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Emergency Preparedness in the 10-Mile Emergency Planning Zone Surrounding Nuclear Power Plants

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Abstract

Objectives—Each of the nuclear power plants in the US is encircled by an Emergency Planning Zone (EPZ). Within each EPZ, government officials, utility professionals, emergency managers, and public health practitioners collectively conduct extensive planning, exercises, and outreach to better protect their communities in the event of a nuclear accident. Our objective was to conduct a cross-sectional study of off-site public health preparedness within EPZs to better understand the dynamics of nuclear preparedness and uncover lessons for all-hazards preparedness.

Methods—Using a qualitative, interview-based method, we consulted 120 county emergency managers, state health preparedness officers, state radiation health officials, and industry officials from 17 EPZs in ten different states.

Results—Interviewees reflected that EPZ emergency preparedness is generally robust, results from strong public-private partnership between nuclear plants and emergency management agencies, and enhances all-hazard preparedness. However, there exist a few areas which merit further study and improvement. These areas include cross-state coordination, digital public communication, and optimizing the level of public education within EPZs.

Conclusions—This first-of-its-kind study provides a cross-sectional snapshot of emergency preparedness in the 10-mile EPZ surrounding nuclear power plants.

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1 Introduction

Half of the US population lives in close proximity to the nation's 65 nuclear power plants (see Text Box 1) (Radiological Emergency Preparedness Program 2013). The safety of the communities living in the Emergency Planning Zones (EPZs) encircling these nuclear power plants has long been the subject of debate. For example, the size of an EPZ and the scope of emergency planning around nuclear power plants are challenged (Thomas et al. 2011 ; Government Accountability Office 2013). This debate intensified after the nuclear disaster in Fukushima stressed the framework for nuclear disaster response, leading some to recommend an evaluation of planning in the US (UPMC Center for Health Security 2012; U.S. Nuclear Agency 2013).

Text Box 1

About Emergency Planning Zones

EPZs are situated as two concentric circles around each plant (see Figure 2) (United States Nuclear Regulatory Commission 1980). The dimensions of each EPZ are based on two anticipated exposure pathways: the first one is a 10-mile radius for the shorter-term "plume exposure pathway" and the second is a 50-mile radius for "ingestion exposure pathway" zone for longer-term exposure. Because the duration of time between a major nuclear plant accident and the start of a major release of radioactive material could be as short as a few hours, preparedness within the 10-mile EPZ is of crucial importance.

We conducted a novel investigation of community-level preparedness activities within 10-mile EPZs, the primary outcome of which was extensive documentation of the opinions of county-level emergency preparedness officials regarding issues of public health as they relate to radiological emergency preparedness. A secondary outcome was to identify principles of best practice – via the synthesis of our research findings – to inform future efforts in public health preparedness for communities located in the vicinity of nuclear power plants and beyond.

2 Methodology

2.1 IRB Approval

Given that the research team interviewed individuals in their professional capacities on their opinions about response systems, this study does not qualify as human subjects research. Therefore, IRB approval for this study was not required.

2.2 Selection Criteria for EPZs

The research team first conducted an informal review of scholarly literature, government reports, industry whitepapers, and media articles to assess the current state of nuclear

emergency preparedness in the US. The review offered valuable guidance and insight into the dynamics of existing nuclear emergency management practices, but revealed little about variation in state preparedness practices, best practices, and outstanding gaps. Therefore, the research team identified a representative sample of 17 EPZs in 43 counties across 10 states. Sites were chosen to reflect the diversity of approaches to ensuring nuclear preparedness, which in turn depend on variables such as governance structures, demographics, and emergency management policies at the state and local levels (Figure 1). For example, two of the states examined had limited or no "home rule"[1] while eight states (including two "commonwealths")[2] practiced home rule. Eight states were part of the Nuclear Regulatory Commission (NRC) Agreement State Program. Additionally, some states operated county-level health departments while others did not. Location-specific challenges, variances in emergency preparedness policies, and the presence of special populations were also considered. For instance, nine states in the sample had developed plans for stockpiling and distributing potassium iodide (KI) to their constituents in the event of an emergency. Some EPZs also spanned state boundaries, raising issues of cross-jurisdictional emergency preparedness and response. Finally, while many of the EPZs studied were home to large urban populations, others contained significant agricultural assets.

2.3 Interviews with Key Informants

Next, the research team conducted a series of exploratory, semi-structured interviews with key informants from state and local governments and representatives from the nuclear industry located within each of the selected EPZs. These individuals, who maintain responsibility for ensuring the health and safety of the public during nuclear emergencies, included public health officials, emergency managers, health preparedness officers, radiation health officials, and nuclear utility managers. We gained access to interviewees by locating their contact information (telephone numbers and email), which was available on the websites of state and local public offices.

Consent to participate in an interview was granted either verbally or via email. The majority of the interviews took place over the phone (88), though a minority of interviewees elected to meet in person (1) or answer questions via e-mail (3). The principal investigators of the project (AA and RM) led each discussion using a protocol of open-ended questions. These questions, which were derived from the informal literature review, addressed issues relevant to the current state of nuclear preparedness in the US (Appendix 1). We employed dedicated note-takers during phone calls in order to retain records of each interview. These notes, in turn, were catalogued on a secure, password-protected server. Findings originating from the interviews were considered not-for-attribution, and the names and institutional affiliations of each informant are not disclosed in this document. Ultimately, the research team completed a total of 92 interviews with 120 individuals.

[1]"Home rule" describes a legal path by which a state grants authority to a local government; home rule creates local autonomy and limits the degree of state influence in local affairs.

[2]Traditionally, commonwealth states have more granular local government entities than non-commonwealth states. For example, a citizen of the Commonwealth of Pennsylvania resides within several distinctive local government entities: a township which is encompassed by a municipality, which is in turn encompassed by a county. Often, each of these entities has its own emergency preparedness practitioners and responsibilities.

2.4 Analysis

Based on recurring themes identified from conversations with the interviewees, the research team categorized the interview findings into nine areas of importance that require continued attention from emergency managers, public health practitioners, and policymakers (see "Findings"). The team then addressed remaining gaps in nuclear preparedness practice in the US, outlined recommendations for strengthening public health preparedness in EPZs, and offered suggestions for future research endeavors in these areas.

3 Findings

3.1 Governance and Duties

Federal law requires that emergency plans be in place for responding to radiological emergencies at nuclear power plants (44 CFR Part 350 2011). The approach to meeting these obligations varies. Indeed, historical attributes of a state impact the organization and distribution of responsibilities. Some states depend heavily on local governments while others contain counties not legally required to adhere to state-level recommendations. All planning is ultimately done in accordance with relevant Nuclear Regulatory Commission (NRC) and Federal Emergency Management Agency (FEMA) guidance and regulations.

State governments share preparedness responsibilities with local governments. Most states utilize a "top down" approach to radiological preparedness, with capacity and responsibility concentrated at the state- and county-levels. Some states, particularly states designated as commonwealths, have greater involvement of municipal officials. One emergency management director noted, "Being a home rule state, the governing authority gets down to the local level – the state has political authority, but the [state] Constitution drives local control down to the village." Similarly, other emergency managers reported that, compared to local governments, the state plays a minimal role in regulating nuclear preparedness activities.

County-level emergency management agencies typically serve as the primary entities responsible for radiological preparedness. Generally, county-level emergency management agencies have a radiological planner on staff. In other cases multiple individuals share tasks. In some states, counties retain in-house radiological analysts, who lend important expertise to preparedness activities. However, some counties prefer that states permit autonomous county-level emergency preparedness activities. For example, officials in one independent city (which did not fall under the jurisdiction of a county-level government), maintained that they are able to control roadways without the need for the state government acquiescence required by their county-level counterparts.

In states that involve municipal governments in planning, some EPZs contain over 20 municipalities, each with an individual serving as a municipal radiological officer slated to represent the municipality in an emergency. These municipalities frequently rely on committed, but aging, volunteers who often perform myriad other municipal tasks, such as serving in the fire department. One informant stated, "We're all wearing a lot of hats. There aren't a lot of experts at the local level." However, interaction with preparedness professionals at the nuclear power plant primarily occurs at the county level. Accordingly, a

prior study reports that county-level personnel were more likely to rate their relationship with nuclear power plants as high quality versus their municipal counterparts (MacManus and Caruson 2010).

State departments of environment and agriculture provide additional support. These agencies conduct field monitoring, inventory agricultural assets, and assist with education.

Additionally, many states are Agreement State Programs (2013). These states have signed an agreement with the NRC authorizing the state to regulate certain uses of radioactive materials (such as medical applications), but not nuclear power, within the state. These states benefit from state-level radiological expertise, cultivated by the enhanced role the state assumes as a program participant, augmenting the emergency preparedness capacity that can be used within EPZs.

Notably – and unlike the case for all-hazards emergencies in which public health preparedness divisions play active roles in preparedness and response– state and county health departments are generally not fully integrated into response efforts. Their role is predominately limited to management of KI, when applicable. In a minority of states, the state health department serves as the location of the state's radiation bureau and source of subject-matter experts on radiation. In other states, the radiation expertise of the state lies outside the health department. County health departments are primarily focused on managing evacuation reception centers and stockpiling/distributing KI.

3.2 Education and Outreach

Public education in EPZs consists of ensuring that the public is aware of what actions to take during emergencies. In most cases the utility company and county-level emergency management agencies collaborate to conduct education.

Interviewees cited meetings, calendars, pamphlets, phone books, and programming on TV and radio as methods used to educate the public about drills, evacuation routes, KI, and other issues. Some local agencies also stated that they have used social media to keep the public informed. However, the use of social media remained more of a "wish list" item for most.

Interviewees sometimes cited outdated means of information sharing, such as phonebooks and calendars, as concerning. Several interviewees explained, however, that they were struggling with maintaining their budgets and that updating to newer technologies was not feasible. One county-level emergency manager also stated that federal regional evaluators do not reward social media efforts, as evaluation criteria stipulates only that information is disseminated annually and suggested means do not include digital formats (United States Nuclear Regulatory Commission 1980). Another informant, a preparedness coordinator, felt that "nuclear power throughout the country has done a horrible job getting messages across to the public. They are overshadowed by the anti-nuke people. If you don't react to the information out there, bad information might stick. The nuclear power agencies and companies really missed the boat on this."

Despite these shortcomings, interviewees were generally confident in their approach to education, citing the fact that most plants have been established for decades and employ a significant percentage of the local population, thereby allowing public health knowledge to diffuse throughout the community. One informant reported, “The public asks a lot of good questions, and we have given them enough information for people to make informed decisions.” Another noted that “as more people become interested in emergency preparedness, being able to quench that thirst for knowledge is important… There is more interest in what is occurring in nuclear energy – and in emergency preparedness.” However, some interviewees also reported particular difficulties in engaging with hard-to-reach populations (e.g., members of younger demographics and farms). Additionally, interviewees expressed concern that younger individuals moving into the EPZ might not assimilate knowledge as well as long-standing residents.

Some interviewees expressed concern about the level of retention the public has of actions to take during an emergency. Participants consistently noted that no formal study of the public’s retention of nuclear safety information had been conducted within their EPZ. A commonly relied upon metric is attendance at events or the changing rate of calls to emergency management. Though jurisdictions were pleased to report that the level of calls did not tend to increase following pre-announced siren tests, others conveyed that they were surprised by the concern expressed in their EPZ following Fukushima. The education of hospital personnel at response hospitals regarding patient care issues is primarily the responsibility of state agencies.

3.3 Evacuation

Every EPZ reported that evacuation is the primary protective action for the public during an emergency, with only select institutions preparing to shelter-in-place (e.g., hospitals and prisons) when conditions permit. Several EPZs have their designated response hospital within the 10-mile EPZ, offering advantages for treating occupational injuries, but posing evacuation concerns.

Most evacuation plans are based on a phased evacuation in which the population in the 2 miles surrounding the plant is automatically evacuated along with the population 5 miles downwind of the plant in a keyhole shape. The remaining population in the EPZ is evacuated according to weather patterns, plume direction, and radiological data. A minority of EPZs surveyed practice a “360/10” evacuation in which a 360-degree evacuation within the 10-mile radius surrounding the plant is ordered.

Informants also reported numerous social, political, and economic concerns when speaking about the challenges of evacuation. One emergency preparedness manager noted, “The biggest concern in not evacuating the psychological aspect of it. If you evacuate 360/10 and nothing happens, how much of an economic impact will there be, as far as reentry goes? We found out by doing our exercises [that] it will be really, really hard – especially for media and public perception – when we don’t adhere to 360/10. We are perceived as being lax or not conservative enough for public protection. We struggle with that.” Still, many interviewees expressed a strong preference for phased evacuation. Interviewees explained that by evacuating everyone simultaneously, there emerges a risk of impeding the

evacuation of individuals closest to the plant, thereby jeopardizing those in the most potential danger. One interviewee also reported that FEMA is promoting a “keyhole” approach, which requires residents in the two-mile ring around the plant to evacuate, along with people in the five-mile ring in the projected path of the radiological release. Others favored 360/10 evacuation because it is less vulnerable to wind shift and other factors, ensuring that the population is evacuated. Many of these participants also believe that shadow evacuation (i.e., a situation wherein people not in the mandatory evacuation zone choose to evacuate) is likely to take place throughout the entire 10-mile EPZ and beyond.”

While most interviewees believed that their evacuation routes were optimized, as determined by evacuation time studies, other concerns about the evacuation process were noted. In some EPZs, there are waterways that would be challenging to evacuate. Similar concerns include instances in which evacuation is physically restricted either by geography, road infrastructure, or weather-related roadway impediments.

3.4 Long-term Sheltering

Many interviewees expressed concerns about where evacuees would be sheltered once evacuated. In some EPZs, the responsibility for planning these shelters fell to non-governmental organizations, such as the Red Cross. In EPZs where the public would not have to cross jurisdictions to evacuate, the process of sheltering was considered to be easier from a governance perspective. Despite anticipating assistance from FEMA, many indicated that it would be challenging to decontaminate, treat, house, and feed volumes of people for a potentially extended period time. Most interviewees expressed a preference for sheltering in place in the event of a nuclear emergency, citing the challenges associated with evacuating certain populations, including prisoners, hospital patients, and nursing home residents. Another notable challenge is ensuring that adequate space is available for every evacuee. One emergency manager noted that his EPZ simply does not have the space to house all evacuees during an emergency, and that complying with American Red Cross sheltering regulations further complicates sheltering efforts.

3.5 Exercises

Within each 10-mile EPZ, utility operators and state and local governments, along with NRC, FEMA, and other federal agencies, take part in evaluated exercises every 2 years. Specifically, these exercises focus on protecting the public from exposure to, and inhalation of, airborne radiation. Interviewees reported that exercises typically include a variety of community stakeholders, including: the nuclear plant, hospitals, nursing homes, daycares, school, municipality offices, and, in some cases, the Coast Guard.

Several interviewees expressed concern that the exercises were “unrealistic” or “antiquated,” and that actions performed during exercises would not be performed during a real emergency. One interviewee noted that most exercises emphasize hostile action-based scenarios even though a focus on natural disasters would be a more realistic approach. Another informant, a preparedness coordinator, stated that an actual emergency “is going to be chaos, even within just a ten-mile zone. When we do drills, the scenarios are pre-fabricated to the point where we know this is going to happen at 10:02, sound sirens at

11:30, all because ‘that’s the way it happens.’ There is no room for the unexpected.” Another coordinator also felt that federal authorities involved in exercises and planning efforts sometimes fail to account for the most realistic threats to nuclear plants:

> “Plants that are on a fault-line or would have to deal with that should look at a capability to deal with those issues, but NRC and FEMA put everything into one-size-fits-all. Planning is made more difficult because of this. We just did an [evacuation time estimate] and they talk about a rapid-moving event (a release within an hour), and we have to deal with that. The whole ETE was based on this and that’s insanity. That will never happen. I don’t want to check a box. I want to have a real capability to deal with real issues. Sometimes the regulators check boxes instead of looking at realistic situations and capabilities.”

Additionally, time and money constraints often prohibit EPZ communities from conducting exercises that explore long-term responses to nuclear emergencies. One interviewee noted that exercises in his jurisdiction had never before accounted for the secondary consequences of a nuclear emergency that might manifest after response and during recovery, stating, particularly after the response phase and during recovery, “Only now after Fukushima are we really thinking about new things – when to open up restaurants, dealing with the fear, assurance.” Interviewees also reported that ingestion phase exercises, which cover a 50-mile radius around the plant and concern the ingestion of contaminated foods and liquids, are not conducted frequently enough to be useful. Given that these exercises occur every 8 years, employee turnover patterns result in many key staff members never having participated in an ingestion phase exercise. Some counties are located in two EPZs and report enhanced preparedness resulting from participating in annual, rather than biannual, exercises.

3.6 Interfacing with Agriculture

Agricultural areas located inside EPZs present nuclear planners with unique challenges to shelter livestock and protect/preserve crops. Establishing contact with farm operators in these areas before and during a nuclear emergency is difficult as individual farm data may be viewed as proprietary and private. Approaches implemented include: creating databases of farms and their relevant crops or livestock, asking that farmers submit annual updates to “special needs cards” which provide an inventory of a farm’s assets, and liaising with community leaders and livestock providers to develop evacuation plans and discuss safety concerns.

Many of the jurisdictions included in this study contained farms, but some lacked specific mechanisms for communicating with agricultural communities and accounting for livestock and crops during public health emergencies. One radiological response coordinator noted, “There is…no database on farms in the EPZ. This is a missing part – when we go to a general emergency, we need to know where the farms are and where feed is stored, etc.” Other interviewees also expressed discontent with their awareness of the types of agricultural assets within the EPZ, with some concerned about the ability to obtain information from state departments of agriculture as well as the US Department of Agriculture. Some states reported positive results from routinely working directly with the state university’s agriculture extension office to maintain communication with farms. One

state reported improved preparedness after the utility decided to begin supporting a radiological emergency preparedness position within the agriculture department. Planners in other jurisdictions also reported that designating farmers themselves as disseminators of emergency information proved effective.

3.7 Utility Company Support for Positions

Interviewees reported that utility companies, to varying degrees, assist in planning and outreach, and generally play a crucial role in building and maintaining human capital within EPZs. Almost all county-level interviewees reported that their radiological positions and budget are financially supported by the utility company, an arrangement that has been ongoing for decades. One emergency manager shared, “If the utility provides lots of money with expectation that [the radiological emergency plan] receives attention, I want to make sure they get what they are paying for. My staff works with them to help implement [the plan].”

Interviewees reported that a strong partnership between county-level emergency planners and their counterparts at the utility are a key component to the effective management of the EPZ. In some places, these relationships were said to involve almost daily communications between individuals.

An interview with a utility representative revealed that the primary focus of the utility is nuclear emergency planning, while the responsibility for addressing the needs of the public resides with municipal institutions, since “they know their counties and fire companies better than we do.” The representative also shared that in some states, legislative funding enables the utility to finance training for nuclear emergency planners. However, in other states, these positions are often filled by volunteers, presenting the utility with staffing problems: “We would prefer that they were all paid. There aren’t many young people volunteering, so [we] are having a hard time filling spots after someone retires or dies.”

3.8 Potassium Iodide

Of states that choose to incorporate KI into their emergency plans, varied means to distribute it are employed. States pre-distribute KI via either their health departments, by mail to residents, or via mail vouchers to be used at their pharmacies to obtain the medication. In states that incorporate KI into their emergency plans, the health department is the coordinator of the program, which makes the health department a larger component in nuclear emergency preparedness relative to that in non-KI states.

Interviewees expressed a number of concerns regarding KI. A common refrain of interviewees in states that participate in the NRC’s KI program[3] was that the uptake/pre-distribution of KI amongst the public is very low (Rosselli et al. 2011; Zwolinski et al. 2012). Interviewees, in some cases, hailed this as a paradoxical benefit as it would delimit any false sense of security engendered by what many fear could be misconceived as a “magic radiation pill.” For example, a health district coordinator noted that “people are not

[3]The NRC KI program provides participating states with supplies of KI for the population within the 10-mile EPZ.

aware at all of the limitations of KI, unfortunately…There is always a risk that someone will take KI and not evacuate." Several informants also acknowledged other challenges associated with refusing to distribute KI. A state-level health manager shared, "Everyone was opposed to [KI] at the state level, but ultimately our chief medical executive realized we couldn't say no, and that we had to focus on the best way we could use it." On a similar note, a preparedness coordinator reported difficulties with educating the public about the utility of KI: "Whenever I talk about KI, I always push the point that it's only for the thyroid, and really, truly, the KI is more for the kids. Of course, we give it out to everyone."

There were concerns that KI use would delay evacuation as people spent time searching for KI. One emergency preparedness director expressed dissatisfaction at the inclusion of KI in the state's plan, stating, "We weren't exactly for the state KI plan. Evacuation is our key… We were never excited about people thinking that the KI would be worth something." Another state, in order to prevent such delays, distributes KI exclusively at reception centers located outside the evacuation area: "For the most part, the plan calls for pre-distribution of KI, but individuals will probably receive KI at the reception center after [decontamination] and monitoring."

3.9 Expanding the 10-mile EPZ

Interviewees were opposed to expanding the 10-mile EPZ without a strong scientific rationale, which they believe had not been articulated. In fact, many shared the judgment that scientific data does not support expanding the 10-mile EPZ based on their understanding that the plant in their EPZ does not contain enough nuclear material to even reach 10 miles. One emergency management director stated, "If the science says to expand it, we'll expand it. But we can't let politics drive decisions." A member of a state department of health concurred, reasoning that "it's important to consider the outcome – that has to do with the potential benefits and costs in relationship to probabilities. If there is no science either way, you are just exchanging arbitrary boundaries." In fact, one planning officer even suggested that scaling the EPZ back to five miles would be a more prudent course of action.

Other reasons cited against expansion are the operational challenges associated with the increase in population covered in a 20-mile zone. One informant noted, "If they were to expand the size of the EPZ, even by a small amount, the area included would be huge. We'd have to go back and reconsider how we do things in light of the added area of responsibility. It's a lot more people that you're bringing into that umbrella." Furthermore, several interviewees pointed out that preparedness activities already take place outside the 10-mile EPZ (including within the 50-mile EPZ). In one particular jurisdiction containing a peninsula, EPZ expansion would actually force residents to evacuate *towards* the nuclear power plant.

3.10 Perceived Gaps

Gaps in nuclear preparedness identified by numerous interviewees included: ongoing challenges associated with inter-jurisdictional collaboration, particularly with respect to divergent approaches between neighboring states; lack of pre-event situational awareness of agricultural facilities and assets within the EPZ; lack of availability of qualified expert

radiological staff; and the need for increased cooperation with federal partners with responsibilities within the EPZ (e.g., US Coast Guard, military bases).

4 Discussion

Based on interviewee reports, several themes were identified by the research team as important findings, avenues for further research, and areas where preparedness might be further enhanced surrounding nuclear power plants.

4.1 Educational and Communication Efforts Should Reflect the Modern Digital Age

During many recent disasters, two-way communication between emergency agencies has become emblematic of a 21st century disaster response.

It is concerning that nuclear power emergency preparedness is limited – by regulation – to employing phone books and calendars as their primary means of public outreach, tools that have largely been jettisoned in favor of improved digital-based applications. Despite the widely shared views that using newer technologies for public messaging would bolster preparedness efforts, social media is seldom used for radiological emergency preparedness in EPZs.

Continued reliance on outdated modes of outreach will hamper the ability of public messaging to reach as wide an audience as possible – a fact reinforced by the utility of social media following the accident at Fukushima (Friedman 2011). Also, the fact that many emergency agencies do not yet have an active social media presence around nuclear preparedness issues limits the situational awareness of emergency agencies. Efforts should be made to update regulation and communication practices to make use of the most effective digital tools.

4.2 Nuclear Power Companies Strengthen Preparedness Activities

The fact that all county-level emergency managers interviewed reported that they receive financial support for nuclear emergency preparedness from nuclear power plants illustrates the fundamental role that utilities play in fostering expertise and capacity at the local level.

The assistance provided by nuclear power companies to emergency management agencies extends beyond the financial to include a close day-to-day working relationship that facilitates the situational awareness of all parties' operational needs, capacity, and status; an open dialogue; and an acute awareness of their interdependence.

This is consistent with emergency preparedness in other realms, where close relationships between private entities and public safety agencies are crucial for resiliency and an efficacious response to emergencies (Chen et al. 2013).

4.3 Public Health Agencies Should be a Major Component of Response

As was evident during the events after Fukushima, the public had an acute demand for public health expertise (Osnos 2011). Since 9/11, public health agencies have expended great effort to augment their public health emergency preparedness activities by bolstering

their public outreach, crisis communication strategies, and ability to provide the public with unified messaging amongst the cacophony of voices during a disaster.

In matters of nuclear power plant emergency preparedness, however, local and state governments largely invest emergency management agencies with the bulk of these responsibilities, while leaving health department emergency preparedness professionals – routinely in action for infectious disease outbreaks and other disasters and emergencies – underutilized.

Efforts should be made to fully integrate public health agencies into EPZ planning at both the state- and local-levels. The expertise and judgment of health officials would be especially important in planning around evacuations during which a whole range of health concerns would exist along with special populations who would need particular attention.

4.4 Scientific Evidence-Base Should Provide Rationale for Planning and Decision Making

Nuclear regulatory agencies should seriously address the position amongst county-level emergency managers that science is not driving policy decisions. Such a perception – whether accurate or not – poses a major challenge for emergency preparedness by fostering disconnect between ground-level workers and senior policy leaders. Prior to any proposed changes to the EPZ, a rigorous and scientific basis should be provided specific to the characteristics of individual plants.

Additionally, the results of recent scientific research should be employed to optimally design public education programs (Glik 2007). In the few instances in which education has been measured, the results of current passive communication efforts are not encouraging (Rosselli et al. 2011; Zwolinski et al. 2012; Review of NUREG-0654 2013). Educational efforts should also reflect emerging data from Fukushima where Internet-based sources of public information about radiation – as opposed to the diffusion of knowledge from neighbors and coworkers – was found to be a predictor of greater comprehension of radiation issues by the public (Kanda et al. 2013).

4.5 Optimizing the Management of Cross-State EPZs

As nuclear power plant EPZs are not always located in one state's jurisdiction (or, in some cases, even one FEMA region) challenges emerge due to disparate planning efforts employed by neighboring states. During an emergency situation, having divergent approaches may have deleterious consequences. To improve coordination and minimize confusion some jurisdictions have imported practices from their neighboring states.

As nuclear power plant emergency preparedness is enhanced, special attention should be paid to these unique situations in which, as Stoto notes, rational loci for emergency planning may not be apparent (Stoto and Morse 2008). Methods for minimizing public confusion should be evaluated and addressed by focused exercises coupled with population interviews.

4.6 All-Hazards Preparedness Implications

State-level interviewees consistently conveyed that counties and municipalities within EPZs were better prepared for all-hazards emergencies than other counties in their state. Increased

emergency planning around the nuclear power plant has repercussions that positively enhance the general preparedness of counties to all hazards, a finding previously noted by McHugh et al. (2004). By virtue of the fact that exercises, communication activities, and enhanced emergency agency funding are present in such counties, spillover effects to blizzard response, pandemic planning, and other areas occur. The public health preparedness activities and structure of counties within 10-mile EPZs should be studied and, perhaps, used as models of preparedness. The aims of such a study would be to evaluate the mechanics of non-nuclear emergency response that occur in EPZ counties and extract procedures and processes that could be replicated in non-nuclear counties.

5 Limitations

Though our study provided a unique opportunity for emergency preparedness officials from varied jurisdictions to provide their impressions regarding emergency planning, due to logistical constraints, it was not feasible to conduct interviews with all individuals responsible for radiological emergency preparedness in all 65 EPZs across the country. Our study could be improved by inclusion of a greater number of states and counties. Also, some findings reported in this study could reflect recall and related biases by interviewees and interviewers. Future studies on this topic may benefit from using a survey instrument to facilitate inclusion of a larger sample size, as well as key community stakeholders and relevant officials from other nations.

6 Conclusion

The aim of this study was to catalog and sample the various public health preparedness activities that occur in the 10-mile EPZs of the nation's nuclear power plants. Our study provides a first-of-its-kind glimpse into the day-to-day activities of nuclear preparedness personnel, identifies current practices and common challenges, and provides a basis for further research into this field, which could include studying response hospitals, cross-state coordination, and optimal approaches to public education.

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Appendix 1. Interview Questions

Organizational

- Describe your local organization for preparing and responding to a radiological emergency?
- What positions/employees are responsible for planning and response?

Exercises

- Why types of exercises are conducted within your EPZ?
- How often are exercises conducted?

- Who are the primary organizers of exercises?
- How are exercises funded?
- What parties are involved in exercises?

Public Education

- What types of public education are conducted within your EPZ?
- What mediums/mechanisms are used in public education (e.g., radio, TV, social media, etc.)?
- How often does public outreach occur?
- Is effectiveness of public education evaluated?

Messaging

- Have prescripted pre- and post-event emergency communications been prepared?
- Through what channels will communication take place?

Hospital Preparedness

- In what ways are hospitals within your EPZ included in preparedness for a radiological emergency?
- Are volunteers included in emergency planning?

Evacuation

- Are evacuation routes predefined?
- Are traffic controls and/or access controls incorporated into emergency evacuation plans?
- Is shelter-in-place part of response planning?

KI

- Is KI pre-distributed within your jurisdiction?
- Is public education on KI conducted? Measured?

Jurisdictions

- Are any other jurisdictions included in planning?
- Do you have other counties or unaffected municipalities on standby for assistance?

Public Health

- What, if any, interaction/coordination occurs with the state or county public health department?

Expansion

- What are your thoughts about expanding the 10-mile EPZ?

Gaps, etc.

- Is there anything you believe is missing from your EPZ that would facilitate better management?
- How do you perceive variations in EPZs around the state/country?
- Is there a particularly exemplary county/EPZ in PA? in the nation?
- Do you notice any differences amongst the encompassed municipalities in their planning? Do they primarily follow the county's lead?

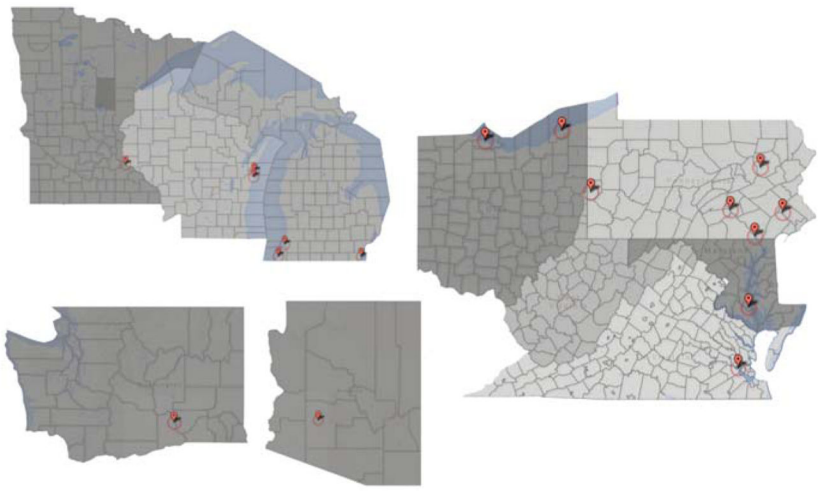

Figure 1.
Participating EPZs.

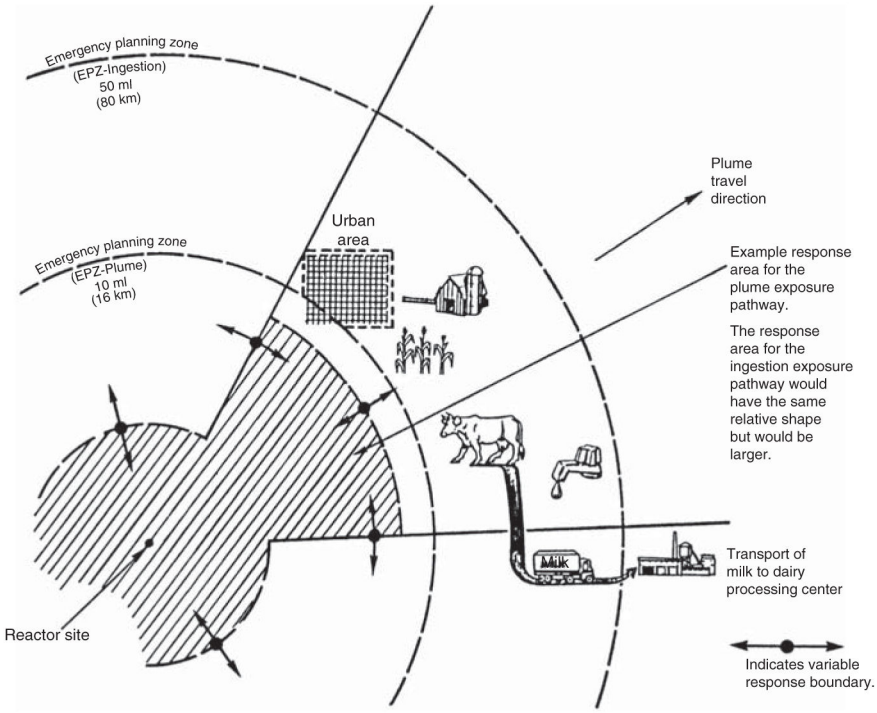

Figure 2.

Concept of EPZs. Image courtesy of the US Nuclear Regulatory Commission (NUREG-0654).