



PSR[®]

PHYSICIANS FOR SOCIAL RESPONSIBILITY

U.S. Affiliate of International Physicians for the Prevention of Nuclear War



NUCLEAR POWER AND PUBLIC HEALTH:
LESSONS FROM FUKUSHIMA,
STILL DANGEROUSLY
UNPREPARED

Introduction

On March 11, 2011, a magnitude 9.0 earthquake occurred about 40 miles northeast of Japan creating a 14-15 meter (46-49 foot) high tsunami that devastated the northeast coast of Japan. Damage to the built environment along the coast and for miles inland was unprecedented. Thousands of lives were lost outright with estimates in excess of 15,000.

Of particular concern, was the Fukushima Daiichi nuclear power station with six reactors situated immediately on the coast. The Daiichi station was designed to withstand only a 5.7 meter tsunami. Off-site power was lost immediately with the earthquake, but emergency electricity from diesel-powered generators could not be sustained because of flooding from the tsunami that struck 40 minutes later. On-site emergency battery power was exhausted in a few hours leading to a station blackout. With station blackout, cooling water for the individual reactors and spent fuel pools was lost. The station blackout also caused severe degradation of local internal monitoring of the condition of the Daiichi reactors and spent fuel pools. Also, external communication was difficult with TEPCO, the Daiichi corporate owner, and with the Japanese government.

With loss of cooling water, reactor fuel overheated, generating hydrogen that eventually led to several hydrogen explosions inside three of the reactor buildings severely damaging the buildings' exteriors and internal infrastructure. Uncontrolled radiation release ensued the evacuation of citizens, eventually in a 12 mile radius. Approximately 170,000 people were evacuated by March 13^[1] in addition to 450,000 who had been previously evacuated because of the tsunami, itself. The Fukushima nuclear station accident was rated at the maximum level of severity by the IAEA and equivalent to the Chernobyl accident over 25 years ago.

Several features of the Fukushima accident are relatively unique including a natural disaster that was beyond-design as a trigger event, massive damage to the extended built environment surrounding the station, prolonged station blackout with failure of all layers of local backup power, and damage to and overheating of spent fuel cooling pools.

Other important features not unique to the Fukushima accident include the associated massive human evacuations, communication problems with information filtering and suppression among local plant operators, corporate leadership, government, and the local and global public. Based on the Fukushima accident, nations other than Japan have begun to deeply reevaluate their own nuclear power programs and aspirations.

U.S. Response to Fukushima

The U.S. Nuclear Regulatory Commission (NRC) began monitoring the Fukushima situation immediately but was hampered initially by the lack of information. An NRC team was sent to Japan to monitor the situation closely and advise and assist where possible. Much worldwide attention was generated when the NRC recommended a 50-mile evacuation radius for U.S. citizens in the Fukushima vicinity. This early recommendation was criticized in an MIT analysis published five months after the accident,^[2] but it now seems clear that the 50 mile evacuation recommendation was indeed justified: reports just this month indicate that the Japanese government were considering evacuating Tokyo, about 180 miles away.

Soon after the Fukushima event, Physicians for Social Responsibility (PSR) published an online mapping tool that calculates populations within with 10 and 50 mile circular areas surrounding each of the commercial nuclear reactors in the U.S. and Canada.^[3] Subsequent analyses have shown that over the past 40 years populations have grown markedly in these established evacuation zones surrounding operating U.S. commercial nuclear reactors.

Within two weeks of the Fukushima event, the NRC had ordered immediate assessment of all reactors in the U.S. regarding beyond-design basis events with special emphasis on spent fuel cooling pools.^[4] Fukushima helped raise widespread awareness of the growing problem of stored spent nuclear fuel at reactor sites. With some difficulty, the Associated Press was able to get state-by-state summary data from the nuclear industry on the amount of spent fuel stored at reactor sites in the U.S.^[5] Robert Alvarez published a detailed report on spent nuclear fuel in the U.S. two months after the Fukushima event along with detailed recommendations for improving safety of spent fuel storage.^[6] His report showed that nearly all spent nuclear fuel ever created by U.S. commercial reactors, approximately 72,000 tons, is still stored at U.S. reactor stations. In the U.S., 75% of all spent fuel is still in wet cooling pools that are poorly protected remaining highly vulnerable to loss of cooling events, terrorist attack, and to severe natural disasters. Most cooling pools are nearly at full capacity, and only in recent years have reactor operators begun to move spent fuel to far more secure dry cask storage. The massive dry casts do not require active cooling and serve as primary and secondary containments. In 2010 PSR published a set of principles for safeguarding spent nuclear fuel at reactor sites.^[7]

The NRC further laid out a plan for the staged evaluation of U.S. reactor stations^[8] with evaluation of severe accident emergency plans for station blackouts and large fires by 30 days, review of inventories and readiness of mitigation equipment at each station at 60 days,^[9] and a Task Force report at 90 days with more comprehensive analysis and recommendations. The Task Force report^[10] was released on schedule in July 2011 and has been subsequently criticized from all sides.^{[11][12]}

Just this month, the NRC finally voted to issue the first proposed rules based on the Task Force report. These initial three rules^[13] cover recommendations for nuclear station operators:

1. To plan for extreme situations such as earthquakes, floods, and other natural disasters especially at stations where there are multiple reactors;
2. To improve instrumentation in spent nuclear fuel storage cooling pools;
3. To enhance hydrogen venting in reactors of similar design as those at the Fukushima Daiichi station in Japan.

Emergency Preparedness

The NRC Task Force Report considered the status of emergency preparedness regulations regarding nuclear station events and noted a series of challenges identified during the Fukushima event that would challenge existing U.S. emergency preparedness planning. These included severe communications breakdown among the following: staff in the actual reactor buildings, the on-site control center, reactor station owners, top government leadership, government regulatory agencies, and emergency responders in the area outside the reactor station.

An independent Fukushima investigation commission was established by the Rebuild Japan Initiative Foundation in Japan. A report co-authored by the Foundation chairman and the independent commission director which was published in the Bulletin of the Atomic Scientists March 1, 2012 details interactions among the Japanese government, TEPCO, the Daiichi station owner, workers on-site at the Daiichi station, Self-Defense Forces, and off-site emergency workers and first responders.^[14]

The Foundation report and the NRC Task Force report suggest a number of factors that should inform the revised planning needed to minimize the potential for disaster at the 104 aging U.S. reactors:

1. The role played by "human elements" during an emergency.
2. It would be difficult to assess radiation levels and radiation dose to humans in a multi-reactor event.
3. During a large natural disaster the ability to notify both government authorities and the public would be difficult.
4. U.S. reactor stations do not have a uniform, robust infrastructure to transmit critical status data to the NRC, nor do they have a "black box" recording real-time data on events for post-accident analysis.
5. Existing U.S. emergency preparedness drills do not consider prolonged station black out, severe regional natural disasters, or multi-reactor events.

6. Fukushima-like events would require extensive, timely assistance from outside the reactor station and this is not addressed in current emergency planning.
7. Despite dismissal of events in the past as too improbable to require formal planning, "Fukushima has clearly shown that these events are a reality," according to the Task Force report.
8. The U.S. has not developed the programs to educate the public on radioactivity and radiologic hazards before possible accidents happen.
9. The U.S. has not developed the capability to inform and direct emergency personnel and the public in real time during an unfolding disaster, regarding actual radiation levels, plume directions, food and water safety, timely distribution of stable potassium iodide, or the rationale of sheltering-in-place advisories to the public.
10. Where severe natural disasters occur that cover more than one state, or reactor stations located on state borders, coordination among mayors, state governors and state emergency systems, and federal agencies would be extraordinarily difficult.
11. Plume pathways from a severe reactor accident would never behave according the simple 10-mile radius paradigm central to the basis of current U.S. emergency planning for reactor emergencies. Neither would a 50-mile or greater radius, used by the Environmental Protection Agency (EPA), for radiation contaminated food and water interdiction as numerous radiation hot spots have been identified in Japan more than 100 miles from Fukushima.
12. Estimated time-for-evacuation in current emergency planning would not likely apply to severe accidents with multiple reactors and severe natural disasters.

Additionally, many of the stakeholders and agencies in Japan involved in the crisis have analogs in the U.S., including the NRC, DOE, EPA, DHS, INPO, NEI,^[15] National Guard, First Responders, state emergency systems, state governors, and mayors. It is instructive to see, from the Japanese point of view,^[16] the dysfunctional interactions during early weeks of the crisis and sobering to ponder how the U.S. could manage a severe nuclear station accident.

Current mandated emergency evacuation plans for U.S. nuclear reactor accidents are based on the 10-mile radius paradigm developed after the Three Mile Island Station reactor meltdown event in 1979. ^[17] A review of the approved emergency plan for the Duane Arnold Energy Center (a nuclear station with one GE Mark 1 reactor) just north of Cedar Rapids, Iowa reveals that that the two tertiary care hospitals in Cedar Rapids are just five and thirteen blocks outside the Duane Arnold station's 10-mile radius. Certainly, a high proportion of health care professionals who work in these medical centers would be displaced. Of special note, during the June-July 2008 flood on the Cedar River that runs through down-

town Cedar Rapids and on which the Duane Arnold station is built, one of the two Cedar Rapids medical centers was flooded and closed for weeks. Cedar Rapids was cut in two by the flooding river and access to Cedar Rapids from the south was cut off by simultaneous flooding of the Iowa River just 12 miles south of Cedar Rapids. On May 25, 2008, an EF5 tornado devastated Parkersburg, Iowa, just 60 miles from the Duane Arnold station. Flooding and tornados occur in the same season in Iowa and elsewhere in the U.S., a fact that should not be overlooked by emergency planners.

A published analysis of emergency preparedness at the state level [\[18\]](#) concluded that states are poorly prepared to respond to a major radiological emergency. Furthermore, the U.S. plans do not consider severe accidents such as occurred at Fukushima Daiichi. South Miami Mayor Philip Stoddard, expressed frustration with the inadequacy of the existing radiological emergency plans for Miami-Dade County regarding the nearby Turkey Point reactor station in a letter dated June 10, 2011 to Florida elected officials.[\[19\]](#)

In 2005, PSR released a series of recommendations on nuclear power and terrorism[\[20\]](#) that urgently focused on the need to secure spent nuclear fuel. In 2006, PSR published a report[\[21\]](#) on emergency preparedness relating to the threat of nuclear terrorism. The report was published shortly after Hurricane Katrina devastated New Orleans. The report observed that "The 50 Disaster Medical Assistance Teams maintained by the Department of Homeland Security and deployed to the Gulf following Hurricane Katrina were overwhelmed quickly." Since 1980, population within 10 miles of reactors in the U.S. has grown[\[22\]](#) by an average of 17%; however near some reactors, the population has doubled.[\[23\]](#) The highest population density around a U.S. nuclear reactor is at Indian Point near New York City, where 17.3 million people live within 50 miles of the reactor. Evacuating these people in the event of a major release of radiation would be impossible. Another report, released by the Nuclear Information and Resource Service (NIRS) [\[24\]](#) details inadequacies in U.S. emergency plans in light of the Three Mile Island, Chernobyl, and Fukushima disasters. This study focuses on human behavior in evacuations and on the growing populations near U.S. reactor stations.

The Department of Homeland Security (DHS) published their strategy for improving emergency response to a terrorist ground level improvised nuclear detonation or an explosive radiologic dispersion device.[\[25\]](#) From a top down perspective, the DHS report describes what systems should be in place, acknowledging the vast gaps between what is needed and what exists in the U.S. The needed emergency infrastructure would include personnel, materials, training, command and control organization, communications systems, and public education and information programs. The National Center for Emergency Preparedness at Columbia University published a related report [\[26\]](#) about the same time with somewhat more specific recommendations for building an emergency response system that can manage some aspects of a nuclear terrorist event. In the case of detonations, efforts should be focused on the gray zones far enough from ground zero that survivors are likely to be found. An analysis by ProPublica published

April 2011^[27] concluded that the U.S. healthcare system was unprepared for a nuclear accident, an assertion that PSR has made for decades.

Natural Disasters in the U.S. and Nuclear Reactors

Could severe natural disasters trigger a nuclear accident similar to Fukushima? A 2004 review by Paul Gunter,^[28] chronicled examples of nuclear reactor stations that were compromised by severe weather events, including floods (Missouri River and the Cooper Station in southeast Nebraska in 1993), tornadoes (Davis-Besse Station near Toledo in 1998), and hurricanes (Turkey Point Station just south of Miami with Hurricane Andrew in 1992). Since the 2004 Gunter report, there have been other natural disasters that affected nuclear power stations.

In April 2011 a tornado set down in the switch yard of the Surry Power Station, near Surry, VA.^[29] Later, in the month, on April 28, 2011, the Browns Ferry Station, the second-biggest U.S. nuclear power station lost off-site power during a monster storm that involved a multistate area.^[30] Browns Ferry has three GE Mark I reactors similar to the reactors at Fukushima Daiichi and was not back on line for about six weeks while the severely damaged regional high voltage lines had to be rebuilt.

The Fort Calhoun Station, on the Missouri River just north of Omaha, NE, had serious flooding in the summer of 2010 and the NRC subsequently found that the station's flood plans were inadequate. A year later in April 2011 the Fort Calhoun Station was put into cold shutdown voluntarily in anticipation of flooding due to unprecedented snow pack in the Montana Rockies. The station was flooded as anticipated with peak inundation in June, and lasting through August. Fort Calhoun is still off line 11 months later.

On a very hot day in August 2003 sagging high voltage power lines grounded on trees in poorly maintained right-of-ways triggering a catastrophic cascade of grid failures over the upper Midwest and the Northeast U.S. and southeast Canada. Within two hours nine U.S. and seven Canadian nuclear power stations relayed off the grid and went into automatic shutdown.^{[31] [32]} In this event, the grid infrastructure was not damaged, but a large geomagnetic storm could cause damage to the infrastructure itself, especially to high voltage transformers.

In March 1989 a geomagnetic storm^[33] due to a coronal mass ejection from the sun impacted the Earth. Canada's Hydro-Quebec power grid went down.^[34] It can take months to repair these high voltage transformers, and up to a year to replace them.^[35]

On August 23, 2011 a 5.8 magnitude earthquake centered in Virginia rattled the Washington DC area and triggered the shutdown of two regional nuclear stations.^{[36] [37]} A week later Hurricane Irene moved up the eastern U.S. seaboard and into New England. The near confluence of two natural disasters in the U.S.

similar to, but less severe, that the Fukushima event is remarkable. The argument of "but it hasn't happened yet" is growing steadily weaker.

Conclusions

...The Task Force appreciates that an accident involving core damage and uncontrolled release of radioactive material to the environment, even one without significant health consequences, is inherently unacceptable. The Task Force also recognizes that there likely will be more than 100 nuclear power plants operating through the United States for decades to come. The Task Force developed its recommendations in full recognition of this environment...[38]

With every passing month since the Fukushima accident last year, more confirmed alarming information about the event is made public, some that had been known by officials but suppressed, some logically obvious in the first few weeks after the accident, but officially denied. Given the realities that U.S. nuclear reactors are not going to be shuttered anytime soon and knowing now what we know from the three most severe accidents, Three Mile Island, Chernobyl, and Fukushima, the consequences of not acting now are glaringly clear. We can no longer perpetuate the myth that nuclear power, at least in the hands of humans, is safe.

Chernobyl was said to be the largest industrial accident in history. Fukushima is likely to inherit that title. The economic consequences of these accidents are huge and certainly exceed the cost of the plants themselves. The long range degradation of human health and wellbeing represents something precious and lost forever. The human cost of sudden, permanent mass evacuation and relocation is incalculable and cannot be monetized. The toxicity and danger of existing spent nuclear fuel cannot be made to go away and will be will a threat to all life on the planet for hundreds of thousands of years.

Recommendations

When you find yourself in a hole, stop digging.[39]

The past experience with catastrophic nuclear accidents and their frequency indicates that no country is prepared physically or financially to deal with the short and long term effects. As opposed to natural disasters, experience has shown us that nuclear catastrophes do not remain isolated but tend to become global problems affecting us all. In reality, there is no cure once these events have happened; the only

options are mitigation and palliation. In the absence of a cure, prevention is the only option. Short of prevention, PSR makes the following recommendations. Each recommendation would ease at least some of the attendant problems associated with such emergencies.

1. Education of the public and First Responders regarding radiation exposure and health;
2. Implementation of, and education of, the public and First Responders about emergency plans for evacuation and sheltering in place;
3. Enhancement of the NRC's ability to monitor a nuclear accident in real time with communication and transparency to the public about such events;
4. Enhanced fuel pool security;
5. A moratorium on building further nuclear power plants until the attendant problems of safety and dealing with waste are openly dealt with and solved in some fashion;
6. The phasing out of nuclear power as a source of energy beginning now.

Closing Thoughts

The issue of the effects of radiation exposure and human health remains controversial. Much of what we know about such effects is based upon the one time dose of radiation received by the populations of Hiroshima and Nagasaki. Unfortunately, studies regarding the long term (over generations) effects of the release of long lived radioactive material into our environment will not be known for literally hundreds of years. Because of cost, time and complexity, these studies are unlikely to be done and, again, we will not see the results. Thus we must rely on our current knowledge which indicates that there is no "safe dose" of radiation. The repeated releases of uncontrolled amounts of long lived radioactive material on unknowing and non-consenting populations exposing them to unknown long term risk is simply an experiment that is unconscionable. It is arrogant of the human race to simply talk about these risks to human health when it affects the entire ecosystem. Each release [40] atmospheric nuclear weapons testing, Chernobyl, Fukushima, and the many leaks, small accidents, and spills compounds the problem over the long term. While each small release (or large release) may be excused or swept under the rug of radiation invisibility, each serves to add to the planet's radiation burden.

Education of the public regarding emergency planning means that such planning must actually be in place. Major studies and responses to natural disasters such as Katrina, let alone Chernobyl and Fukushima indicate that such planning is currently woefully inadequate. Indeed, given the history of such events along with current funding crises around the world, it is very unlikely that such planning can and will be implemented in the U.S. let alone developing, impoverished countries with nuclear programs. In

Physicians for Social Responsibility *Lessons from Fukushima, Still Dangerously Unprepared*

addition, policies such as providing prophylactic iodine tablets to those living near nuclear power plants or providing meaningful education regarding evacuation in the event of an accident, have been fought by the nuclear industry because they might frighten people and undermine the illusion that nuclear power is safe.

The history of the nuclear industry (nuclear weapons and nuclear power) has been one of secrecy, cover-up, and minimization. It is apparent that this culture remains rampant today. Such behavior has happened at Chernobyl and Fukushima with two very different political and economic systems. This is likely to continue to be the case. It is not in the interests of the nuclear industry and their companion governments to be open about the worst case scenarios, even as they unfold. It is human nature to hope and wish that such things are not happening and to actively deny things that are happening. This is the nature of the nuclear industry. The Japanese now openly acknowledge that they were very, very lucky.

The nuclear industry is saddled with three deadly and inescapable “P”s, Price, Pollution, and Proliferation. It is a costly, polluting industry that is inextricably tied to the further spread of nuclear weapons. It is an industry whose time has passed.

[1] Harlan, C. and Mufson, S., Japanese nuclear plants' operator scrambles to avert meltdowns, *The Washington Post*, March 13, 2011, <http://www.washingtonpost.com/wp-dyn/content/article/2011/03/12/AR2011031205493.html> (accessed 2/27/12)

[2] Buongiorno, J, et al., Technical Lessons Learned from the Fukushima-Daiichi Accident and Possible Corrective Actions for the Nuclear Industry: An Initial Evaluation, MIT-NSP-TR-025 Rev. 1, July 26, 2011. page 6. http://web.mit.edu/nse/pdf/news/2011/Fukushima_Lessons_Learned_MIT-NSP-025.pdf (accessed 2/29/12)

[3] Evacuation Zones for Nuclear Reactors, an online mapping tool, Physicians for Social Responsibility, <http://www.psr.org/resources/evacuation-zone-nuclear-reactors.html> (accessed 2/29/12)

[4] NRC Inspection Manual, Temporary Instruction 2515/183, Followup to the Fukushima Daiichi Nuclear Station Fuel Damage Event, March 23, 2011. <http://pbadupws.nrc.gov/docs/ML1107/ML11077A007.pdf> (accessed 2/29/12)

[5] Associated Press, Nuclear waste accumulates at U.S. plants, March 23, 2011, an interactive map, http://hosted.ap.org/specials/interactives/_national/spent-nuclear-fuel/ (accessed 2/29/12)

[6] Alvarez, R., Spent Nuclear Fuel Pools in the U.S.: Reducing the Deadly Risks of Storage, Institute for Policy Studies, Washington, DC, May 2011, http://www.ips-dc.org/files/3284/spent_nuclear_fuel_pools_in_the_US-final.pdf (accessed 2/29/12)

[7] Principles for Safeguarding Nuclear Waste at Reactors, Physicians for Social Responsibility, March 24, 2010. <http://www.psr.org/nuclear-bailout/resources/principles-for-safeguarding.html> (accessed 3/4/12)

- [8] Apostolakis, G., Post Fukushima: NRC Response, Plenary Session, Harvard Electricity Policy Group, June 2, 2011. <http://www.nrc.gov/about-nrc/organization/commission/comm-george-apostolakis/apostolakis-06-02-2011-hef.pdf> (accessed 3/3/12)
- [9] Nuclear Engineering International News, USNRC reviews and discusses its Fukushima Response, June 16,2011. <http://www.neimagazine.com/story.asp?storyCode=2059868> (accessed 3/3/12)
- [10] Miller, C., Chair, Near-Term Task Force Review of Insights from the Fukushima Dai-ichi Accident, Recommendations for Enhancing Reactor Safety in the 21st Century, July 12, 2011. <http://pbadupws.nrc.gov/docs/ML1125/ML112510271.pdf> (accessed 3/1/12)
- [11] NEI, Letter to NRC Chair, Gregory Jaczko. http://www.nei.org/filefolder/071511_NRC_NRCNearTermTaskForceReport_1.pdf (accessed 3/3/12)
- [12] Makhijani, A., Preliminary Review of Recommendations for Enhancing Reactor Safety, in the 21st Century, Institute for Engineering and Environmental Research, July 19, 2011. http://www.nei.org/filefolder/071511_NRC_NRCNearTermTaskForceReport_1.pdf (accessed 3/3/12)
- [13] U.S. NRC to issue first post-Fukushima safety rules, Reuters, March 1, 2012. <http://www.reuters.com/article/2012/03/02/us-utilities-nrc-fukushima-idUSTRE82101Y20120302> (accessed 3/3/12)
- [14] Funabashi, Y. and Kitazawa, K, Bull Atomic Scientists, March 1, 2012, Fukushima in review: A complex disaster, a disastrous response, 1-13. <http://bos.sagepub.com/content/early/2012/02/29/0096340212440359> (free download accessed 3/1/12)
- [15] DOE=Department of Energy; DHS=Department of Homeland Security; INPO=Institute of Nuclear Power Operations (a nuclear industry group focusing on safety, created after Three Mile Island); NEI=Nuclear Energy Institute, nuclear industry spokes group)
- [16] ~~Op.cit.~~, Funabashi.
- [17] Criteria for Preparation and Evaluation of Radiological; Emergency Response Plans and Preparedness in Support of Nuclear Power plants, U.S. Nuclear Regulatory Commission, NUREG-0654 FEMA-REP-1 Rev. 1 <http://www.nrc.gov/reading-rm/doc-collections/nuregs/staff/sr0654/r1/sr0654r1.pdf> (accessed 3/4/12)
- [18] Watkins, S., et al., State-Level Emergency Preparedness and Response Capabilities, Disaster Med Public Health Preparedness, 2011, 5:S134-42. http://www.dmph.org/cgi/reprint/5/Supplement_1/S134 (accessed 3/5/12)
- [19] Stoddard, P., Letter to Miami-Dade County Elected Officials, June 10, 2011. <http://www.google.com/url?sa=t&rcct=j&q=radiological%20emergency%20plan%20letter%20mayor%20philip%20stoddard%20florida%20legislators&source=web&cd=1&ved=0CCcQFjAA&url=http%3A%2F%2Fweb.miamibeachfl.gov%2FWorkArea%2Flinkit.aspx%3FLinkIdentifier%3Ddid%26ItemID%3D65132%26libID%3D68110&ei=BidUT-XNDcb9sQKqv4HwBQ&usg=AFQjCNFGFXIV6qx0Dz0K7SDnSTHAIxhgoA&cad=rja> (accessed 3/4/12)
- [20] Nuclear Power and the Terrorist Threat (Factsheet), Physicians for Social Responsibility, 2005. <http://www.psr.org/nuclear-weapons/nuclear-terrorism-threat-to.pdf> (accessed 3/4/12)

- [21] Helfand, I., et al., The U.S. and Nuclear Terrorism: Still Dangerously Unprepared, Physicians for Social Responsibility. <http://www.psr.org/resources/the-us-and-nuclear-terrorism.html> (accessed 3/12/12)
- [22] Donn, Jeff, US nuclear evacuation plans haven't kept up with population, Associated Press, June 27, 2011. http://www.msnbc.msn.com/id/43529122/ns/us_news-environment/t/us-nuclear-evacuation-plans-havent-kept-up-with-population/ (accessed 3/4/12)
- [23] Nuclear neighbors: Population rises near US reactors, interactive online map comparing 2000 and 2010 census data. http://www.msnbc.msn.com/id/42555888/ns/us_news-life/t/nuclear-neighbors-population-rises-near-us-reactors/#.T1P-FvU8UsI (accessed 3/4/12)
- [24] Briefing Paper on Emergency Preparedness at U.S. Nuclear Reactors, Nuclear Information and Resource Service, 2012. http://www.msnbc.msn.com/id/42555888/ns/us_news-life/t/nuclear-neighbors-population-rises-near-us-reactors/#.T1P-FvU8UsI (accessed 3/4/12)
- [25] DHS Strategy for Improving the National Response and Recovery from and IND Attack, U.S. Department of Homeland Security, March 24, 2010. <http://publicintelligence.info/DHS-INDResponse.pdf> (accessed 3/4/12)
- [26] Redlener, I., et al., Regional Health and Public Health Preparedness for Nuclear Terrorism: Optimizing Survival in a Low Probability/High Consequence Disaster, National Center for Disaster Preparedness, Columbia University Mailman School of Public Health, April 2010. <http://www.ncdp.mailman.columbia.edu/files/Nuclear%20Event-Whitepaper.pdf> (accessed 3/4/12)
- [27] Fink, S., U.S. Health Care System Unprepared for Major Nuclear Emergency, ProPublica, April 7, 2011. <http://www.propublica.org/article/us-health-care-system-unprepared-for-major-nuclear-emergency> (accessed 3/4/12)
- [28] Gunter, P., November 2004, Natural Disasters and Safety Risks at Nuclear Power Stations, Nuclear Information and Resources Service. <http://www.nirs.org/factsheets/naturaldisaster&nuclearpower.pdf> (accessed 3/4/12)
- [29] Squires, P., Tornado cuts power to Surry nuclear power plant, Virginia Business News, April 18, 2011 <http://www.virginiabusiness.com/index.php/news/article/tornado-cuts-power-to-surry-nuclear-power-plant/> (accessed 3/4/12).
- [30] DiSavino, S., Alabama nuclear plant shuts safely after tornados, Reuters, April 28, 2011. <http://www.reuters.com/article/2011/04/28/us-utilities-operations-tva-browns-idUSTRE73R3RT20110428> (accessed 3/4/12)
- [31] Northeast blackout of 2003, Wikipedia. http://en.wikipedia.org/wiki/Northeast_blackout_of_2003 (accessed 3/4/12)
- [32] Minkel, J., The 2003 Northeast Blackout -- Five Years Later, August 13, 2008, Scientific American. <http://www.scientificamerican.com/article.cfm?id=2003-blackout-five-years-later> (accessed 3/4/12)
- [33] Solar Superstorm, NASA Science News. http://science.nasa.gov/science-news/science-at-nasa/2003/23oct_superstorm/ (accessed 3/4/12)

- [34] March 1989 geomagnetic storm, Wikipedia. http://en.wikipedia.org/wiki/March_1989_geomagnetic_storm (accessed 3/4/12)
- [35] Marusek, J., Solar Storm Threat Analysis, Impact 2007. <http://www.breadandbutter-science.com/SSTA.pdf> (accessed 3/4/12)
- [36] Bell, M, East Coast earthquake: 5.8 magnitude epicenter hits Virginia, August 23, 2011, The Washington Post. http://www.washingtonpost.com/blogs/blogpost/post/earthquake-rattles-washington-east-coast/2011/08/23/gIQAAdypEZJ_blog.html (accessed 3/4/12)
- [37] Lemonick, M., What the east coast earthquake means for US nuclear plants, The Guardian, <http://www.guardian.co.uk/environment/2011/aug/24/east-coast-earthquake-nuclear-plants> (accessed 3/4/12)
- [38] Miller, C., Chair, Near-Term Task Force Review of Insights from the Fukushima Dai-ichi Accident, Recommendations for Enhancing Reactor Safety in the 21st Century, July 12, 2011. <http://pbadupws.nrc.gov/docs/ML1125/ML112510271.pdf> (accessed 3/1/12)
- [39] Rogers, W., 1879-1935 (Also known as the first law of holes.)
- [40] Kyshtym disaster, 1957 Explosion at a U.S.S.R. reprocessing plant with a contamination plume more than 300 kilometers long , Wikipedia. http://en.wikipedia.org/wiki/Kyshtym_disaster (accessed 3/4/12)