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A PUBLIC HEALTH PERSPECTIVE ON THE U.S. RESPONSE TO THE FUKUSHIMA RADIOLOGICAL EMERGENCY

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Abstract

On 11 March 2011, northern Japan was struck by first a magnitude 9.0 earthquake off the eastern coast and then by an ensuing tsunami. At the Fukushima Dai-ichi Nuclear Power Plant (NPP), these twin disasters initiated a cascade of events that led to radionuclide releases. Radioactive material from Japan was subsequently transported to locations around the globe, including the U.S. The levels of radioactive material that arrived in the U.S. were never large enough to cause health effects, but the presence of this material in the environment was enough to require a response from the public health community. Events during the response illustrated some U.S. preparedness challenges that previously had been anticipated and others that were newly identified. Some of these challenges include the following: (1) Capacity, including radiation health experts, for monitoring potentially exposed people for radioactive contamination are limited and may not be adequate at the time of a large-scale radiological incident; (2) there is no public health authority to detain people contaminated with radioactive materials; (3) public health and medical capacities for response to radiation emergencies are limited; (4) public health communications regarding radiation emergencies can be improved to enhance public health response; (5) national and international exposure standards for radiation measurements (and units) and protective action guides lack uniformity; (6) access to radiation emergency monitoring data can be limited; and (7) the Strategic National Stockpile may not be currently prepared to meet the public health need for KI in the case of a surge in demand from a large-scale radiation emergency. Members of the public health community can draw on this experience to improve public health preparedness.

Keywords

dose assessment; emergency planning; public information; radiation

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INTRODUCTION

On 11 March 2011, northern Japan was struck by two disasters: first a magnitude 9.0 earthquake centered 130 miles off the eastern coast and second by an ensuing tsunami. These natural incidents caused widespread death and destruction in Japan. As of March 2012, 15,854 people were confirmed dead and 3,155 were still missing and presumed dead because of this disaster (WHO 2012).

The Fukushima Dai-ichi Nuclear Power Plant (NPP) was one of the facilities affected by these natural disasters. The destruction that occurred at this site led to significant loss of coolant, resulting in reactor core meltdown and large radionuclide releases from the site. These releases resulted in widespread radioactive contamination of residential areas, agricultural land, and coastal waters. Thousands of Japanese citizens were evacuated from around the Fukushima site during the early days of the crisis, and even two and a half years later, many of those people have not yet been allowed to return to their homes (Dickson 2011; New York Times 2013). To date, there have been no confirmed deaths because of the radioactive releases from the Fukushima reactors, but public concerns have resulted in Fukushima Medical University undertaking a multi-year study to investigate long-term, low-dose radiation exposure to people from the incident (Yasumura et al. 2012).

As events unfolded in Japan, the U.S. public health community prepared to respond as needed. One of the agencies that prepared was the Centers for Disease Control and Prevention (CDC). The CDC Emergency Operations Center (EOC) activated on 11 March 2011 in anticipation of the tsunami then crossing the Pacific Ocean affecting Hawaii, other Pacific islands, or the West Coast of the continental U.S. Although severe tsunami impacts did not occur, as the emergency at the Fukushima Dai-ichi nuclear power plant became known, the CDC EOC prepared to respond to its first radiological emergency.

Over the next week, the CDC EOC began first working single shifts of 12 h d^{-1} or more, evolving eventually into two 8-h shifts per day. This went on for approximately 6 wk before the CDC EOC was fully deactivated. CDC staff were concerned initially about citizens of Japan and U.S. citizens living, working, or visiting in Japan as this multifaceted disaster unfolded. As the Fukushima incident progressed, it was clear that some yet unknown level of radioactive fallout would reach locations outside of Japan and that people living in these areas would be concerned about the potential impacts of this fallout on their health. As a result, CDC staff became increasingly concerned about the impact of the incident on Pacific islanders and residents of the continental U.S. Challenges that CDC encountered during the time the CDC EOC was active included:

- The level of effort expended by the CDC staff in the EOC was considered to be challenging for many reasons; some CDC staff had never participated in any kind of a response involving radiation or radioactive materials;
- There were relatively few radiation subject matter experts at CDC to guide the technical side of the response;
- The terminology used in radiation was significantly different from the terminology used in other public health disciplines with which CDC staff are familiar; and

- The CDC response was not confined to the CDC EOC in Atlanta. CDC dispatched liaisons to the National Security Staff (NSS) and the U.S. Nuclear Regulatory Commission (NRC) in Washington. Two CDC personnel participated with staff from the National Cancer Institute and the Food and Drug Administration in a U.S. Department of Health and Human Services (DHHS) medical team that went to Tokyo, Japan, to assist the U.S. embassy staff in responding to the Fukushima incident.

CDC EOC staff worked with state, local, and federal partners to provide public health protective action recommendations to concerned citizens. Specific areas covered included:

- Use and availability of potassium iodide to protect the thyroid gland from radioiodine;
- Development of protocols for screening passengers returning to the U.S. from Japan for radionuclide contamination;
- Evaluation of requirements for screening cargo entering the U.S. from Japan for radionuclide contamination; and
- Evaluation of the levels of radionuclides found in air, food, and water in the U.S.

The development and release of public communications materials related to these and other public health issues were key activities throughout the response. CDC staff also participated actively in the interagency Advisory Team for Environment, Food, and Health (USDHS 2008). This Team played a role in understanding and checking the technical information from Fukushima as it became available and in preparing communications to others involved in the public health response who were not radiation experts.

Concurrent with the early CDC EOC activities, from 21 March until 24 March 2011, a group of 436 participants and distinguished speakers attended the CDC-sponsored Bridging the Gaps: Public Health and Radiation Emergency Preparedness conference in Atlanta, Georgia (CDC 2012). This conference had been planned for over 18 mo. The conference was held within 10 d of the earthquake, tsunami, and subsequent emergency at the Fukushima NPP in Japan. This made conference deliberations timely and relevant to specific issues, such as local emergency response preparation and guidance for a radiological incident. The initial goal of the conference of preparing the public health and clinician workforce for radiological and nuclear terrorism incidents as a critical need of our time was never more evident, and it provided an initial forum for the exchange of information and ideas between CDC and its state, local, and federal public health partners. Further, the Bridging the Gaps conference was immediately followed by the initial meeting of the National Alliance for Radiation Readiness (NARR) (NARR 2012). NARR is a coalition of public health, healthcare, and emergency management organizations committed to improving the nation’s ability to prepare, respond, and recover from radiological emergencies.

For several weeks, U.S. state, local, and federal public health officials worked long hours responding to the Fukushima incident. These agencies prepared their after-action reports, identifying those issues that went well and those challenges that need to be further addressed. The purpose of this paper is not to attempt to catalog all of the challenges identified by the U.S. public health community but to raise some significant challenges that CDC identified because of its participation in this response. This information may be helpful to the public health community as it deliberates its role in preparing for potential future incidents involving the release of radioactive material to the environment.

SIGNIFICANT CHALLENGES

Population monitoring

Japan issued mandatory evacuation orders for people living within 20 km of the Fukushima Dai-ichi plant and a mixture of voluntary and mandatory evacuation orders for people living between 20 km and 30 km away. Japanese authorities screened hundreds of thousands of displaced people for radioactive contamination using handheld instruments or fixed portal monitors. In some locations, screened individuals received certification cards indicating they were not contaminated.

Under the Nuclear/Radiological Incident Annex of the National Response Framework (USDHS 2008), monitoring of people for potential radionuclide contaminationis primarily a state and local responsibility. In 2007, CDC issued comprehensive guidance to public health departments on how to organize a population-monitoring program (CDC 2007). However, a 2010 survey by the Council of State and Territorial Epidemiologists (CSTE) revealed that only three of 37 responding states (8%) reported adequate capacity to conduct population-based exposure/contamination monitoring, and most states reported insufficient equipment and health physics expertise to assess exposure and to interpret monitoring data (CSTE 2010).

Radionuclides released from the Fukushima NPP were transported to the U.S. and other locations outside Japan via (1) atmospheric transport, (2) ships and airplanes, (3) passenger luggage, and (4) returning airline passengers. Fallout from atmospheric transport in the U.S. was not large enough to result in the need for any population monitoring effort. However, the other forms of radionuclide transport into the U.S. did result in some monitoring effort. For example, U.S. Customs and Border Protection (CBP) initially screened all incoming passengers and cargo arriving from Japan. Three passengers arriving from Japan were identified by CBP as potentially contaminated (Wilson et al. 2012). CDC, state, and local public health officials developed protocols for further monitoring of those identified passengers (CDC 2011). However, implementing these protocols was challenging in light of the state and local limitations noted above. Furthermore, public health agencies can quarantine individuals if necessary to control the spread of an infectious disease. However, unlike the case for communicable diseases, public health agencies at the state and local level have varying legal authority to detain and require passengers to undergo further monitoring for radionuclide contamination and decontamination if they choose not to do so voluntarily.

The public health community continues to identify strategies for ensuring population monitoring in a mass casualty public health incident. CDC guidance to states includes suggestions to develop mutual assistance programs with other states by identifying available resources (e.g., monitoring equipment, personnel, etc.) to meet population-monitoring needs, but these will not suffice to respond to a major radiological incident (CDC 2007). CDC is also working with the Conference of Radiation Control Program Directors (CRCPD) to help states set up programs to recruit local radiation experts as volunteers to assist with population monitoring (CRCPD 2011). Interagency efforts (involving CDC, EPA, FEMA, the U.S. Department of Energy, the U.S. Nuclear Regulatory Commission, among others) continue to identify radiation monitoring resources available in federal departments and agencies, including both equipment and personnel, to support state and local efforts and to develop an interagency plan to mobilize those resources, if ever they are required.

A gap exists between requirements for optimal public health response to a nuclear or radiological event and available response capacity, including radiation experts, to fill that gap. If this gap is not closed, important radiation health screening services may not take place in a timely manner to inform people whether they have been contaminated, and concerned citizens may limit access to or drain already limited resources. Shelters may refuse admittance to displaced people, and air and ground ambulances may refuse transport of contaminated patients. Additionally, long-term monitoring for potential excess cancer risk and treatment may be impeded, and the public health system, unable to answer people's most pressing question of "Is my family safe?" may lose credibility (CDC 2012).

HEALTHCARE CAPACITY

Gaps exist in domestic preparedness for the medical consequences of a catastrophic public health emergency involving the release of radioactive material. DHHS has developed playbooks for how the federal government would support states in response to catastrophic radiological and nuclear incidents, but the playbooks do not provide specific details regarding integration of state-federal response efforts. A template for a state/local playbook for a nuclear detonation is available to state/local planners on the DHHS PHE.gov website (USDHHS 2011). However, while 81% of U.S. hospitals have response plans for radiological accidents or attacks, only 18.7% have exercised those plans (Niska and Shimizu 2011).

Medical expertise and treatment capacities for response to radiation emergencies are limited. Shortfalls that previously have been described include the number of available hospital beds; the availability of medical supplies, including radiation-specific medical countermeasures; the availability of burn beds; the ability to transport large numbers of patients; and the general lack of knowledge among health care providers about radiation and radiation-related illnesses (NCRP 1985; Council of State and Territorial Epidemiologists 2010). One consequence of the lack of knowledge is fear-born reluctance to care for or transport potentially contaminated patients (USDHHS 2011). If the gap between optimal response and healthcare capacity is not closed, it may not be possible to provide care to many injured people in a large-scale incident (generally considered as affecting hundreds or more people) who could receive treatment if the system is enhanced (CDC 2007).

Furthermore, a monitoring program may be needed to assess the long-term health impacts of the exposed population. The most recent example of such a program is the effort by the Japanese government to conduct radiation dose assessments for approximately two million residents affected by the Fukushima Dai-ichi NPP incident in March 2011 and offer health screening for those who need it (Bird 2011). This program may follow some residents for up to 30 y (Asahi 2011). A detailed plan on how an extensive long-term health monitoring program would be implemented in the United States does not currently exist.

Subject matter expert personnel shortage

Public health preparedness for infectious disease emergencies benefits from the wide range of expertise in the public health community at all levels, including infectious disease physicians, microbiologists, laboratory specialists, and infectious disease epidemiologists. In contrast, the number of public health officials with expertise in radiation health is extremely limited. The 2010 Council of State and Territorial Epidemiologists (CSTE) report found that few full-time equivalent staff work regularly in radiation emergency response within state public health departments (CSTE 2010). The limited and declining number of health physicists, who as a profession specialize in radiation protection, further complicates the situation (HPS 2008). The need during a domestic emergency of consequence likely would go unmet as public health would compete unsuccessfully for these experts with other responding agencies and healthcare organizations. This situation is unlikely to improve as enrollment in training programs is declining, and many experts trained in the era of federal support now are retired or approaching retirement (HPS 2008).

Public health departments and agencies could benefit by using radiation experts for disaster preparedness as well as supporting routine use of radiation resources (Mazurek and Barishansky 2013). This gap in radiation-protection expertise can be addressed by recruiting and training radiation-safety professionals who serve in industry and academia as local community volunteer resources (HSC 2010). Ongoing efforts by CDC and CRCPD support the states in reaching out to health physicists, medical physicists, radiation-protection technologists, nuclear-medicine technologists, radiologic technologists, and other radiation professionals who can be recruited and trained as a radiation response volunteer corps, closely associated with local Medical Reserve Corps programs (CRCPD 2011). If the gap is not closed, few public health agencies will be able to fulfill their responsibilities as outlined in the National Response Framework (DHS 2008) and the supporting implementation plans that have been developed by various agencies.

Public health communications

During the response to the Fukushima incident, it became clear that a timely, coordinated public messaging strategy is an important component of any emergency response involving radiation or radioactive materials. Since that time, the U.S. has developed messaging for a variety of radiological incidents (FEMA 2013). This includes pre-scripted messages specific to the actual incident information and location, as well as guidance on how best to use multiple information outlets, including TV, radio, and print journalism as well as internet and social media sites.

The DHS Federal Emergency Management Agency and NSS included state public health partners in this message development. The NARR worked directly with CDC and the DHHS Assistant Secretary for Preparedness and Response during the Fukushima response to help develop public health messages for use by CBP and CDC. These messaging strategies may reduce delays and inconsistent information dissemination.

Radiation units

As expected, the radiation monitoring data and dose assessment information that became available from Japan during the Fukushima incident were expressed exclusively in the International System of Units (SI); i.e., Becquerel (Bq) and Sievert (Sv). Many U.S. guidance and informational documents are primarily in traditional units; i.e., curie and rem. This dichotomy required that measurements and projections had to be constantly translated among systems. These translational efforts required time and resources, and while generally straightforward, introduced unnecessary opportunities for calculation errors in the decision-making process. This unit difference also complicated communications between radiation subject matter experts, senior government officials, other professionals involved in the response, and members of the general public.

SI radiation units have been used worldwide for many years, but the U.S. has never fully adopted them. The *Health Physics Journal* has a long-standing policy that requires the use of SI units for all quantities presented in its publications. The National Council on Radiation Protection and Measurements has long recommended that SI units be used exclusively (NCRP 1985). At its meeting in West Palm Beach, FL, on 26 June 2011, the Health Physics Society (HPS) Board of Directors adopted the position that “SI units should be used exclusively when expressing radiological quantities.” The HPS subsequently issued a formal Position Statement on this subject (HPS 2012). Consideration might be given to adoption of this position by all radiation-related organizations in the U.S. It could remove one potential source of error and confusion in the event of another radiation incident of the magnitude and worldwide impact of Fukushima.

Exposure standards

One way to protect people from the health consequences of excessive radiation exposure during an emergency is to define levels for the maximum radiation exposure permitted from various sources or circumstances. These levels, called “protective action guides (PAGs),” are based on complex calculations including factors such as the type of radiation or radionuclide, assumptions about route and duration of exposure, long-term cancer risk, age of the exposed individual, and the varying sensitivities of different organ systems. PAGs may be different in magnitude from other exposure standards used to define practices that limit occupational exposure in radiation work and exposure to the public during non-emergency situations. After a contaminating incident, authorities will use the PAGs to assess whether, or for how long, people can remain or work in a contaminated area and whether contaminated foodstuffs may be released for consumption.

In the United States, various agencies set exposure standards and PAGs depending upon their jurisdictions, each using different calculations and different assumptions. These may be determined by statute, leaving limited discretion to the agencies and experts. International agencies have additional and different standards. For example, when the radionuclide ^{131}I was identified in a sample taken from Tokyo’s drinking water system, the Government of

Japan applied PAGs of 100 Bq L^{-1} for children and 300 Bq L^{-1} for adults. The U.S. currently has no PAGs for drinking water (USEPA 1992), adding a needless, inhibiting, and dangerous complication to the response to a domestic disaster when guidance is needed immediately to inform evacuation, cleanup and re-occupancy, and food and water safety.

Radiation exposure standards that provide clear, specific evidence and risk-based guidance and are consistent with international standards will help alleviate potential concerns that may arise in the absence of such standards.

Monitoring data aggregation and sharing

Prior U.S. planning for a radiological incident, as embodied in the Nuclear/Radiological Incident Annex to the National Response Framework (USDHS 2008), indicates that early in the response, the U.S. Department of Energy (DOE) will activate its Federal Radiological Monitoring and Assessment Center (FRMAC). Each department and agency that either collects or uses monitoring data will send representatives to the FRMAC in order to ensure that all contribute the data they collect and have access to the total range of data and resulting interpretations.

During the Fukushima response, however, the FRMAC was not activated, and no single central source aggregated either monitoring data collected by U.S. agencies in Japan or data collected by federal or state agencies in the United States. As a result, public health authorities who were responsible for preparing assessments for decision makers had to poll various agencies and, in the case of data from Japan, use data posted on Japanese government and commercial Internet sites.

State, local, and tribal public health officials must have information such as:

- Projected plume arrival time and locations;
- Radionuclides identified in the release;
- Environmental monitoring data collected within their jurisdiction; and
- Monitoring information for incoming cargo.

The difficulty of obtaining data such as this during the Fukushima response sometimes resulted in delayed or incomplete work on assessments needed to support public health decision making.

One significant issue raised by the Fukushima incident was that much of the environmental monitoring data was being gathered in Japan at the request and in support of Japan’s internal response needs. Although these data were generated by Japan for internal use, access to this information, such as radionuclides identified in the release, would have been useful for planning by the international public health community. Absent a common approach to aggregating, analyzing, sharing, and archiving data during an international radiological incident, state, local, and federal agencies may lack the data necessary to make appropriate public health protective actions. In addition, the inability to share information with states could potentially strain working relationships with public health partners and cause decision making at the state level to be more difficult (CDC 2007, 2012).

Potassium iodide stockpiling and distribution

If potassium iodide (KI) is administered just before or when a person is exposed to radioactive iodines, it can help protect the thyroid gland from potentially harmful effects due to that exposure. Under current NRC emergency preparedness regulations, states with populations living within the 10-mile Emergency Planning Zone (EPZ) of a commercial NPP must consider including KI as a protective measure to supplement sheltering and evacuation. For states that choose to incorporate KI into their plans, the NRC offers funding for an initial KI supply and additional one-time funding for replenishment. Each state decides whether and how to use the KI, and NRC reports that, of 34 states with populations living within a 10-mile EPZ, 21 states chose to receive KI tablets (USNRC 2011). Some localities may choose to focus on evacuation rather than distribution of KI, so local preferences will vary, making standardization difficult. There is also a 50-mile Ingestion Pathway EPZ for interdiction (and monitoring) of food and water to prevent intake of radioactive iodine (USNRC 2011).

During the Fukushima incident, some citizens within the continental U.S. became very concerned about the possibility of being exposed to radioiodine in fallout from Japan. Levels of radioiodine measured in environmental media never approached any level where the use of KI would have been recommended (Tupin et al. 2012). Nevertheless, over-the-counter supplies of KI were exhausted along the west coast of the U.S., although CDC and other public health authorities specifically recommended that KI not be taken.

Because of the limited time window for effective use of KI, federal health planners assumed that they could not transport KI from CDC's Division of Strategic National Stockpile (SNS) to local U.S. jurisdictions in time to be effective for those within a 10-mile EPZ. For those beyond this distance, evacuation and avoidance of ingestion have been deemed to be appropriate protective actions (USNRC 2011). As a result, no current requirement directs the SNS to maintain KI in its inventory, and only a very limited amount of KI is currently available in the SNS. The Fukushima experience demonstrates that an NPP emergency may evolve over days, possibly providing sufficient lead-time to move drugs from central stockpiles. As a result, it may be helpful to reevaluate whether and how much KI to hold in the SNS or whether other caches should be placed strategically across the country. If an NPP emergency resulted in inadequate KI supplies available within the 10-mile EPZ and/or for people at risk of exposure beyond the 10-mile EPZ, the SNS may not be currently prepared to meet the public health need for KI. It is also possible that public demand, as seen in the U.S. during the Fukushima incident, could cause a "run" on commercial supplies, thus rapidly depleting them and preventing those who need KI from having access through commercial sources (Schneider and Smith 2012).

CONCLUSION

The nuclear reactor emergency at Fukushima Dai-ichi was a crisis for both Japan and the international community. As with any crisis, it also presents opportunities to learn and prepare for similar incidents in the future. Events in both Japan and the U.S. during the response illustrated some U.S. preparedness challenges that previously had been anticipated and others that were newly identified. Some of these challenges are presented above. Our sympathies remain with the Japanese people, who will be dealing with the consequences of this incident for years to come. The global public health community has the opportunity to draw on the lessons learned from this unfortunate event to expand and enhance preparedness for possible future nuclear and radiological accidents.

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