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After Fukushima: Managing the Consequences of a Radiological Release

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Even amidst the devastation following the earthquake and tsunami in Japan that killed more than 20,000 people, it was the accident at the Fukushima Daiichi nuclear power plant that led the country's prime minister, Naoto Kan, to fear for "the very existence of the Japanese nation." While accidents that result in mass radiological releases have been rare throughout the operating histories of existing nuclear power plants, the growing number of plants worldwide increases the likelihood that such releases will occur again in the future. Nuclear power is an important source of energy in the U.S. and will be for the foreseeable future. Accidents far smaller in scale than the one in Fukushima could have major societal consequences. Given the extensive, ongoing Nuclear Regulatory Commission (NRC) and industry assessment of nuclear power plant safety and preparedness issues, the Center for Biosecurity of UPMC focused on offsite policies and plans intended to reduce radiation exposure to the public in the aftermath of an accident. This report provides an assessment of Japan's efforts at nuclear consequence management; identifies concerns with current U.S. policies and practices for "outside the fence" management of such an event in the U.S.; and makes recommendations for steps that can be taken to strengthen U.S. government, industry, and community response to large-scale accidents at nuclear power plants.

On March 11, 2011, a 9.0 magnitude earthquake occurred off the Pacific coast of Japan, causing 15-meter tsunami waves that overwhelmed the protective seawalls of the Tohoku region. The earthquake and subsequent tsunami alone constitute one of the worst natural disasters in Japan's history, with more than 20,000 victims and a projected cost of over $300 billion.[1] At the time of the earthquake, 3 of 6 nuclear power units were operating at the Fukushima Daiichi nuclear power plant. The earthquake disrupted offsite power to the plant and triggered a scramming process leading to reactor shutdowns. The subsequent tsunami and breach of the protective seawall flooded the back-up power units at the Fukushima Daiichi plant, causing the reactors and spent fuel pools to lose their emergency cooling capabilities. On March 12, explosions occurred at 3 units, which are assumed to have been caused by pressure from the hydrogen released by damaged reactor cores, leading to a large release of radioactive materials.[2] By the end of that day, the Japanese government had extended mandatory evacuation from a 10-km to a 20-km radius from the Fukushima Daiichi plant. In total more than 110,000 people have been evacuated.[2] Due in part to the containment present at Fukushima, the total radioactive release from the Fukushima Daiichi nuclear power plant is currently estimated to be about 5.5% that of the Chernobyl accident. The prevailing winds at the time of the accident appear to have blown a significant portion of the radioisotopes out to sea. Nevertheless, in terms of contamination

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with cesium 137 (Cs-137), a radioisotope with a half-life of about 30 years, the Fukushima plant has released about one-fifth of the amount of Cs-137 that was released during the Chernobyl accident over a significantly smaller area of land.[3] The extensive cesium contamination in the areas around the Fukushima Daiichi plant and neighboring prefectures (with deposition projections well over 100,000 MBq km^{-2}) represent an unprecedented challenge in decontamination and recovery efforts.[4]

Nuclear power is an important source of energy in the U.S. and will be for the foreseeable future. Accidents far smaller in scale than the one in Fukushima could have major societal consequences. Given the extensive, ongoing Nuclear Regulatory Commission (NRC) and industry assessment of nuclear power plant safety and preparedness issues, the Center for Biosecurity of UPMC's assessment focused on offsite policies and plans intended to reduce radiation exposure to the public in the aftermath of an accident. The project sought to foster communication among the many federal, state, and local agencies involved in nuclear accident preparedness and response as well as relevant groups in academia, industry, and nongovernmental organizations. This report provides an assessment of Japan's efforts at nuclear consequence management; identifies concerns with current U.S. policies and practices for "outside the fence" management of such an event in the U.S.; and makes recommendations for steps that can be taken to strengthen U.S. government, industry, and community response to large-scale accidents at nuclear power plants.

Methodology

The Center studied the events surrounding the response to the Fukushima Daiichi nuclear power plant accident, reviewed current U.S. government policies and practices for nuclear consequence management, and performed a comprehensive review of the published literature and U.S. government documents. The Center conducted a series of semistructured interviews with 94 domestic and international experts in the fields of health physics and radiological emergency management from the White House, the U.S. Centers for Disease Control and Prevention (CDC), the U.S. Department of Energy (DOE), the U.S. Environmental Protection Agency (EPA), the U.S. Federal Emergency Management Agency (FEMA), the U.S. Nuclear Regulatory Commission (NRC), the U.S. Department of State (DOS), the U.S. Department of Defense (DOD), state health departments, and experts from industry, professional organizations, academia, and relevant international organizations. Questions focused on 4 topical areas as they related to the Fukushima Daiichi accident and U.S. policy:

1. Emergency planning and response
2. Medical and public health interventions and countermeasures
3. Communication and public health education
4. Reentry and recovery policy

The analysis of these conversations provided the structure for a workshop on December 13, 2011, which was attended by 26 participants. Both the workshop discussion and our premeeting phone conversations were held on a not-for-attribution basis (see sidebar for a list of participating organizations). Expert input at the workshop and in the preceding interviews was considered advisory to the analysis. The Center did not attempt to achieve consensus in its discussion with experts. Accordingly, the findings and the recommendations in this report represent the analysis and judgments of the Center for Biosecurity staff and do not necessarily reflect the views of those who were interviewed for this project. The project was funded by the Center for Biosecurity. The project protocol was reviewed by the Institutional Review Board at the University of Pittsburgh and was determined to meet all necessary criteria for "exempt" designation.

"Outside the Fence" Issues

The NRC is now assessing nuclear safety and preparedness issues, or "inside the fence" issues, to ensure the integrity of U.S. commercial nuclear power plants. While efforts to prevent a power plant accident should remain a top priority, the Center's analysis of lessons learned from the Fukushima Daiichi accident focused on offsite policies and plans, or "outside the fence" issues, intended to reduce radiation exposure to the public following a radiological release from a commercial nuclear power plant.

Issue 1: Emergency Planning and Protective Guidelines

Following the Fukushima Daiichi accident, the Japanese government concluded that the country's existing framework for offsite emergency response—the Emergency Planning Zone (EPZ) structure—had proved inadequate to guide evacuation decisions. In an effort to improve the timeliness of decision making during a radiological release, a working group of the Japanese Nuclear Safety Commission has proposed replacing the existing EPZ with a 3-tiered emergency planning strategy. The 5-km (3.1-mile) radius surrounding a nuclear power plant would constitute the precautionary action zone (PAZ), within which unconditional protective actions are instituted (eg, evacuation) once a plant reaches an Emergency Action Level (EAL). An EAL is a predetermined, site-specific, observable disruption in nuclear power plant function that would constitute an emergency prior to any release of radioactive materials. The second tier would be a 30-km (18.6-mile) Urgent Protective Action Planning Zone (UPZ) in which protective actions would be dependent on environmental

Participating Organizations

State and Local Public Health Agencies

Multnomah County Health Department
New Jersey Department of Health and Senior Services
New York State Department of Health
Pennsylvania Department of Environmental Protection
Public Health—Seattle & King County
Tarrant County Public Health
Texas Department of State Health
Vermont Department of Health
Washington State Department of Health

Federal Agencies

Office of the Assistant Secretary for Preparedness and Response (HHS)
U.S. Centers for Disease Control and Prevention
U.S. Department of Agriculture
U.S. Department of Energy
U.S. Department of Homeland Security
U.S. Department of State
U.S. Department of Veterans Affairs
U.S. Environmental Protection Agency
Federal Emergency Management Agency (DHS)
U.S. Food and Drug Administration (HHS)
Health Protection Agency—UK
National Cancer Institute (HHS)
U.S. Nuclear Regulatory Commission
U.S. Public Health Service (HHS)
The White House

Academia

Columbia University
Fukushima Medical University
Johns Hopkins University
Pennsylvania State University
University of Alabama at Birmingham
University of Illinois Medical Center
University of Louisville
University of Nevada, Las Vegas
University of Portsmouth—UK
University of Pittsburgh Medical Center
University of Texas at Austin
University of Wisconsin—Madison
Vanderbilt University Medical Center

Professional and Industry Organizations

American Nuclear Society
Association of State and Territorial Health Officials
Argonne National Laboratory
Battelle Memorial Institute
BD Consulting
Conference of Radiation Control Program Directors
Dade Moeller, Inc.
Emergency Response Technology Integration Center
Exelon Corporation
International Atomic Energy Agency
ICF International
Los Alamos National Laboratory
National Alliance for Radiation Readiness
National Council on Radiation Protection & Measurements
National Association of County and City Health Officials
North Texas Radiation Response Group
Nuclear Energy Institute
Sanders Engineering
West Penn Allegheny Health System

monitoring for radiation within the 30-km circle around the plant. The third tier would apply to residents in the 31- to 50-km (19.3- to 31.1-mile) zone, which would constitute the Plume Protection Area (PPA) in which practical protective actions would be recommended to prevent exposure as the radioactive plume passes (eg, sheltering indoors).[5-7]

In the U.S., each nuclear reactor is surrounded by 2 circular planning zones: the Plume Exposure Pathway EPZ, covering a 10-mile radius around the reactor, and the Ingestion Exposure Pathway EPZ, which encompasses a 50-mile radius surrounding each reactor.[8] Within these areas, state and local governments take predetermined specific preparedness precautions, including emergency exercises, community-wide public education programs, and possibly the predistribution of potassium iodide (KI). The NRC's original guidance establishing the EPZs noted that, should response efforts be necessary beyond the planning zones, the detailed preevent planning done within the EPZ is meant to "provide a substantial base for expansion of response efforts" to areas outside the EPZ.[8] The emergency response surrounding the Fukushima Daiichi nuclear power plant validates this anticipatory approach to expanding emergency response efforts as an accident unfolds.

The accident does, however, raise questions about the trade-off between making decisions in real time and the advantages of emergency response decisions that are automatically triggered in the event of an impending radiological release. Given the Japanese experience, it would be worthwhile for the U.S. to reevaluate its own evacuation protocols to include mandatory evacuation zones, which could prevent delays in evacuation and radiological exposure. Furthermore, the breadth of contamination found in Japan, which extended beyond 30 km (18.6 miles), suggests that a 10-mile plume exposure EPZ may be inadequate. The NRC has recognized in its near-term review of the Fukushima Daiichi accident that "[w]hile the U.S. EP framework has always noted that the plume exposure pathway EPZ provides a basis for expansion, insights from real-world implementation at Fukushima, including the realities of multiunit events, might further enhance U.S. preparedness for such an event."[9(p61)] The NRC and FEMA should evaluate the sufficiency of the EPZ structure surrounding U.S. commercial nuclear power plants based on the Fukushima Daiichi experience.

U.S. nuclear power plants are required to exercise emergency plans with the NRC, FEMA, and offsite authorities at least once every 2 years to ensure that state and local officials remain proficient.[8] FEMA's role is to review and provide findings to the NRC on planning and preparedness activities of state, tribal, and local governments; licensee emergency response organizations, if applicable; and other supporting organizations.[10] The NRC, on the other hand, is responsible for overseeing the overall status of emergency preparedness. Some project participants conveyed that current exercise activities may not be done rigorously or frequently enough to adequately prepare nuclear power plant areas for a major event. For apparent funding reasons, the ingestion pathway exercises for the 50-mile Ingestion Exposure EPZ may be moved from being performed every 6 years to every 8 years. Participants cautioned that this could hamper maintaining the institutional experience of a public health department, as staff turnover is more likely over longer times. Participants also noted that few exercises are performed as "no notice," and exercises do not test to failure for fear that a plant may be forced to shut down. In order to enhance the rigor and utility of the exercises, participants suggested some form of "no fault" exercises be adopted that would permit plants to continue operating following an exercise that had tested to failure while necessary adjustments are made.

To guide the response of state and local authorities in an emergency zone during a radiological release caused by a nuclear power plant accident, the EPA has published the Protective Action Guidelines (PAG). The PAG manual currently provides advice for the early and intermediate phases of an accident based on levels of anticipated radiation exposure. For example, during the early phase of a radiological event, the EPA recommends evacuating an area if the expected dose for the first few days of the accident exceeds 1 rem.*[1] During the intermediate phase of an event, the EPA recommends relocation of populations from an affected area if the *annual* projected dose is expected to exceed 2 rem.[11] Of note, the Department of Homeland Security (DHS) provides distinct PAG threshold limits for emergency response professionals during the early phases of an accident.[12]

The U.S. PAG manual differs from protective guides used by the international community, known as Operational Intervention Levels (OILs), which are defined as the values of environmental measures of radiation, like radiation dose measurements, above which specific actions should be taken in emergency situations.[13] OILs differ from PAGs in that they do not depend on projected dose calculations. Instead, they recommend actions based on real-time monitoring, often using on-the-ground field measurements, intended to enable a faster response. The U.S. should reevaluate the relative balance of PAGs and OILs used in response planning to a nuclear power plant radiological release, given the disruptions to the radiation monitoring systems witnessed in Japan.

Issue 2: Potassium Iodide (KI) Policy

One of the byproducts of the nuclear fission of plutonium or uranium in a nuclear plant's reactor core is the beta- and gamma-emitting isotope radioactive iodine or radioiodine (I-131). This radioactive isotope has a half-life of 8 days and poses a human health threat in the form of thyroid disease. The thyroid gland is the major target of I-131 because, unlike other tissues, it is able to store I-131. At high doses, I-131 causes thyroid cell death, leading to hypothyroidism, but at lower doses DNA damage occurs, leading to mutations and possibly malignancy.[14]

Potassium iodide (KI) is an over-the-counter medical countermeasure that can diminish the uptake of radioactive iodine by the thyroid gland and prevent thyroid cancer in children and developing fetuses. It was approved by the FDA in December 1978. The use of KI decreases the risk of the development of a subsequent thyroid cancer by saturating the thyroid gland with iodine and rendering it unable to absorb carcinogenic I-131. The FDA guidance specifies that KI be taken when the predicted thyroid exposure is 50 milli Seiverts (mSv) for children, pregnant women, and breast-feeding women; 100 mSv for adults between 18 and 40 years; and >5 Sv for those above age 40.[15] Several adverse events can occur with KI administration, including gastrointestinal symptoms, allergic reactions that could be life threatening, and transient changes in thyroid function. Project participants stressed that while the individual level risk for the occurrence of these side effects is low, as larger populations are administered KI, the absolute numbers of those experiencing side effects could become large.

That KI has no value in protecting adults from cancer is well known by professionals and backed by scientific data. The thyroid gland displays an age-related sensitivity to the effects of I-131. Because younger individuals have faster growing thyroid glands, consume more milk, and breathe faster (allowing more inhalation of I-131), a child's thyroid gland is exquisitely—and almost exclusively—at risk for the deleterious effects of I-131. Because the fetal thyroid gland can concentrate I-131 at 3 months' gestation, it is also susceptible to I-131's effects.

The carcinogenic effects of I-131 are also accentuated by iodine deficiency, which was prevalent in the populations exposed during Chernobyl. After the Chernobyl accident, the inhalation exposure route was not the primary route of

*Rem stands for *roentgen equivalent man* and is a unit of radiation dose equivalent used to measure the effects of ionizing radiation on humans.

radioiodine exposure. Consumption of food and water that had been contaminated with radioiodine prior to its dissipation was the chief means of exposure.[16] For this reason, project participants emphasized that Chernobyl data cannot be extrapolated to the U.S., as FDA, EPA, and USDA interdiction would eliminate the ingestion pathway.

The Hanford Study, which assessed the risk of thyroid disease in U.S. populations exposed to I-131 from a nuclear weapons facility, found no increased risk for thyroid cancer in any age group—a finding that one project participant stated was likely due to the iodine-replete status of the U.S. population. Based on the available science, including the data from Chernobyl as well as Hiroshima, the National Academies of Science concluded that "the risk of thyroid carcinoma in adults exposed to radioactive iodine in fallout is very low, and can be assumed to be absent for adults over 40 years old although at very high doses there is a risk of hypothyroidism."[14(p67)]

U.S. federal policy recommends that states consider stockpiling and distributing KI as an adjunct to evacuation, which is the single most important protective measure available. Of 35 U.S. states that lie within the 10-mile EPZ of a nuclear power plant, 24 states predistribute KI as part of their emergency planning, and 9 do not. KI is stockpiled in the Strategic National Stockpile (SNS). However, there are few plausible scenarios in which KI distribution from the stockpile could occur quickly enough to make a major difference in a community. During Fukushima, Japan made a preliminary request for KI from the U.S. stockpile, but it was eventually not needed. Little KI was administered to the Japanese population, as radiation thresholds for KI administration were not exceeded. The experience with Fukushima did, however, provide some foreshadowing of possible U.S. demand for KI: As the plume of radioisotopes released from the Japanese power plant blew across the Pacific, many in the U.S. began to demand KI.

Issue 3: Communications and Public Health Education

From a risk perception standpoint, nuclear reactor accidents rank among the highest in technologies that are uncontrollable, catastrophic, and lethal. Ionizing radiation from nuclear disasters evokes an unparalleled sense of dread compared to other potential health threats, like carbon dioxide, mercury, and pesticides, or even other sources of radiation such as X-rays in the medical setting or radon in the household setting. Although there were no casualties from the accident at Three Mile Island (TMI), TMI seems to have augmented the American perception that nuclear accidents are disasters of "immense proportions."[17]

When a mass radiation contamination event occurs, the public fear factor and low baseline knowledge about radiation create a major communications challenge. In the absence of consistent, trustworthy messaging from government authorities, members of the public may act in ways that put them in harm's way. Without guidance from the government, residents of the town of Namie in Fukushima prefecture evacuated north, into the plume, believing that the winter winds would be blowing south.[18] In the U.S., where a state governor would be responsible for mandating evacuations, the interface of the federal government with state and local officials will be especially important. A good example of a well-organized communication process is the Chemical Stockpile Emergency Preparedness Program (CSEPP), a program jointly managed by DHS and the Department of the Army that provides emergency preparedness assistance and resources to communities surrounding the Army's chemical warfare agent stockpiles. CSEPP reaches out to community organizations, churches, businesses, and other public entities for preevent planning to establish rosters of people that needed to be phoned or texted should an emergency occur.[19] There does not appear to be an analogous top-down process in the Radiation Emergency Preparedness Program (REPP). Proactive messaging positions the government to fill the void of information immediately following an accident and combat the flood of information that will persist from unvetted media outlets in the weeks and months following an accident.

Federal communication efforts are complicated by the need to coordinate information and messages from many agencies. The CDC, DOE, EPA, FEMA, HHS, NRC, and the White House were all included in the domestic response to the Fukushima accident. Furthermore, and in contrast to the nuclear power plant accidents at Three Mile Island and Chernobyl, the Fukushima Daiichi accident has highlighted the new challenges of communicating with the public in the "information era" of 24-hour news cycles and social media outlets.[20]

It also became clear that levels of radiation as measured by traditional metric units (eg, Sieverts) are meaningless to the public. According to one project participant, the Japanese government began distributing textbooks and other education materials on radiation throughout the Fukushima prefecture. Relative risk diagrams comparing the levels measured in and around Fukushima to what one might receive on a long plane ride or in a CT scan attempted to provide the public with some relatable form of information that could serve as a rationale for the public exposure limits determined by the Japanese government. Participants suggested that, while these charts may prove helpful in translating radiation measurements to health concepts, there is an overriding demand by the public to receive actionable advice that will help them protect themselves and their dependents. Project participants suggested that U.S. communication during the Fukushima accident would have been best shared by 2 spokespeople: a nuclear safety professional and a public health official. Because a nuclear power plant accident and a subsequent radiological release are both technological and public health disasters, and given public concerns about the health effects of ionizing radiation, it seems important to include a health expert in the federal messaging approach alongside a nuclear regulatory official.

Issue 4: Reentry and Recovery Policy

Prior to the Fukushima accident, planning for nuclear accidents in Japan had not taken into account the possibility of wide-scale contamination, major socioeconomic impact, and the possibility that large numbers of people would be displaced for extended periods of time, and perhaps indefinitely. The experience with that accident has raised questions about recovery from mass radiological events in which the health effects of residual ionizing radiation can be less threatening than the enormous socioeconomic impact of widespread contamination itself. The challenge is to define the acceptable level of post-accident population risk from radiation exposure.

Twenty years ago, the EPA published the PAGs as the official decision-making document to be used during a radiological emergency. The PAGs establish principles for early and intermediate-phase response, but the agency deferred writing its chapter on the late phase, or recovery phase, indicating that "additional radiation protection guidance for recovery will be developed at a later date."[11(piii)] Almost immediately after the publication of the PAGs in 1992, an interagency working group dedicated to developing late-phase guidance was convened.[21] In January 2009, its findings were published as a draft for public comment. The draft was, according to project participants, withdrawn from consideration by the incoming EPA administrator later that month. In January 2011, the EPA distributed a "significantly revised version" of the late-phase PAGs to the interagency working group for review. Until that review is completed and late-phase PAGs are published, there will be no clear federal policy for recovery and reentry after a nuclear accident.

Similar to the PAGs issued by DHS for late-phase recovery after an incident involving a radiation dispersal device (RDD) or an improvised nuclear device (IND), which call for cleanup to be achieved through a "site-specific optimization process," the EPA's 2009 draft recovery strategy also applied this approach.[22] Instead of using a strict, inflexible radiation measurement to determine when it is safe to reenter a contaminated area, an "optimization" process weighs a number of factors along with health risks—such as possible future land uses, cleanup options and approaches, technical feasibility, costs, cost-effectiveness, infrastructure, local economy, and, ultimately, public acceptance.[23] Late-phase PAGs would address the decontamination of property, which can last from months to years after an accident.

While both IND/RDD recovery plans and draft EPA guidance for a nuclear power plant accident called for optimization, actual current U.S. regulatory policies for recovery after a nuclear accident apply a very different philosophy. Optimization, as a concept, drives recovery by balancing radiation risks against socioeconomic considerations under emergency circumstances. Current U.S. policies, such as the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), use more conservative, nonemergency thresholds based on the Linear No-Threshold (LNT) model,[24] which assumes that no level of ionizing radiation is safe. Such a model strives for a level of radiation that is likely to be impractical after a major accident and may be inconsistent with the public's desire to return to homes and businesses in ways that alter their risk-tolerance thresholds. The international community, namely the International Commission on Radiological Protection (ICRP), has adopted optimization and has issued implementing guidelines, which are currently under consideration by U.S. agencies.

Participants called for improved state and local exercises to examine critical issues related to recovery policy. One example of such an exercise was Liberty RadEx. This was a national exercise sponsored and designed by the EPA to practice and test federal, state, and local assessment and cleanup capabilities following a mock "dirty bomb" attack. Importantly, the exercise practiced late-phase responsibilities, including working with stakeholders and the public to plan for community recovery. Many of Liberty RadEx's findings echoed concerns expressed by our project's participants, including that recovery policy for wide-area contamination is inadequate and improved public communication is needed.[25]

The issue with which all parties grapple is the conundrum of how to prepare meaningfully for radiological accidents like the one at Fukushima that may occur only once in a generation. There is a policy divide between those who believe preparedness requires attention to low-probability, high-consequence events, such as that represented by the Fukushima accident and akin to preparing for the 100-year flood or hurricane, versus those who believe preparing for such low-probability events would siphon scarce resources away from more probable immediate needs. The Center's judgment is that serious planning for low-probability, high-consequence events is critically important, especially if done in a resource-efficient way.

Issue 5: A Human Capital Crisis in Radiation Safety

A 2010 report by the Council of State and Territorial Epidemiologists (CSTE) points out that few full-time employees work in radiation emergency response in state public health departments.[26] The Center's investigation also found that in the post–Cold War era, there are fewer incentives academically and professionally to pursue careers in health physics, thereby exacerbating the lack of expertise in public health departments. According to the Health Physics Society, the number of students graduating with

BS, MS, or PhD degrees in health physics has declined steadily in recent years.[27]

Project participants suggested that the U.S. government should incentivize careers in health physics by providing traineeships or graduate school grants contingent on public service in the field following graduation. Some in industry have formed relationships with local educational institutions, providing scholarships and training to ensure a pipeline of qualified graduates. In the meantime, efforts are under way by the Conference of Radiation Control Program Directors (CRCPD) to incorporate local volunteer radiation professionals into existing health volunteer programs to assist in the response to a radiological event.[28] As another way to augment the trained workforce in the aftermath of an accident, it was suggested that the CDC might engage health physicists from around the country to be available to help with response. A network of trained professionals could help with radiation screening and assessment, much as the Medical Reserve Corps provides medical assistance during catastrophic health emergencies by, for example, administering vaccinations during pandemic flu.

In Japan, volunteers included individuals decontaminating their own homes, people cleaning contaminated streets and schools, and the famous Fukushima 50—the team of workers, emergency services personnel, and scientists who volunteered to remain on-site, enduring high doses of radiation as they worked to cool fuel rods.[29] History indicates that volunteers would come forward after a major disaster in the U.S. Most recently, residents of the U.S. Gulf states volunteered to clean up following the Deepwater Horizon oil spill, only to have their services refused because of liability concerns. Fukushima may represent a watershed experience in radiological event response, as the significant role of community volunteers is becoming more evident. Accordingly, meeting participants stressed the importance of incorporating volunteers into recovery policy and drawing on trained radiation professionals from throughout the country as well as untrained volunteers from the affected area. In particular, there was a need expressed for radiation protection standards that can be clearly applied to members of the public acting in this capacity.

Recommendations

1. The U.S. should evaluate the adequacy of current Emergency Planning Zones.

In light of the Fukushima experience, the U.S. EPZ system should be carefully assessed to determine the following: Are planning zone distances sufficient to accommodate the potential radiation hazards posed by multiple units of a power plant, spent fuel storage, and the possibility of extended releases? Is the existing decision-making process during plant emergency conditions sufficiently timely and dynamic to be effective for conditions identified at Fukushima? Do we have sufficiently robust radiation measurement and modeling systems in place to monitor radiation threats in the aftermath of a large-scale accident? Would those systems still be functioning despite large-scale power loss or other disruption? Do current nuclear plant safety goals adequately reflect the socioeconomic impact of a wide-scale contamination event? Answers to these questions should guide future evaluations of U.S. EPZs.

2. The U.S. should improve the emergency exercise process for commercial nuclear power plants.

Emergency exercises need to challenge participants with both expected and unexpected scenarios, including ones that may involve protracted releases and longer-term response. Currently, due to likely regulatory consequences, domestic commercial nuclear power plants are not challenged as they should be. No-fault tabletop exercises should become part of the exercise process. Other good options to increase preparedness include regional exercises (eg, Liberty RadEx) that can accommodate a number of agencies and states on a periodic basis.

3. U.S. federal policy should downplay use of KI and emphasize evacuation.

A major concern is that KI instills a false sense of security among the population and that demand for KI might delay evacuation. For states that have already committed to KI distribution, it would be extremely difficult to move away from that position without a substantial investment in public education. Given the likelihood that plans to provide (or predistribute) KI in the event of a nuclear accident will continue, it is paramount that the most important emergency response message is always: "Evacuate first—do not waste precious time looking for KI or waiting for it."

4. The U.S. government should expand preevent education and improve postevent communication.

Community resilience to radiological threats in the U.S. would benefit from preevent education and postevent communication efforts that provide straightforward and actionable protective advice to the public. Public communication efforts must use all available media outlets and remain consistent across all levels of government—federal, state, and local. Ongoing federal agency efforts to understand how to educate the public before and during a crisis are important and should be supported. Furthermore, a nuclear power plant accident and a subsequent radiological release is both a technological and public health disaster. Given public concerns about the health effects of ionizing radiation, it seems important to include a health expert in the federal messaging approach alongside a nuclear regulatory official. In the future, it would be wise for the NRC and the CDC to consider jointly addressing the public about the threats posed by a compromised nuclear power plant and its public health consequences.

5. The U.S. should articulate a clear plan for recovery after a large-scale accident.

With a late-phase protective action guide pending for the past 20 years, and little planning and exercising being conducted for the recovery phase, a serious gap exists in U.S. recovery planning following a nuclear power plant accident. The consequence of continued inaction could be misdirection, delays, and confusion, as has been demonstrated in Japan, where the public struggles to recover lives and livelihoods. The U.S. government should publish a late-phase PAG to guide recovery planning and response, articulate its approach for recovering from a major radiological release, and develop guidance to aid state and local authorities in dealing with their responsibilities for mitigating exposure, managing decontamination and cleanup, and resettling displaced populations. This emerging set of benchmarks needs to be exercised periodically in a manner that does not detract from current emergency preparedness obligations at nuclear power plants.

6. The U.S. should take steps to sustain professional radiological expertise in the public sector.

A number of actions can be taken to ensure a sustained supply of this essential expertise for federal and local governments. First, the federal government once offered graduate school grants and traineeships to encourage entry by nuclear safety and health physics graduates into the public sector—that can be reinstated with relative ease and with little budgetary burden. Second, existing resources can be leveraged better to provide support where needed and, in a major emergency, shared across agencies and between geographical areas. Finally, a means to convey the experience possessed by the existing cadre of radiological response professionals should be created through a mentoring program or other participatory means by which their knowledge can be captured for their successors.

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