

LESSONS FROM FUKUSHIMA AND CHERNOBYL FOR U.S. PUBLIC HEALTH

Briefing Book



Spring 2011

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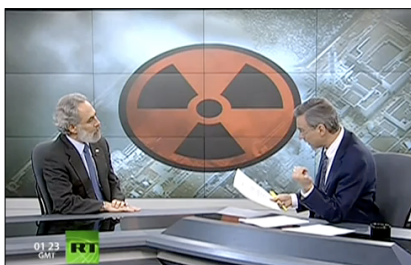
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About Physicians For Social Responsibility

Physicians for Social Responsibility (PSR) is a non-profit scientific and educational organization that is the medical and public health voice for policies to prevent nuclear war and proliferation and to slow, stop and reverse global warming and toxic degradation of the environment. With 50,000 members and e-activists, 31 chapters, and 41 student chapters, PSR is the largest physician-led organization in the country addressing the gravest threats to health and human survival. Our members, along with national and chapter staff, form a unique nationwide network committed to a safer, healthier world.

Founded in 1961, PSR led the campaign to end atmospheric nuclear testing by documenting the presence of strontium 90, a byproduct of atomic testing, in children's teeth. During the following two decades, PSR's work to educate the public about the dangers of nuclear war grew into an international movement with the founding of International Physicians for the Prevention of Nuclear War. In 1985, PSR shared the Nobel Peace Prize awarded to IPPNW for building public awareness and pressure to end the nuclear arms race.

During the 1990's, PSR built on this record of achievement by helping to end new nuclear warhead production and winning an international moratorium on explosive nuclear testing. Understanding that nuclear war continues to be the most acute threat to human life and the global biosphere, PSR continues its commitment of 50 years to the elimination of nuclear weapons. As steps toward that goal, PSR advocates for deep cuts in nuclear arsenals, taking nuclear weapons off hair-trigger alert, and ratification of the Comprehensive Nuclear Test Ban Treaty. PSR supports alternative strategies for conflict resolution, including increased diplomacy and the rule of law.



In 1992, recognizing new dangers threatening our world, PSR expanded its mission to include environmental health to address issues such as global climate change, proliferation of toxics, and pollution. PSR's mobilization of the medical community on environmental health issues led to a collaboration among MIT, the Harvard School of Public Health, Brown University and PSR's Greater Boston chapter that resulted in *Critical Condition*, a definitive volume on human health and the environment. Since then, PSR has brought the medical and public health perspective to advance environmental health and protect today's and future generations from the health effects of global warming and toxic degradation of the environment, and promote renewable energy solutions and energy security.

PSR has consistently opposed nuclear power because of its risk to public health and association with the proliferation of nuclear weapons. In fact, PSR was revitalized as an organization in 1979 in the wake of the Three Mile Island nuclear accident. Having been engaged on this issue for more than 30 years, PSR physicians, several of whom have visited Chernobyl, have a long standing interest in preventing the negative public health consequences of nuclear energy and the nuclear fuel cycle. Since 2008, PSR's Safe Energy program has been working to prevent new subsidies for the construction of new nuclear reactors. With the ongoing nuclear crisis in Japan, PSR has intensified its focus on the unacceptable risk to public health posed by nuclear reactors.

Executive Summary

The 25th Anniversary of the nuclear reactor accident in Chernobyl on the Belarus-Ukraine border serves to remind us of the dangers to public health posed by nuclear power. The importance of reacquainting ourselves with the ongoing difficulties at the Chernobyl disaster site and surrounding lands are underscored by the March 2011 disaster at the Daiichi nuclear power plant complex near Fukushima Japan.

Physicians for Social Responsibility provides this Briefing Book to help educate the public, the press and policymakers of the public health issues regarding nuclear reactor accidents. PSR has also developed a new online Evacuation Zone map (www.psr.org).

Overview of Radiation and Health

The history of exposure to radiation started with the discovery of X-rays in 1895. Scientists recognized the damaging effects of radiation early in the 20th Century but did not seriously understand its significance until well after World War II, when the world truly entered the Nuclear Age. The difference between background natural radiation and that added by human activity must be recognized to properly understand this history. The nuclear reactor accidents of the last 30 years have placed our world in an Age of Consequences.

Risks To Public Health



The National Research Council of National Academies' BIER VII Report in 2005 confirmed that any exposure to radiation – including background radiation – increases a person's risk of developing cancer. Lower doses result in less chance of harm than higher doses, but the relative cancer risks of radiation exposure are far higher in women and children than in men. Estimating the risk of cancer in a population or in individuals exposed to radiation is highly dependent on various factors: the intensity of exposure, the age and sex at exposure, and the various routes of exposure.



Nuclear Reactor Accidents

Since the accident at Three Mile Island near Harrisburg, PA in 1979 (a Level 5 incident implying high probability of significant public exposure to radioactive material), there have now been two Level 7 events (the highest level on the International Nuclear Event Scale). The first was at Chernobyl in 1986 which released enormous amounts of radiation directly contaminating 77,000 square miles of land. Radiation was distributed in the atmosphere, in days, over the entire Northern Hemisphere. Twenty-five years later, the Chernobyl reactor site continues to leak radiation into the environment forcing the government to spend an additional \$1.6B euros to build a "new safe confinement" structure over the top. The March 2011 incident in Fukushima rapidly evolved to Level 7 with three severely damaged reactors and their respective spent fuel cooling pools and it remains far from controlled six weeks later. Both the Chernobyl and Fukushima accidents have led to massive evacuations that have implications for emergency preparedness in the U.S.

Challenges of Accident Evacuation

Twenty-five years after the Chernobyl accident, there is still a 30 km exclusion zone surrounding the reactor and areas up to 400 km away are still uninhabitable. In the immediate wake of the Fukushima incident, the Japanese government rapidly increased the emergency evacuation zone from 3 km to 10 km, and then to 20 km with a stay-indoors warning from 20-30 km. The current official U.S. emergency evacuation zone for nuclear reactor accidents is 10 miles (16.1 km). Five days after the Fukushima incident began and based on software simulations, the U.S. Nuclear Regulatory Commission recommended a 50-mile (80.5 km) evacuation zone for U.S. citizens who might be near Fukushima.

Considering the Fukushima and Chernobyl experiences, the official 10-mile zone in the U.S. is probably not adequate. Physicians for Social Responsibility ran simulations of a loss of coolant accident for the Braidwood reactor near Chicago. The study predicted that 20,000 people would receive lethal doses of radiation and 200,000 would suffer from radiation sickness. In a similar simulation conducted by the Union of Concerned Scientists for the Indian Point nuclear power plant near New York City, approximately 44,000 would die within the first year with additional 518,000 deaths from cancer over time. Millions of citizens would have to be permanently relocated and economic losses could reach \$2 trillion.

When one considers all the nuclear plants in the US and on the border of Canada, over 111 million people - 1/3 of the population of the US – lives within 50 miles of a nuclear reactor. Using a new online tool available from PSR, a 50 mile evacuation zone can be mapped around the Indian Point nuclear reactor. Over 17 million people fall within the evacuation zone. There is no conceivable way that these people could be evacuated in the case of a serious accident at the plant. The Calvert Cliffs nuclear plant located outside Washington, DC would require 3.1 million people to be evacuated.

Emergency evacuation of this number of people would be challenging. It is clear that the authorities and health care system would not be able to properly protect the health of all the people and vulnerable populations which would need to be moved in the case of such an accident, let alone the massive number of injured, or potentially injured and symptomatic victims.

Growing Problem of Spent Nuclear Fuel

Another key lesson to be learned from the ongoing Fukushima Daiichi complex crisis is the vulnerability of spent nuclear fuel kept in cooling pools at nuclear power plants. Not only was there loss of coolant to the reactor cores but there was loss of coolant to the spent fuel. Paradoxically, spent nuclear fuel is far more radioactive and thermally active than fresh fuel – so much so that the rods require heavy shielding and constant cooling for at least five years before they can be safely transferred to secure storage. In the U.S., a typical cooling pool contains 2-5 times as many rods as are in the associated reactor. While the active reactor core is inside a reactor pressure vessel that is in turn housed in a robust containment structure, the cooling pools are often protected by only a simple structure. Of all spent fuel ever generated in U.S. commercial nuclear reactors, less than 25% has been transferred to safer dry cask storage. For these reasons, spent fuel cooling pools are a serious risk that must be considered in accident scenarios.

Overview of Radiation and Health

Jeffrey J. Patterson, DO, PSR Immediate Past President

April 17, 2011

The issue of radiation safety has once again been thrust into the public consciousness by the continuing events around the nuclear power plant disaster in Japan.

There are some basic principles to consider regarding the question of radiation exposure. First, there is no “safe” or non-harmful level of radiation. Second, we are all exposed to radiation: background radiation, with which we evolved, and medical radiation, which may be necessary and life saving as determined and controlled by the patient and physician.

Finally, there is another form of exposure which has been thrust upon the world since the advent of the nuclear age. This occurs with the release of radiation throughout the nuclear fuel cycle, nuclear weapons use and testing, and the “controlled” and catastrophic releases of long lived radionuclides from the nuclear power industry. This is quite a different issue and is not “natural” and should not be included as acceptable “background”.

The history of radiation exposure is instructive when we consider this topic. In 1895, Wilhelm Rontgen discovered X-rays. Subsequently, Becquerel discovered that invisible emanations from uranium would expose radiographic plates. Marie Curie and her husband carried this work further, leading to the use of x-ray machines in WWI. Madame Curie, it is said, enjoyed the glow of radioactive materials in test tubes that she kept in her desk. She died at age 67 from a plastic anemia thought to be caused by her work with radiation. Damaging effects of radiation were noted early on by radiologists who found that they were dying at earlier ages than their colleagues.

Yet even in the 1970's the risks of radiation were still being discovered. At that time, it was common medical practice to x-ray pregnant women during labor to see if the pelvis was “adequate”, a procedure, incidentally, that was absolutely worthless from a medical point-of-view. Dr. Alice Stewart did seminal work which revealed that even one x-ray in utero increased a fetus's chances of getting leukemia later in life. Despite criticism of this work by the nuclear industry, physicians no longer perform x-rays on pregnant women unless absolutely necessary.

The trend through the nuclear age has been toward the general recognition that there is no “safe” or “harmless” dose of radiation. The National Research Council of the National Academies, in a comprehensive report entitled “Health Risks from Exposure to Low Levels of Ionizing Radiation,” BIER VII, recognizes that radiation exposure has a linear relationship to the development of cancer. There is no level of exposure below which there is no risk.

Most of the data on the effects of radiation exposure are derived from studies of the survivors of the bombings of Hiroshima and Nagasaki, from intentional medical irradiation, and from a few high dose accidents. The Hiroshima exposure was a one-time dose largely composed of gamma and x-rays since the bombs were exploded high in the air producing very little fallout. This is very different from the releases from nuclear testing, and accidents at Kyshtym, Chernobyl, and Fukushima which have irretrievably released long-lived radionuclides such as cesium-137, strontium-90, and plutonium-239 into the environment that will continue to expose living creatures for hundreds to thousands of years.

The track record of governmental education on radiation and protection of the public is poor. For example, the US government warned the Kodak Corporation of impending nuclear tests so that they could protect their film in Rochester, NY where rain and snow storms would bring down the radiation. There was no warning given to

farmers, families with children who would drink contaminated milk, or pregnant mothers across the country. Other gross examples include the cover-up of the Kyshtym disaster by the US and the USSR and lack of information about Chernobyl for the first three days that it was happening.

It is simply unknown what will be the distant health consequences to humankind of these very long-lived radionuclides in the global environment. Evidence to date is that consequences are likely to be cumulative, just as the contamination accumulates. Einstein's prophetic words are still relevant, "The splitting of the atom has changed everything save our mode of thinking. Thus we drift toward unparalleled catastrophe."

Radiation and the Risk to Public Health

Ira Helfand MD, Former PSR President

April 15, 2011

Since the beginning of the Fukushima disaster on March 11, we have been told repeatedly by industry spokesmen and government officials that the radiation discovered in the air, drinking water and food is "safe" or that it does not pose a threat to public health. We have been told specifically that 100 mSv is a threshold below which there are "No detectable health effects."

Unfortunately this is not true.

It is the consensus of the medical and scientific community, summarized in the National Research Council BEIR VII report, that there is no safe level of radiation. Any exposure, including exposure to naturally occurring background radiation, creates an increased risk of cancer. The BEIR report concluded specifically that a 100 mSv dose confers a one in one hundred risk of getting cancer. While that risk may be relatively low for one person, if 100 people receive that dose, one of them will get cancer. And if a million people are exposed to that dose, ten thousand of them will get cancer. There is no way that this can be considered a "safe threshold."

There are two other aspects of radiation exposure we need to understand to properly evaluate the public health risk:

1. Not all people exposed to radiation are affected equally. Women are significantly more vulnerable to radiation exposure than men. Children are much more vulnerable than adults to the effects of radiation, and fetuses are even more vulnerable.

2. Radiation from internal emitters is very different from external beam radiation. If you are standing near a source of radioactivity like a damaged fuel rod, you are exposed to a given rate of radiation only as long as you are near the fuel rod. But if you inhale or ingest a radioactive particle, that particle will continue to irradiate you for as long as the particle is in your body and remains radioactive. Unfortunately, there are a number of radioactive elements produced in large quantities in a nuclear reactor that are biologically

active—they are actively taken up by the body and incorporated into our tissues. Iodine-131 is concentrated in the thyroid gland and causes thyroid cancer. Cesium-137 behaves like potassium. It is absorbed and distributed throughout the body. Cesium-137 has a half life of 30 years, and causes many different types of cancer. Strontium-90 is chemically similar to calcium. It is deposited in bone and, with its 29 year-half life, continues to irradiate bone and bone marrow for decades. It causes bone cancer and leukemia. Plutonium-239 with a half life of 24,200 years, is intensely carcinogenic if inhaled and causes lung cancer in microscopic doses.



These long-lived radioactive isotopes remain dangerous for centuries, and, in the case of plutonium, for hundreds of thousands of years. Once they are released into the biosphere, they work their way through the ecosystems, as do other industrial toxins; they move up the food chains and become progressively more concentrated in foodstuffs and complex forms of life, including human life. Land which is contaminated by these radioactive poisons becomes unhealthy and even uninhabitable.

Nuclear Reactor Accidents

Steven Starr, PSR Senior Scientist

April 2011

All large nuclear power reactors, regardless of their design, produce enormous inventories of deadly radioactive poisons. Each of the 104 U.S. commercial operating nuclear reactors – like the reactors at Fukushima Daiichi – stores their highly irradiated spent fuel on site in spent fuel pools; each pool holds 5 to 10 times more long-lived radioactivity than does the reactor core. A single spent fuel pool holds more Cesium-137 than was deposited by all atmospheric nuclear weapons tests in the Northern Hemisphere combined.[1] Thus a catastrophic accident at one nuclear reactor has the potential to release massive amounts of radioactive fallout, and unfortunately, experience has borne this out.

Nuclear reactors routinely release “low levels” of a variety of radioactive isotopes. This includes venting of radioactive gasses or releases of radioactive “tritiated” water. Although these releases probably have some public health effects, the nuclear reactors are supposed to prevent the bulk of their radioactive contents from reaching the ecosystem. However, despite the efforts of the nuclear industry, a number of serious accidents have occurred in which large quantities of high-level radiation have been discharged into the environment.

Three Mile Island

The worst accident which has occurred to date in the United States took place in 1979 at Harrisburg, Pennsylvania, when the Three Mile Island nuclear reactor experienced a partial meltdown of its nuclear core. The accident caused the release of up to 13 million curies of radioactive gases, less than 20 curies of iodine-131, converting a \$2 billion reactor into a \$1 billion liability.[2]

The accident at Three Mile Island was rated a 5 on the 7-point International Nuclear Event Scale (INES). According to INES, a level 5 accident entails the “Release of large quantities of radioactive material within an installation with a high probability of significant public exposure.”[3] Although the health effects from the release of this radiation were said to be minimal, this has been disputed by some experts, who point to recent data from the Center for Disease Control and Prevention, which show the areas downwind from Three Mile Island as having the highest rates of thyroid cancer in the United States.[4]

The INES scale is designed so that the severity of an event is about ten times greater for each increase in level on the scale. There have been other accidents inside and outside the United States that have involved both military and civilian nuclear facilities. However, only two have been rated “Major Accidents” - level 7 - at Chernobyl and Fukushima Daiichi, which is at least 100 times more severe than the accident at Three Mile Island. INES states that Major Disasters are accidents involving “Major release of radioactive material with widespread health and environmental effects requiring implementation of planned and extended countermeasures.”[5]

Chernobyl

On April 26, 1986, the fourth reactor of the Chernobyl nuclear power station exploded during a test while operating under full power. Enormous amounts of radiation were propelled miles above the plant and were distributed throughout the entire Northern Hemisphere. The U.S.S.R. did not inform its citizens or the world of the disaster until radiation set off alarms in Sweden. The evacuation of the city of Pripyat (population 50,000), located nearby the Chernobyl reactor, was not begun until two days after the explosion. The city was permanently abandoned and remains a ghost town.

The total amount of radiation released by the Chernobyl catastrophe remains a subject of debate. Official Russian sources estimated that about 4% of the contents of the reactor were released; however, this only included the releases recorded over the Soviet Union and it is suspected that at least twice this much was distributed elsewhere in Europe. The graphite core of the reactor burned and emissions continued until May 10. Other estimates range from 30-40% of the reactor fuel having been released, including approximately 3 million curies of cesium-137 and 47 million curies of iodine-131[6]; some Russian scientists say up to 80-90% of the reactor fuel was released during the weeks in which the reactor burned.

One thing is certain, radioactive materials from the destroyed nuclear reactor heavily contaminated about 77,000 square miles of land. About 1100 square miles of territory surrounding and adjacent to the reactor was subsequently declared uninhabitable and made into a permanent exclusion (closed) zone; it will remain uninhabitable for centuries (see Figure 1). From 1986 to 2000, 350,400 people were evacuated and resettled from the most severely contaminated areas of Belarus, Russia, and Ukraine. The gigantic cost of the nuclear catastrophe severely impacted the U.S.S.R., Ukraine and Belarus.

Unfortunately, the Soviet Union went to great lengths to hide the consequences of the Chernobyl catastrophe. For three years, the U.S.S.R. intentionally and irreversibly falsified hospital and medical records; they made it illegal for any physician to diagnose a radiation-related illness in the 840,000 "liquidators" who did the clean-up operations at Chernobyl. The extensive cover-up made it impossible to do the sort of "case-control" epidemiological studies normally performed after a major toxic event, and this has led to great controversy about the extent of morbidity and mortality caused by the disaster.

Consequently, there are a great range of estimates of death and illness caused by the Chernobyl accident. For example, the website of the World Nuclear Association says that 30 people died from the accident.[7] The World Health Organization and the International Atomic Energy Agency reported in 2005 that 50 people had died from radiation from the accident, and that 4000 more would likely die from cancer associated with radiation.[8] However, the Union of Concerned Scientists currently estimates that 27,000 excess cancer deaths will be attributable to the accident, excluding thyroid cancers.[9] Moreover, a new report by the International Physicians for the Prevention of Nuclear War reports 90% (more than 700,000) of the liquidators (those who participated in the containment and cleanup of Chernobyl) have become invalids and more than 112,000 had died by 2005.[10] In 2009, a report published by the New York Academy of Sciences (NYAS) estimated that 985,000 excess deaths occurred between 1986 and 2004 as a result of radioactive contamination from Chernobyl.[11] The NYAS estimates took note of the fact that a large percentage of the radioactive fallout from the accident was not confined to the lands adjacent to Chernobyl. Europe received more than 50% of the gaseous-aerosol radionuclides, and many areas still remain contaminated.

In 2006, Great Britain's Ministry of Health reported that 355 farms in Wales, 11 in Scotland, and 9 in England, pasturing more than 200,000 sheep, continued to be dangerously contaminated with cesium-137.[12] In 2009, a total

of 18,000 head of livestock in Norway were found to have grazed on plants contaminated with residual radioactivity from Chernobyl. In Germany, over 1,000 wild boar killed in the 2010 hunting season were found to be contaminated with levels of radiation above the permitted limit, presumably due to radioactive fallout from Chernobyl.

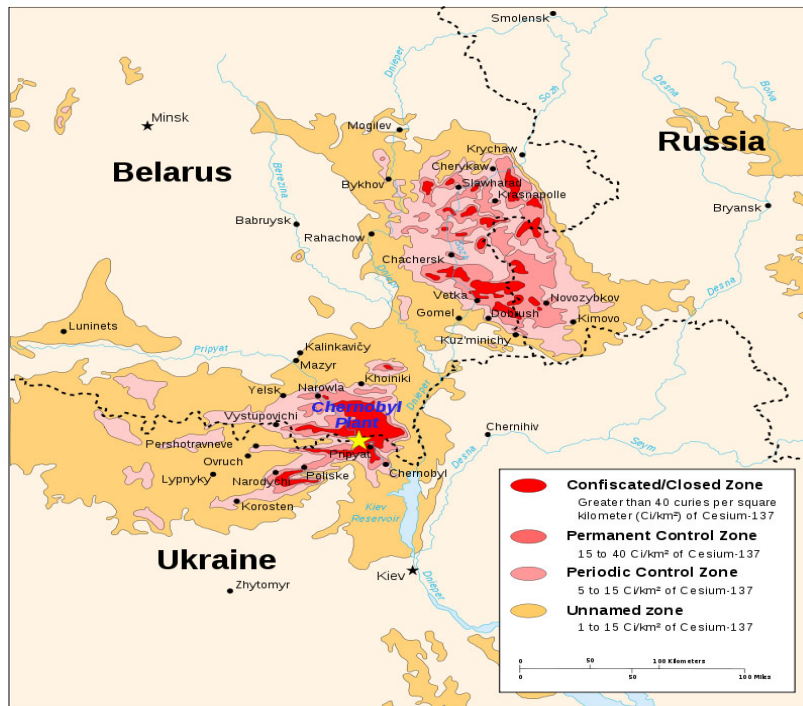


Figure 1. Map of cesium-137 radiation levels in 1996 around Chernobyl

One of the major assumptions made by the nuclear industry is that there are few or no significant health and environmental consequences associated with “low doses” of radiation or the ingestion of small amounts of radionuclides. Extreme caution is needed to not confuse the vague term, “low doses” with “safe doses” of radiation. In addition to the BIER VII report conclusions, new research done by scientists at the University of South Carolina (USC) further contradicts this assertion. The USC studies show dramatic declines in wildlife populations living in the contaminated regions near Chernobyl as a probable consequence of exposure to radionuclides. Birds showed a 50 percent decrease in species richness and a 66 percent drop in abundance in the most contaminated areas (compared to areas with normal background radiation) in the same neighborhood. Furthermore, mutation rates and developmental abnormalities are dramatically higher, and survival rates and fertility are lower, in regions of moderate to high contamination.[13]

Other scientists and medical doctors have also noted significant health problems arising in children whose diets are made up of foodstuffs grown in contaminated soils containing Cesium-137 and Strontium-90 from Chernobyl. In 2000, at the scientific session of the General Assembly of the National Academy of Sciences of Belarus, it was stated in the reports of the physicians and the Chernobyl Committee that the number of the healthy children in Belarus had decreased from 85% (in 1985) to only 20% (in 1999). [14]

Fukushima

On March 11, 2011, a massive earthquake (magnitude 9.0) and subsequent 46 foot high tidal wave (tsunami) struck the six nuclear reactors at Fukushima Daiichi, on the northeast coast of Japan. The entire facility was flooded and its connection to the electrical grid was broken. All power to operate the plant's cooling systems was lost and the reactors began to overheat causing a partial core meltdown in reactors 1, 2, and 3. This led to breakdown of the fuel rods and subsequent hydrogen explosions which destroyed the secondary containment in reactors 1, 3, and 4, in the areas where the spent fuel ponds were located. An explosion likely damaged the containment vessel for reactor 2 and fires broke out at reactor 4 where the reactor fuel had been moved from the reactor vessel to the spent fuel pond. The highly irradiated fuel rods stored in spent fuel pools of units 1-4 began to overheat as water levels in the pools dropped. On April 14, the Tokyo Electric Power Company admitted that the spent fuel rods at reactor 4 had likely been damaged, after elevated levels of radioactive iodine-131, cesium-134 and cesium-137 were detected.

The accident at Fukushima has already released far more radioactivity than did the Three Mile Island accident. The French radiation protection authority estimates that about 2.4 million curies of Iodine-131 had been released by March 22, 2011. Radioactive fallout from the crippled Fukushima reactors has already covered large areas of Japan's main island, Honshu, even though most of the radiation was blown out over the sea. Japanese officials have warned against consuming vegetables and milk from regions near the Daiichi nuclear complex and have urged residents to avoid giving tap water to children and infants.[15]

The situation at Fukushima is far from under control. According to the Atomic Energy Society of Japan, melted fuel rod fragments have sunk to the bottoms of reactors 1, 2 and 3 and could theoretically burn through the pressure vessels if emergency water-pumping operations are seriously disrupted. This would result in a further massive release of radioactivity to the environment, and could make it impossible for workers to remain on site to combat the disaster. Officials, optimistically, say it will take at least two or three months until the situation can be stabilized.[16]

There are seven leaking radiation sources at the Japanese site: the three damaged reactors and four spent fuel pools. Although it is currently unlikely that all of these materials could be released into the environment, these sources together contain far more long-lived radioactive materials, notably cesium-137, than did the Chernobyl nuclear reactor.

The Big Picture

Chernobyl severely impacted the Soviet economy and visited great hardship, suffering, illness and death upon hundreds of thousands of liquidators and those forced to flee from the disaster, as well as to the millions of unfortunate people who now must live in the contaminated lands of Belarus, Ukraine and Russia. The exclusion zones will remain closed to human habitation for centuries; cancers and genetic disease will continue on indefinitely. The bitter consequences of Chernobyl will transcend time and space.

Every time we build and operate a nuclear reactor, we do so with the implicit assumption that we shall forever be able to contain the radioactive poisons we create in the reactor. In doing so, we presume that we can predict the future for centuries and millennia to come, that we can isolate and protect nuclear reactors and nuclear waste from every single catastrophe that nature and man can inflict, including earthquakes, tsunamis, volcanic eruptions, asteroids, human error, terrorism and war. History has already shown us that such assumptions are indeed both foolish and futile.

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Nuclear Reactor Accident Evacuation Questions

Andrew S. Kanter, MD MPH, PSR President-Elect

April 16, 2011

The accidents in Chernobyl and Fukushima provide important lessons regarding the danger to public safety and the need for evacuation zones that are appropriate and feasible around nuclear power plants if they are to continue to operate.

Immediately after the accident, the Japanese government evacuated a 3 km zone around the plant, which then was expanded to 10 km and later to 20 kms with a stay-indoors zone from 20-30 km. Although still preliminary, radiation detection information from the Fukushima Daiichi reactor accident showed that significant radiation was and is being detected well outside the official 20 km evacuation zone. Aerial monitoring by unmanned drone aircraft detected a swathe of elevated radiation Northwest from the plant out to about 25 miles (see Figure 2)[1].

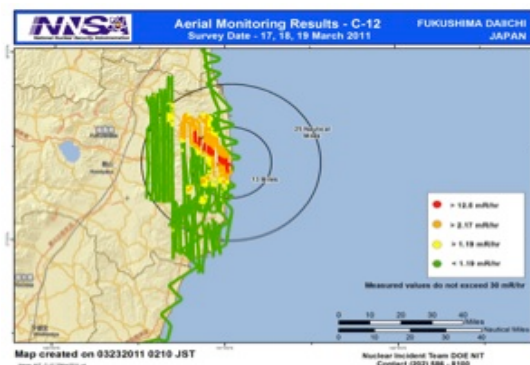


Figure 2. Aerial radiation detection around Fukushima.

Most of the areas around Fukushima were apparently spared a more significant radioactive release because most of the time the prevailing wind has been blowing out to sea, rather than back over the populated areas of Japan. We will not know for sure what the actual radiation dose was immediately around the site as detectors were knocked out by the tsunami. However, radiation monitoring provided by the preparatory commission for the Comprehensive Nuclear-Test-Ban Treaty Organization provided through the Austrian Meteorological Service (ZAMG) shows that over the first several weeks the plume mostly has been blown out to sea (see Figures 3-8).

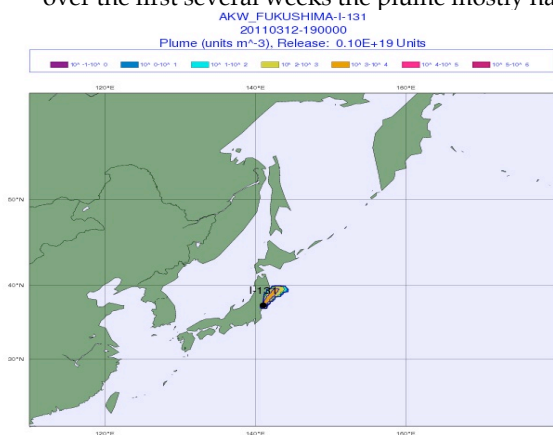


Figure 3. I-131 radiation plume on 3-12-11

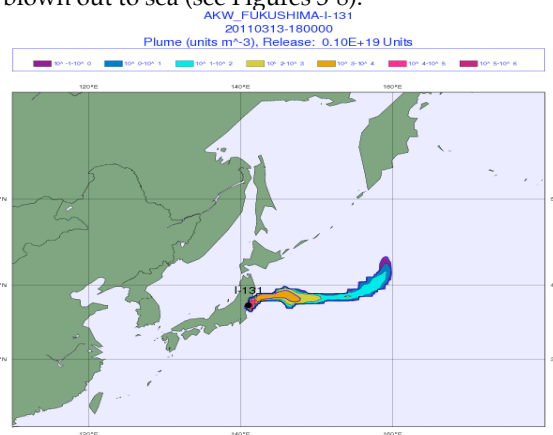


Figure 4. I-131 radiation plume on 3-13-11

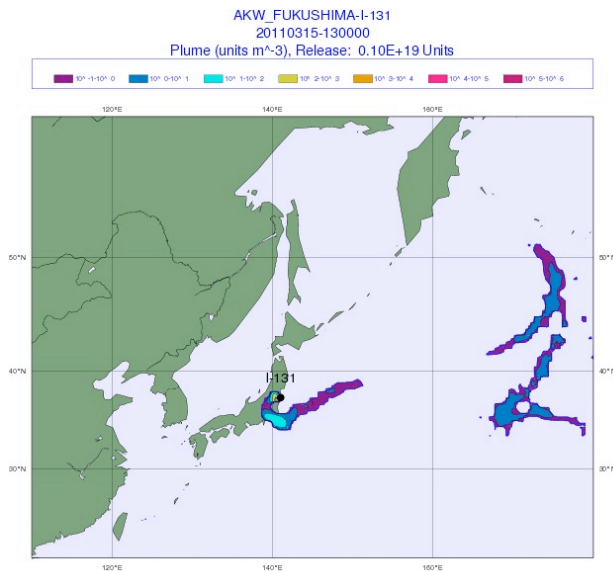


Figure 5. I-131 radiation plume on 3-15-11

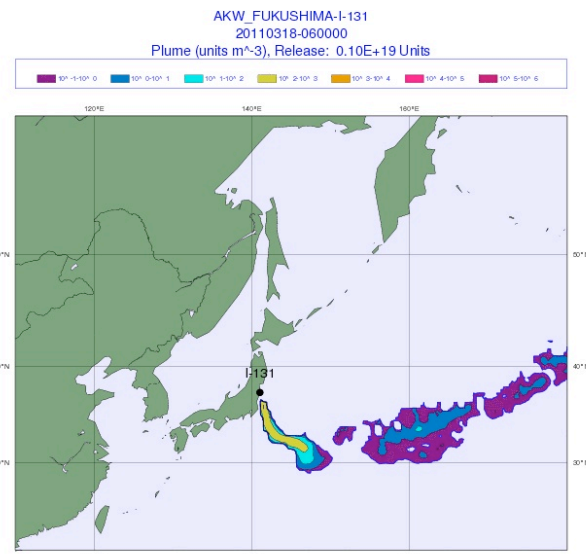


Figure 6. I-131 radiation plume on 3-18-11

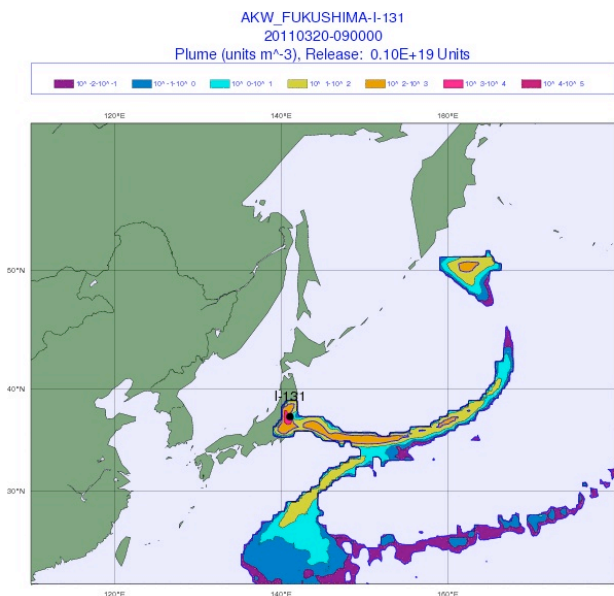


Figure 7. I-131 radiation plume on 3-20-11

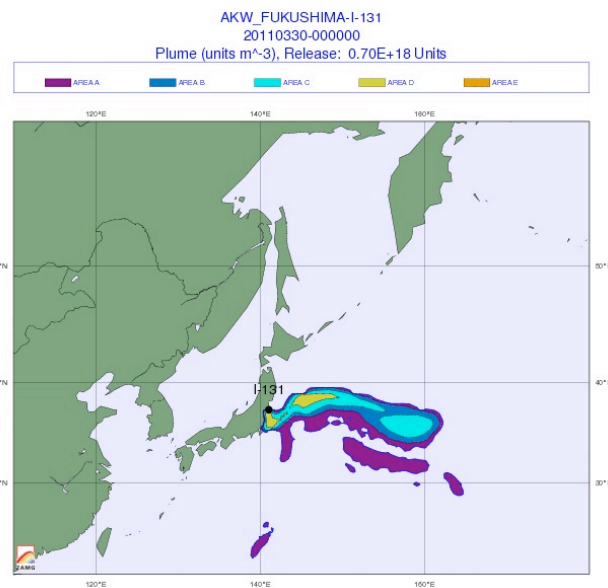


Figure 8. I-131 radiation plume on 3-30-11

Radiation measurements of soil samples taken as far away as 50 km from the site show levels of cesium-137 which exceed the cut-off used for determining the long-term evacuation zone around Chernobyl.

The current permanent exclusion zone around the Chernobyl reactor extends for 30 km (18.7 miles) and 5800 square km (2240 square miles) and are heavily contaminated. Other areas 300-400 km (185-250 miles) away in Belarus are uninhabitable (see Figures 9 and 10 for comparison of Chernobyl and Fukushima). Hundreds of thousands of square kilometers of forest and agricultural area are off limits or required decontamination. [2]

Comparison of Chernobyl and Fukushima soil contamination levels of Cesium-137
 Overlaid numbers are in units of kiloBecquerel / m²
 Fukushima numbers are based on the approximate average soil measurements from each region from March 21 till April 11, 2011.
 Soil readings were reported in Bq/kg. The methodology states samples were averages of the top 5cm of soil.
 Topsoil weighs 1kg per L, and 50L covers 1 square meter 5cm deep. Thus, we multiply Bq/kg by 50kg/m² to get Bq/m².
 For the Chernobyl map, 1 Curie / km² = 37 Bq / m²
 Fukushima Data from http://www.mext.go.jp/component/english/_icsFiles/afieldfile/2011/04/11/1304851_041110.pdf

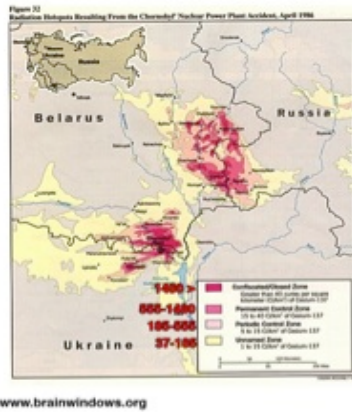


Figure 9. Chernobyl Cesium-137 levels

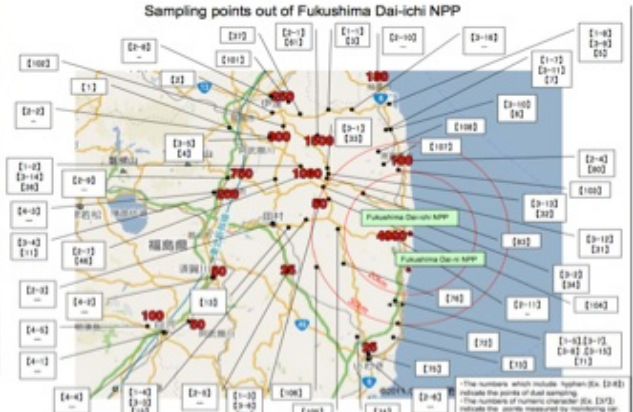


Figure 10. Fukushima Cesium-137 levels

It is clear that the original evacuation zones around the Fukushima reactors and the current 10 mile evacuation zone mandated in the U.S.[3] is insufficient. We can only postulate what the actual contamination in Japan would have been if the prevailing winds had not been over the ocean. Chairman of the Nuclear Regulatory Commission, Gregory Jaczko, on March 16, 2011, announced a 50 mile evacuation zone for all Americans near the Fukushima plant. However, this recommendation was not accepted by the Japanese government for its own people, nor has this recommendation been included as standard evacuation planning for U.S. nuclear reactors. The Japanese government commissioned an institute to perform a simulation based on the data known as of March 16 using a program called SPEEDI (System for Prediction of Environmental Emergency Dose Information). This suggested that doses were going to be much higher outside the 20 km zone, even out to 45 km. This did prompt expansion of the evacuation zone around the Fukushima site, but still did not include all the people who were at risk.

It is clear from the experience of both Chernobyl and Fukushima that not only is a 50 mile evacuation zone prudent, it is required based on actual experience. This is particularly true in that the U.S. has 23 identical Mark I Boiling Water Reactors as those in crisis in Japan. Using similar simulation software provided by the US Government,[4] Physicians for Social Responsibility did an analysis of what would happen from a nuclear reactor accident near a major metropolitan area—in this case the Braidwood reactor outside of Chicago. The simulation modeled a loss of coolant accident with exposure of the reactor core, a containment breach, and release of the reactor’s superheated radioactive fuel into the air. The resulting plume (see Figure 11) of radioactive materials would extend north from the reactor itself to the northern edges of metropolitan Chicago, and east into Indiana and Michigan.

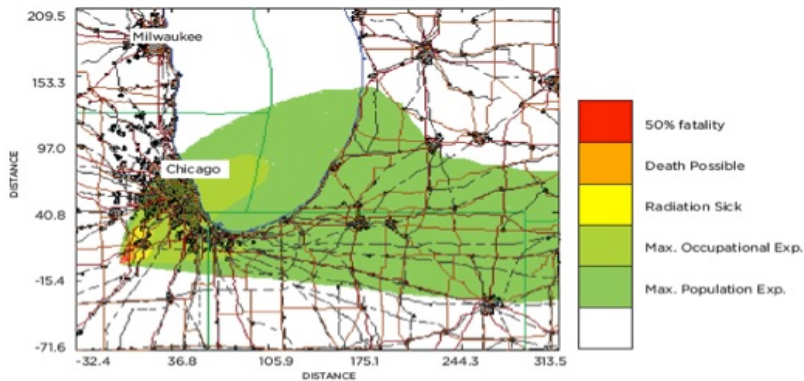


Figure 11. Radiation plume from simulated Braidwood reactor incident near Chicago

The population would be exposed to different levels of radiation depending on the distance from the reactor, duration of exposure (for this simulation, it is assumed that the exposure would continue for one week), and the wind pattern. It is estimated that more than 7.5 million people would be exposed to radiation (receiving greater than the maximum allowed annual population dose), of which 4.6 million would receive a dose equivalent of the maximum allowable occupational exposure for one year. More than 200,000 would receive high enough doses to develop radiation sickness and 20,000 might receive a lethal dose (LD 50), according to our projections.

The acute exposure levels shown in Figure 12 below reveal the intensity of radioactivity, the risk to first responders, and the size of the area requiring evacuation. Radiation doses that are high enough to produce acute radiation sickness would affect an area encompassing parts of Kankakee, Will and Grundy counties. The area that would require evacuation or other protective measures is shown as the orange area identified as EPA PAG (Environmental Protection Agency Population Action Guideline). As shown by the map, this includes the majority of the City of Chicago, extending east to Gary and South Bend, Indiana.

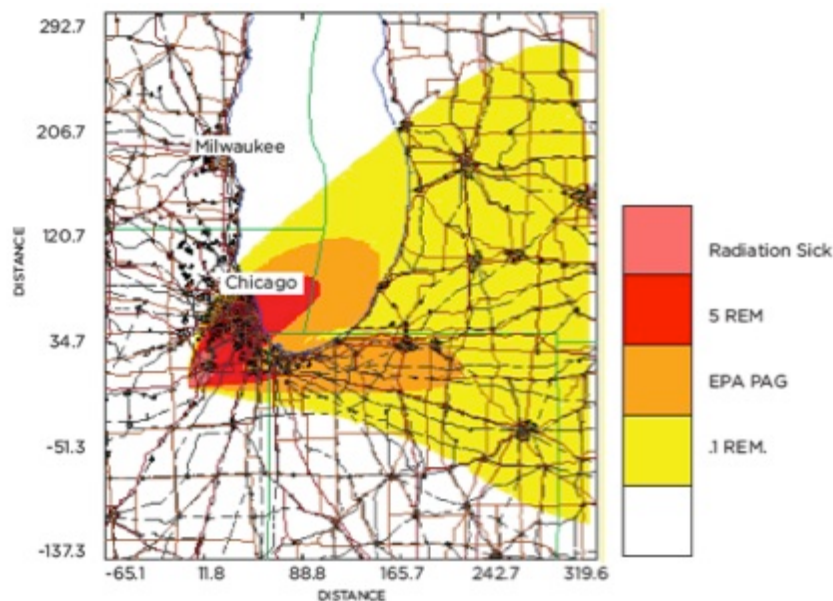


Figure 12. Radiation acute exposure levels from simulated Braidwood reactor incident near Chicago

The number of acutely ill people in this scenario would overwhelm all available care facilities; about 113 hospitals would fall within the occupational exposure zone (including two Veterans Administration hospitals), affecting more than 32,000 potential beds. Nearly 20,000 physicians in five counties would receive greater exposure than occupational maximums for radiation exposure from the plume.

First responders, including firefighters, would also be injured. The closest firefighters would either suffer lethal doses or suffer from radiation sickness and be unlikely to provide a sustained response to the emergency. Another 10,500 firefighters in 355 other departments would exceed occupational exposures from the plume itself and would be unavailable to respond within the highly contaminated area. Police departments also would be hard hit in the closest towns, with an estimated 38 police officers receiving potentially lethal doses of radiation.

It is clear that the authorities and health care system would not be able to properly protect the health of all the people and vulnerable populations which would need to be moved in the case of such an accident, let alone the massive

number of injured, or potentially injured and symptomatic victims. The experience from Hurricane Katrina was that even 1 million people with several days notice could not be adequately evacuated.

Dr. Edwin Lyman of the Union of Concerned Scientists (UCS) performed a similar study of a core meltdown at the Indian Point nuclear power plant (located 35 miles north of New York City). This showed an even higher death toll and greater destruction than illustrated in the PSR scenario described above.[5] In this study, a meltdown at the Indian Point power plant could result in 44,000 people dying from radiation poisoning within a year and 518,000 cancer deaths over time. Millions of people in the greater New York City area would have to be permanently relocated because the resulting contamination would leave huge geographic areas uninhabitable for many years or decades. Economic losses from such an attack, according to the UCS study, could be from \$500 billion to \$2 trillion.

When one considers all the nuclear reactors in the U.S. and on the border of Canada, over 111 million people - 1/3 of the population of the U.S. - lives within 50 miles of a nuclear reactor. Using a new tool available from PSR [6], a 50 mi evacuation zone can be mapped around the Indian Point nuclear reactor. Using this tool (see Figure 13), over 17 million people fall within the evacuation zone. There is no conceivable way that these people could be evacuated in the case of a serious accident at the plant. The Calvert Cliffs nuclear plant located outside Washington, DC would require 3.1 million people to be evacuated (see Figure 14).

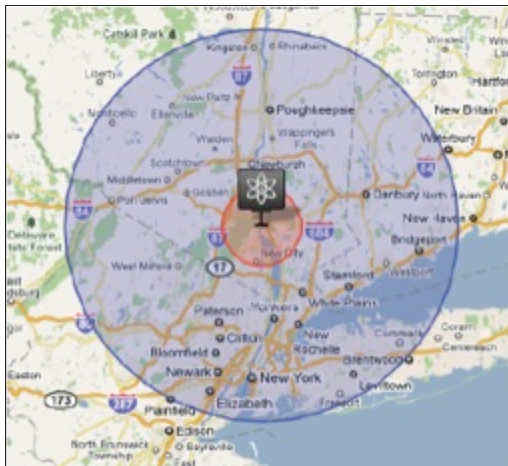


Figure 13. Indian Point evacuation zones
(New York City area)

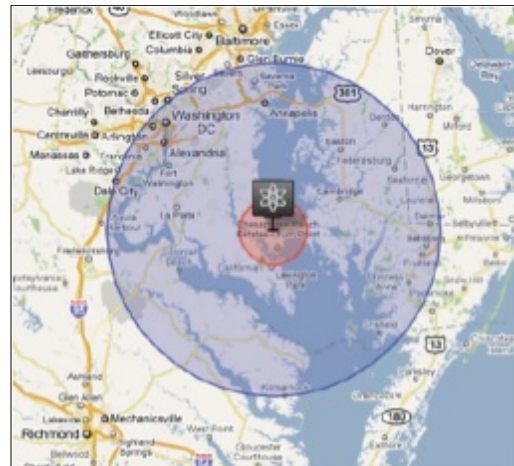


Figure 14. Calvert Cliffs reactor evacuation zones
(Washington DC area)

[1] <http://blog.energy.gov/content/situation-japan/>

[2] Medvedev Z. The Legacy of Chernobyl. WW Norton Press, New York, 1992.

[3] <http://www.nrc.gov/reading-rm/doc-collections/cfr/part050/part050-0047.html>

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[5] Lyman ES. Chernobyl on the Hudson? Union of Concerned Scientists, September 2004.

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Growing Problem of Spent Nuclear Fuel

John W. Rachow PhD MD, PSR President

April 17, 2011

Fresh uranium dioxide nuclear fuel (approximately 4% fissile Uranium-235 and 96% non-fissile Uranium-238) has relatively low radioactivity, can be fused into ceramic pellets, packed into thin metal tubes, and easily handled. However, when arranged in assemblies of multiple rods in close proximity, the neutrons from the fission of the Uranium-235 becomes dense enough to sustain a chain reaction releasing tremendous heat and producing radioactive waste products.

It is also possible to use mixed uranium-plutonium oxide (MOX) fuel in nuclear reactors, as is the case of the #3 reactor at Fukushima. This fuel formulation is inherently more dangerous and difficult to handle at all stages of its life cycle. Fresh MOX fuel contains Plutonium-239. When spent, MOX has more plutonium and other transuranics than normal uranium-based nuclear fuel and has much higher thermal activity. [MIT 2003].

With advanced engineering, these nuclear reactions are used at the heart of nuclear reactors to generate steam that can drive turbines that turn electric generators. To power the reactors, ceramic/uranium dioxide pellets are packed into fuel rods made from zirconium alloy tubes, up to about 14 feet in length and approximately 0.4" in diameter. To form a nuclear reactor core, rods are arranged in assemblies of 64 to several hundred rods each. Each assembly can weigh up to 1000 lb, and several hundred such assemblies form the core of a nuclear reactor. Fuel rods become spent in about 18 months and have to be replaced during a procedure requiring reactor shutdown for 5-6 weeks when about one-third of the assemblies are replaced. Shutdown and subsequent restart entail complex steps during which the reactor is not generating steam and no electricity is being generated.

Partially spent and fully spent nuclear fuel is extremely hot and radioactive in contrast to fresh fuel. Safe management of spent fuel rods is quite challenging. A U.S. Nuclear Regulatory fact sheet [1] states that after storage in a cooling pool for 10 years the surface radioactivity of a spent fuel assembly is still about 10,000 rem/hour. A 500 rem dose delivered to a whole person in a single exposure is fatal. Close proximity to a single 10-year-old spent fuel assembly would deliver a fatal whole body radiation dose in about 3 minutes.

Zirconium is chosen as fuel rod cladding because this metal has the special property of minimally impeding the flight of neutrons. However, zirconium alloys rapidly oxidize at moderately high temperatures (over 1600 degrees F) and in the presence of water, oxidation produces hydrogen gas. If cooling of spent rods is lost for even a short time, temperature rises so precipitously that the zirconium begins to exothermically oxidize—technical parlance for burning—releasing the radioactive materials contained inside. Considering the contents of spent fuel rods, a zirconium fire, is an extremely dangerous event. Storage of spent rods assemblies under least 20 feet of water in actively circulating cooling pools for at least five years is required before rods can be stored in dry shielded casks. Loss of cooling water to either a reactor core or a cooling pool is extremely dangerous as was demonstrated in Fukushima and should never be allowed to happen.

According to a General Accounting Office report in 2003:

One of the most hazardous materials made by man is spent nuclear fuel—the used fuel periodically removed from reactors in nuclear power plants. Without protective shielding, the fuel's intense radioactivity can kill a person exposed directly to it within minutes or cause cancer in those who receive smaller doses. As the fuel ages, it

begins to cool and becomes less radiologically dangerous—some of the radioactive particles decay quickly, within days or weeks, while others exist for many thousands of years [2].

The U.S. has no permanent repository for high level nuclear waste. The 104 operating nuclear power reactors in the U.S. currently generate 2,000 metric tons of spent nuclear waste per year and to date have accumulated 71,862 tons of spent nuclear fuel that is permanently stored on-site according to industry data [3]. Of the total spent fuel, 54,696 tons are stored in cooling pools and only 17,166 tons have been moved to safer dry cask storage. The industry does not reveal the quantity of spent fuel stored at individual nuclear sites, but state totals are reported by the Nuclear Energy Institute.

Taking a state like Iowa as an example, with only one reactor which came on line in 1974 and is now re-licensed to operate through 2034, there are currently 465 tons of spent fuel stored on site; 345 tons in its cooling pool and 120 tons in dry cask storage [3]. The Iowa reactor is a GE type 4 BWR with Mark 1 containment, nearly identical to the units at the Daiichi complex near Fukushima, Japan. This GE reactor model has a single cooling pool located in the containment building above the reactor itself.

Estimates of the spent fuel in the ill-fated Fukushima Daiichi sister units suggest only 50-150 metric tons in each of the individual reactor pools [4]; considerably less than lies in the cooling pool associated with the one nuclear power reactor in Iowa.

The cooling pools are 40 feet deep and are steel lined with concrete walls up to six feet thick as radiation shielding. Because most pools were nearing capacity a decade ago and there was no permanent repository in the foreseeable future, original fuel assembly racks in the pools were reorganized to allow a more compact arrangement and increase capacity beyond the original designs. This was done not only because pools were at their design capacity, but movement of spent fuel assemblies to dry cask storage is time consuming and expensive. Transition to dry cask storage has begun over the last decade, but most reactors continue to store the spent fuel in cooling ponds beyond five years.

Spent fuel assemblies are typically kept on cooling pools for ten years, but after as little as five years in the cooling pools, fuel rod assemblies can be packed into massive sealed casks. Casks are approximately nine feet in diameter and 20 feet tall with walls of steel and concrete for radiation shielding [5]. Casks can each contain 20-50 spent fuel assemblies. The sealed casks are pressurized with helium that circulates passively through cooling fins to dissipate the heat generated by the contained spent fuel [6]. It is uncertain how casks are monitored for rising temperatures or radiation leakage.

Casks weigh upward of 120 tons. The Connecticut Yankee plant was cited by the NRC in recent years for dropping a loaded 180 ton dry cask 4 inches onto a concrete surface. [7]. Should a deep geological repository ever be developed, safe transport of these massive casks to the repository will be a daunting undertaking.

The toxic “life span” of spent nuclear fuel is about one million years [6], and this is one of the basic design parameters to be considered when developing a permanent high level waste storage site according to US law. Thus, owners of nuclear reactors are essentially required to manage this most hazardous of all man-made wastes, forever, and certainly well beyond the final shutdown and decommissioning of a plant. If new reactors are built in the future as desired by proponents of nuclear power, the prospects of accelerating accumulation of this million-year waste is truly overwhelming. Just as the costs of the total life cycle of doing so are effectively unlimited, the risk of a devastating accident involving a cooling pool becomes steadily more likely.

Additional recommended principles for safeguarding spent fuel at reactor sites have been made by PSR and a number of other national organizations and individuals. [8]

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<http://www.psr.org/nuclear-bailout/resources/principles-for-safeguarding.pdf>

PSR Experts



Jeff Patterson, DO

PSR Immediate Past President

Dr. Jeff Patterson is a professor in the Department of Family Medicine at the University of Wisconsin School of Medicine and Public Health in Madison, WI. In this role, he maintains an active family practice and teaches residents in family medicine. This has been his academic and clinical base since 1975.

He has been active in Physicians for Social Responsibility and is currently the president of National PSR. PSR is the US affiliate of The International Physicians for the Prevention of Nuclear War, winners of the 1985 Nobel Peace Prize. He has traveled extensively in the former USSR and has lectured about the effects of nuclear weapons and radiation there, in Europe, as well as in the US. Dr. Patterson has visited Chernobyl and sites of nuclear testing and nuclear weapons' production in the former Soviet Union. His special interests include the medical effects of radiation, non-violent alternatives to war as means of preventing war, and sustainable methods of ameliorating climate change.

Dr. Patterson is the medical director of the Hackett Hemwall Foundation (HHF), a charitable foundation doing medical work in Honduras, Mexico, and the Philippines. Through the foundation, with the help of many dedicated volunteers, he has taught physicians from over 20 countries around the world the procedures of prolotherapy to treat chronic pain. The HHF projects have provided treatment for chronic pain and the treatment of varicose veins for thousands of patients and this work is continued by physicians who have been trained in these countries. The foundation also supplies medical supplies, computers, and school supplies to clinics, hospitals, and schools in Honduras annually.

In addition to producing a DVD teaching video for training in prolotherapy, Dr. Patterson has taught seminars widely in the US and other countries. With his colleagues, Dr. Patterson has established the University of Wisconsin Department of Family Medicine as one of the premier research centers for prolotherapy.



Peter Wilk, MD

PSR Executive Director

Dr. Peter Wilk has been active for the past 30 years in public health advocacy organizations and medical organizations concerned with preventing nuclear war and addressing other threats to global survival. He was named Executive Director of PSR in February 2009. He has a long association with PSR, having served as a PSR Board member for many years and as PSR's President in 1995 and 2000. As executive director, Dr. Wilk leads the largest physician-led organization in the United States working to address the gravest threats to human health and survival.

Dr. Wilk has held leadership positions with International Physicians for the Prevention of Nuclear War (IPPNW), acting as the Co-Vice President for North America from 1996 to 2000 and Speaker of the International Council from 2004 to 2008. He served as Congress Chair and led in organizing the 2002 joint PSR & IPPNW "Summit for Survival" World Congress in Washington, DC. He also served as the President of PSR/Maine from 1983 to 1994 and from 1998 to 2008.



Andrew S. Kanter, MD MPH

PSR President Elect (2012)

Dr. Kanter is president-elect of Physicians for Social Responsibility and has been involved in education and advocacy around nuclear issues since 1982. He has co-authored articles about the real and potential public health consequences associated with nuclear reactors and has presented reactor accident simulations in Chicago and before the UN Nonproliferation Treaty Preparatory Conference. He is an internist and is Assistant Professor of Clinical Biomedical Informatics and Clinical Epidemiology at the Earth Institute, Columbia University where he directs the Columbia International eHealth Lab (CIEL). He is a graduate of both Harvard Medical School and Harvard School of Public Health.

Dr. Kanter is also President of the NY City Chapter of PSR, has been on the Board of National PSR since 2002 and is on the Board of Directors for the International Physicians for the Prevention of Nuclear War.



Ira Helfand, MD

Former PSR President

Dr. Helfand is past president of Physicians for Social Responsibility. He has lectured and published widely on the dangers of nuclear weapons and nuclear power. He currently chairs the PSR Board committee that oversees its work on nuclear war prevention, and represents PSR as the North American Vice President on the board of the International Physicians for the Prevention of Nuclear War. He is a board-certified internist at Family Care Medical Center in Springfield, Massachusetts and a graduate of Harvard College and Albert Einstein Medical College of Medicine.



Steven Starr, MT

PSR Senior Scientist

Mr. Starr is a PSR Senior Scientist, who studied nuclear engineering as an undergraduate and has Bachelor degrees in General Studies and Clinical Laboratory Sciences. He is an Associate Member of the Nuclear Age Peace Foundation. He has had a life-long interest in the prevention of nuclear war and has published extensively on this subject. He maintains an in-depth web site, www.nucleardarkness.org, on the climate effects of nuclear war that include widespread famine. The website has versions in four languages. He is a certified Medical Technologist and Technologist in Blood Banking.



John Rachow, PhD MD

PSR President

Dr. Rachow is the President of Physicians for Social Responsibility for 2012 and holds a doctorate in chemical engineering and has medical training in internal medicine, rheumatology, and geriatrics. He is currently an Assistant Clinical Professor in Internal Medicine at the University of Iowa. He has been on the PSR Board since 2006 and has been active in the Iowa Chapter of Physicians for Social Responsibility since 2002.

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