today's culture of bureaucracy and starting to invest in long-term, trust-building efforts. Though it makes for an easy slogan, it will no doubt be a challenge to implement because it requires a complete cultural shift in federal agencies.

Indeed, what experts and bureaucrats need to realize now is that, while secrecy and technology-minded expertise have always ruled nuclear weapons programs, dealing with the legacy of radioactive waste is first and foremost a social problem—which no technology alone will ever resolve. So, whether experts and decision-makers like it or not, voluntary organizations involved in social welfare will have to play a central part of any successful management and disposal strategy regarding radioactive waste, if we are to bring about the long-term commitment required for this complex and urgent task. Such a cultural shift, if ever implemented, would require an audacious structural reform where principles of voluntarism, trust, and negotiation are at the core of the management, disposal and regulation of nuclear weapons waste in the United States.

In that respect, the clean-up of the contaminated sites provides the opportunity to test these principles on which the "reset" button nuclear waste policy must be based.

Disclosure statement
No potential conflict of interest was reported by the author.

Funding

This research received the support of the European Union's Horizon 2020 research and innovation program under the Marie Sklodowska-Curie grant agreement No 739850, as well as the MacArthur Foundation under the Nuclear Security Fellowship program at the Center for International Security and Cooperation at Stanford University.

Notes on contributor

François Diaz-Maurin (http://cisac.fsi.stanford.edu/people/francois-diaz-maurin) is a nuclear security visiting scholar at the Center for International Security and Cooperation (CISAC) at Stanford University and a European Commission Marie Sklodowska-Curie Fellow. He received his doctorate in environmental science and technology in 2013 from the Universitat Autònoma de Barcelona, Spain. Before joining academia, he worked as an engineer on the design of nuclear energy technologies in France and in the United States.

References

Alley, William M., and Rosemarie Alley. 2012. *Too Hot to Touch: The Problem of High-Level Nuclear Waste*. Cambridge University Press.

Marmor, Schelomo, Pamela R. Portschy, Todd M. Tuttle, and Beth A. Virnig. 2015. "The Rise in Appendiceal Cancer Incidence: 2000–2009." *Journal of Gastrointestinal Surgery* 19 (4): 743–50. https://doi.org/10.1007/s11605-014-2726-7.

Porter, Theodore M. 1995. *Trust in Numbers: The Pursuit of Objectivity in Science and Public Life*. Princeton, New Jersey: Princeton University Press. https://press.princeton.edu/titles/5653.html.

Robinson, Scott E., James W. Stoutenborough, and Arnold Vedlitz. 2017. *Understanding Trust in Government: Environmental Sustainability, Fracking, and Public Opinion in American Politics.* Routledge Studies in Public Administration and Environmental Sustainability. New York, NY: Routledge.

Szymendera, Scott D. 2017. "The Radiation Exposure Compensation Act (RECA): Compensation Related to Exposure to Radiation from Atomic Weapons Testing and Uranium Mining." 7-5700-R43956. CRS Reports. Washington, D.C.: Congressional Research Service. https://fas.org/sgp/crs/misc/R43956.pdf.

Tampio, Nicholas. 2017. "Treat People as Citizens." *Aeon Essays*, October 18, 2017. https://aeon.co/essays/why-rule-by-the-people-is-better-than-rule-by-the-experts.

US Army Corps of Engineers of the St. Louis District, Formerly Utilized Sites Remedial Action Program (FUSRAP). Undated. http://www.mvs.usace.army.mil/Missions/Centers-of-Expertise/Formerly-Utilized-Sites-Remedial-Action-Program/

US Defense Department. 2018. "Nuclear Posture Review 2018." Special Report. Washington, D.C.: Office of the Secretary of Defense. https://www.defense.gov/News/Special-Reports/NPR-

2018.

US Energy Department. 1997. “Linking Legacies: Connecting the Cold War Nuclear Weapons Production Processes to Their Environmental Consequences.” F2002-00544. Washington, D.C.: US Energy Department, Office of Environmental Management. https://energy.gov/em/downloads/linking-legacies-connecting-cold-war-nuclear-weapons-production-processes-their.

Wynne, Brian. 1992. “Misunderstood Misunderstanding: Social Identities and Public Uptake of Science.” *Public Understanding of Science* 1 (3): 281–304. https://doi.org/10.1088/0963-6625/1/3/004.