POLICY FORUM: NUCLEAR SAFETY

Nuclear Power Plants and Their Fuel as Terrorist Targets

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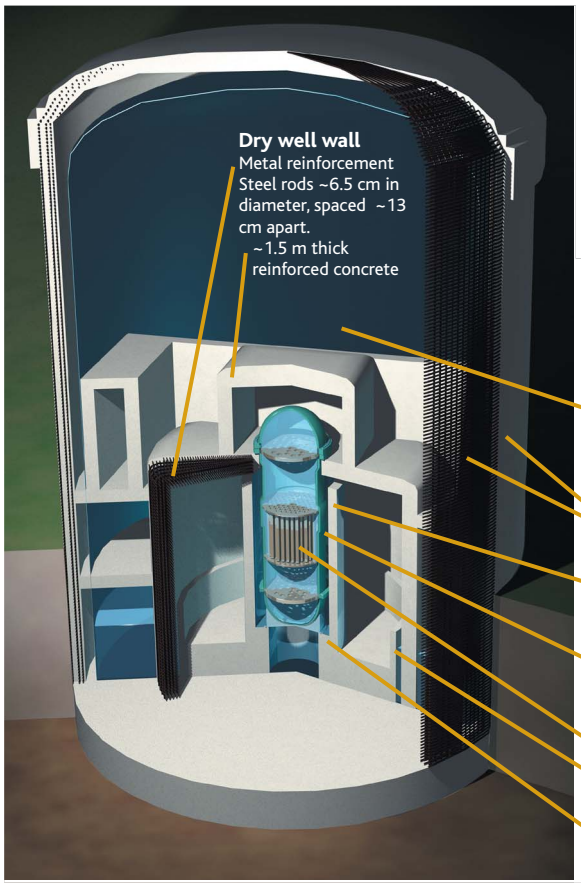
If you watch television or read repeated public statements of concern about nuclear power plants as terrorist targets, you would be justified in believing that spent nuclear fuel casks being shipped to Nevada for storage are each a nuclear catastrophe just waiting to be triggered. These casks have been called "mobile Chernobyls," and we are told they are capable of causing "tens of thousands of deaths" (*1*). What are the facts about the safety of nuclear shipments and power plants?

Since 11 September 2001, the U.S. nuclear industry and its regulators have been reevaluating plant and fuel shipment safety. These studies are being kept secret. But it is no secret that basic engineering facts and laws of nature limit the damage that can result. Extensive analysis, backed by full-scale field tests, show that there is virtually nothing one could do to these shipping casks that would cause a significant public hazard (*2, 3*). Before shipment, the fuel elements have been cooled for several years, so the decay heat and the short-lived radioactivity have died down. They cannot explode, and there is no liquid radioactivity to leak out. They are nearly indestructible, having been tested against collisions, explosives, fire, and water. Only the latest antitank artillery could breach them, and then, the result was to scatter a few chunks of spent fuel onto the ground. There seems to be no reason to expect harmful effects of the radiation any significant distance from the cask.

Similarly, we read that airplanes can fly through the reinforced, steel-lined 1.5-m-thick concrete walls surrounding a nuclear reactor and inevitably cause a meltdown resulting in "tens of thousands of deaths" and "make a huge area of the U.S. uninhabitable for centuries," to quote some recent stories (*4*). However, there seems to be no credible way to achieve that result (*5, 6*). No airplane, regardless of size, can fly through such a wall. This has been calculated in detail and tested in 1988 by flying an unmanned plane at 215 m/s (about 480 mph) into a test wall 3.6 m thick. The plane, including its fuel tanks, collapsed against the outside of the wall, penetrating a few centimeters. The engines were a better penetrator, but still dug in only 5 cm. Analyses show that larger planes fully offset their greater impact by absorbing more energy during their collapse. Higher speed increases the impact, but not enough to matter. And inside the containment wall are additional walls of concrete and steel protecting the reactor.

Is it possible to cause a nuclear reactor to melt down some other way? Yes, it happened at Three Mile Island (TMI) in 1979. Reactors are much improved since then, and the probability of such an accident is now much less. But suppose it happens, through terrorist action or other; what then? Well, the TMI meltdown caused no significant environmental degradation or increased injury to any person (*7–10*), not even to the plant operators who stayed on duty. It has been said that this lack of public impact was due primarily to the containment structure. But studies after the accident showed that nearly all of the harmful fission products dissolved in the water and condensed out on the inside containment surfaces. Even if containment had been severely breached, little radioactivity would have escaped. Few, if any, persons would have been harmed.

To test how far the 10 to 20 metric tons of molten reactor penetrated the 13-cm-thick bottom of the reactor vessel on which it rested, samples were machined out of the vessel and examined. The molten mass did



Multiple layers of safety at nuclear power plants.

Boiling water reactor

Containment vessel
~4 cm thick steel cylinder
~55 m tall

Shield building wall
~1-meter-thick reinforced concrete. Steel rods ~6.5 cm in diameter, spaced ~13 cm apart

Bio shield
Leaded concrete ~1.2 m thick with steel lining ~2.5 cm thick inside and out

Reactor vessel
~21.3 m tall. ~6.4 m in diameter. High tensile steel 10 to 20 cm thick

Reactor fuel

Weir wall
Concrete 46 cm thick. ~7.3 m tall

Pedestal
Concrete ~1.6 m thick with steel lining ~2.5 cm thick inside and out

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not even fully penetrate the 0.5-cm cladding, confirming tests in Karlsruhe, Germany, and in Idaho, that the "China syndrome" is not a credible possibility (*8–10*).

The accident at Chernobyl in 1986 is simply not applicable to American reactors. The burning graphite dispersed most of the fission products directly into the atmosphere. Even in that situation, with no evacuation for several days, the United Nations' carefully documented investigation UNSCEAR-2000 (*11*) reported that there were 30 deaths to plant operators and firefighters, but no significant increase in mortality or cancer due to irradiation of the public have been observed (*12*, *13*). A possible link between exposure and thyroid cancer is still under study (*14*). The terrible and widespread consequences of that accident—increased suicide, alcoholism, depression, and unemployment (*15*), plus 100,000 unnecessary abortions (*16*)—were caused primarily by fear of radiation and by poor planning based on that fear. The evacuated lands are generally now no more radioactive than the natural background levels where many people have lived healthily for generations.

Three Mile Island nuclear power plant.

CREDIT: DOE

It's not surprising that some people overstate the concern about radiation, for whatever reason. But it is surprising that most nuclear advocates are reluctant to challenge such claims. They say they just want to be cautious. But striving for maximum caution leads to the assertion that we should act as if even the tiniest amount of radiation might be harmful, despite the large body of good scientific evidence that it is not (*17–22*). This policy has scared people away from mammograms and other life-saving treatments and has caused many Americans to die each year from pathogens that could have been killed by food irradiation (*23*). It has piled regulations on nuclear medicine facilities that caused many of them to shut down. And now, "permissible doses" have been pushed below those found in natural radiation backgrounds (*24–26*).

Such cautiousness has drawbacks when applied to design and operation of nuclear facilities. But it is particularly dangerous when applied to terrorism. To tell people that they and the Earth are in mortal danger from events that cannot cause significant public harm is to play into the hands of terrorists by making a minor event a cause for life-endangering panic. Now is the time to clear the air and speak a few simple scientific and engineering truths.

References and Notes

1. "[A] major fire is possible which could release 25 times more radioactive material than Chernobyl... such a fire could render 29,000 square miles uninhabitable...cause 28,000 cancer deaths and $59 billion in damage." B. C. Smith, *The Tech*, 1 May 2002. Available at: www-tech.mit.edu/V122/N22/col22brice.22c.html.
2. The shipping casks and the spent fuel are described in the 207-page Appendix J of the *Yucca Mountain Environmental Impact Statement* (DOE/EIS-0250, Government Printing Office, Washington, DC, 2002); available at: www.ymp.gov/documents/feis_a/vol_2/eis_j_bm.pdf
3. For an independent analysis, see J. L. Sprung *et al.*, *Re-examination of Spent Fuel Shipment Risk Estimates* (NUREG/CR-6672, Sandia National Laboratory, Albuquerque, NM, 2000); available at http://ttd.sandia.gov/nrc/nuregcr6672/chap1.pdf
4. "You could have tens of thousands to hundreds of thousands of fatalities from cancer ... the downwind path from these types of casualties could extend for hundreds of miles." P. Leventhal, Director of Nuclear Control Institute, on the Cable News Network, 1 February 2002; "Nuclear specialist Mark Gaffney said that an attack on a plant could make a huge area of the US uninhabitable for centuries." D. Nelson, in OneWorld UK, 2 November 2001 (www.oneworld.net/uk). To which the Government reportedly responded, "Of course it would be a big mess. Would it lead to multiple tens of thousands of deaths? That's much less certain." B. Henderson, Nuclear Regulatory Commission (NRC) representative, in K. Davidson, *San Francisco Chronicle*, 5 October 2001, p. A6. NRC Commissioner Nils Diaz recognized the need to correct this situation in his plenary talk at the American Nuclear Society Conference, Hollywood, FL, 10 June 2002: "I do not believe nuclear power is being portrayed in a balanced manner.... This is probably the fault of all of us who know better ... public health and safety consequences might very well be nuclear power and radiation technology's strongest and most favorable arguments when comparing risks and benefits." But on 5 August 2002, the Associated Press reported that NRC declared that "the best available way" to prevent a public health hazard is "controlling the airspace over atomic power plants."
5. "A hijacked commercial airliner loaded with explosive jet fuel like the one that hit the Pentagon on September 11 could not penetrate a U.S. nuclear power reactor and release deadly radiation," from a Reuters report, 17 June 2002, of a National Press Foundation Seminar. The report, commissioned by the Nuclear Energy Institute of independent contractors, is being reviewed by industry experts and will be completed this fall. The study reports detailed computer modeling, confirmed by large-scale tests.
6. Videotapes of tests of an unmanned airplane impacting a mockup of a section of containment wall can be seen at www.sandia.gov/media/NRgallery00-03.htm.
7. J. G. Kemeny, Chairman, *The Need for Change: The Legacy of TMI*, Report of the President's Commission on the accident at Three Mile Island, October 1979 (Government Printing Office, Washington, DC, 1979), 179 pp.
8. Organization for Economic Cooperation and Development (OECD), *Three Mile Island Reactor Pressure Vessel Investigation Project: Achievements and Significant Results*, Proceedings of an open forum sponsored by the OECD Nuclear Energy Agency and the U.S. Nuclear Regulatory Commission, Boston, MA, 20 to 23 October 1993.
9. See especially N. Cole, T. Friderichs, B. Lipford, pp. 81–91 of (*8*), "Specimens Removed from the Damaged TMI Reactor Vessel."
10. N. Cole, "TMI-2, A learning experience: Assessing the damage" (MPR-889, MPR Associates, Alexandria, VA, 1985).
11. *Sources and Effects of Ionizing Radiation: UNSCEAR 2000 Report to the General Assembly, with Scientific Annexes* (U.N. Scientific Committee on the Effects of Atomic Radiation, U.N. Publications, New York, 2000); available at www.unscear.org/reports.htm. See especially "The Chernobyl accident," vol. 1, p. 13 and the extensive scientific annexes, specifically vol. 2, Annex J, "Exposures and effects of the Chernobyl accident."
12. This report (*11*) was reviewed and the conclusions on Chernobyl reaffirmed in the 3rd International Conference, Health Effects of the Chernobyl Accident: Results of 15 Years of Follow-Up Studies, Kiev, Ukraine, 4 to 8 June 2001, sponsored by UNSCEAR; the World Health Organization; other U.N. agencies; and Ukraine, Belarus, and Russia; available at www.unscear.org/chernobyl.htm. Z. Jaworowski, member and former chairman of UNSCEAR, discusses the significance of these findings in *Phys. Today* **52**, 24 (1999).
13. Z. Jaworowski, *Science* **293**, 605 (2002).
14. See D. Williams, *Nature Rev. Cancer* **2**, 543 (2002) and recent news coverage [R. Service, *Science* **292**, 420 (20 April 2001)].
15. *The Human Consequences of the Chernobyl Nuclear Accident: A Strategy for Recovery, A Report Commissioned by UNDP and UNICEF, with the support of UN-OCHA and WHO* (25 January 2002). The report (356KB) is summarized in a U.N. news release at www.undp.org/dpa/frontpagearchive/2002/february/7feb02/ and is available for download at that URL.
16. G. Walinder, "Has radiation protection become a health hazard?" (Swedish Nuclear Training and Safety Center, Nykoping, 1995).
17. H. F. Henry, *JAMA* **176**, 671 (1961).
18. A.M. Brues, *Science* **128**, 693 (1958).
19. L. Gerber *et al.*, *Q. Rev. Biol.* **74** (no. 3), 273 (1999).
20. R. S. Yalow, *The Scientist* **2** (13 June), 11 (1988).
21. L. E. Feinendegen, M. Pollycove, *J. Nucl. Med.* **42** (no. 7), 17N (2001).
22. M. Pollycove, L. E. Feinendegen, *J. Nucl. Med.* **42** (no. 9), 26N (2001).
23. The FDA site on Food Irradiation, www.fda.gov/fdac/features/1998/398_rad.html states, "A May 1997 presidential report, 'Food Safety from Farm to Table,' estimates that 'millions' of Americans are stricken by food-borne illness each year and some 9,000, mostly the very young and elderly, die as a result." There is general agreement that this number could be reduced markedly by food irradiation, but reliable estimates will not be available until irradiation is in widespread use.
24. The U.S. Environmental Protection Agency set an annual limit on radioactivity in primary drinking water, based on a permissible annual dose of 0.04 mSv/year [65 Fed. Reg. 76708 (7 December 2000), with technical justification in the Notice of Data Availability, 65 Fed. Reg. 21576 (21 April 2000) and its Technical Support Document]. Natural radiation background typically varies from less than 1 mSv/year to about 10 mSv/year. The U.S. average is about 3 mSv/year. (NCRP Report no. 94, available from the National Council on Radiation Protection and Measurements, 7910 Woodmont Avenue, Bethesda, MD 20814, USA.) In high-background regions, doses to populations range up to several hundred mSv/year, with no indications of adverse health effects. [UNSCEAR 2000, cited in (*11*), vol. 1, Annex B.]
25. *Low Level Radiation Health Effects: Compiling the Data*, J. Muckerheide, Ed. [Radiation, Science, and Health (RSH), Needham, MA, ed. 2, 1998]; with revisions and preliminary contents for the 3rd ed.; available at http://cnts.wpi.edu/rsh/docs, with access to UN reports on the Chernobyl accident health effects provided by the Center for Nuclear Technology and Society (CNTS) at Worcester Polytechnic Institute. James Muckerheide, Director of CNTS and Massachusetts State Nuclear Engineer, contributed to authoring this statement. RSH, along with the Nuclear Energy Institute, the National Mining Association, and several municipal water districts are currently suing the U.S. Environmental Protection Agency, charging that by basing its rules on the premise that low-dose radiation is harmful at any level, EPA is arbitrarily and capriciously failing to follow the best peer-reviewed science as required by law.
26. The most comprehensive compilation and evaluations of the biology and health effects of low-dose ionizing radiation from 1898 to 1988 are T. D. Luckey, *Hormesis with Ionizing Radiation* (CRC Press, Boca Raton, FL, 1980) and *Radiation Hormesis* (CRC Press, Boca Raton, FL, 1991).
27. The authors are all members of the National Academy of Engineering, but this statement does not constitute an official statement of the academy.

Authors' response to letters

Our Policy Forum paper documents that engineering tests and analyses of radioactivity from molten nuclear fuels, with failed containment, under realistic worst-case assumptions, would produce few, if any, casualties. Commenters have made no attempt to answer the referenced reports that support this conclusion and refute their position.

Commenters have questioned the use of Sandia tests that rocketed an aircraft into a concrete block. These tests were not intended to prove containment invulnerability, but to confirm calculations that impact energy disintegrates large aircraft, with little penetration. Containment damage itself cannot lead to reactor damage. But we examined worse accidents or terrorist events that destroy redundant plant systems inside or outside containment, rupturing containment penetrations, producing ground-level, unfiltered releases. Even in this extreme situation, the radioactivity remains largely bound in the fuel. Condensing water and the physical-chemical properties of fuel retains most radioactivity in water and structures (as at Three Mile Island). Condensing water limits releases, which are not in readily dispersible forms, nor do they remain in respirable forms. This minimizes inhalation hazards (*1*).

Spent fuel pool radioactivity has lost the short-lived and most volatile products and has insufficient energy to disperse in hazardous forms. Even hypothesized zirconium fires would only burn cladding and structures, external to the fuel, adding little to the radioactivity release.

In the worst case scenario, near-plant contamination would warrant evacuation, but not urgently; there would be time for evacuation without significant public health risk. Radioactivity dispersed widely has lower concentrations, in low-hazard forms. Our Policy Forum documented [in notes (*11*–*15*)] that even ejecting Chernobyl radioactivity directly to the environment, burning for 10 days, without evacuation or interdicting contaminated food, caused few, if any, deaths or injuries among the public. (Most evacuated area dose rates remained below those of high natural radiation areas.) The average effective dose (8.2 mSv in 5 million people) is small compared with doses from hundreds of millions of relevant medical exposures showing no adverse effects at much higher doses (*2*, *3*).

Brenner and von Hipple correctly note increased thyroid cancer rates from the Chernobyl accident (about 2000 cases) but do not acknowledge that the references we cited document that these cases are readily treated, producing few if any (none confirmed) fatalities, with expected normal health and life-span, with patients taking thyroid hormones. No other cancer increases have been identified.

Analyses that predict many deaths use invalid release quantities, materials characteristics, dispersion, dose estimates, and dose consequences. For example, the Department of Energy spent fuel cask missile damage study assumes no cleanup and exposes "victims" for 1 year. Even so, the highest dose is tolerable, and if the "victims" walked away, it would be negligible. Similarly, a Nuclear Regulatory Commission report falsely "predicts" radiation deaths 500 miles from spent fuel fires (*4*).

Brenner concedes that the issues of nuclear terrorism relate to a very small individual lifetime risk, but he claims that multiplied by a very large number of people, it presents a significant public health concern using linear no-threshold (LNT) assumptions. Lyman similarly "predicts" thousands of deaths. But there is no scientific basis for such predictions.

NCRP-121 states, "Few experimental studies, and essentially no human data, can be said to prove, or even provide direct support for the concept… It is conceptually possible, but with a vanishingly small probability, that any of these effects could result from the passage of a single charged particle… It is a result of this type of reasoning that a linear non-threshold dose response relationship cannot be excluded." (*5*, p. 45).

NCRP-136, cited by Brenner, states "It is important to note that the rates of cancer in most populations exposed to low-level radiation have not been found to be detectably increased, and that in most cases the rates have appeared to be decreased." (*6*, p. 6) The LNT fails at every level—molecular, cellular, microorganism, animal, and human. Organisms' responses produce beneficial, nonlinear health effects (*7*). Natural radiation varies from below 1 mSv/year to 10 mSv/year, with local areas exceeding 100 mSv/year. Inhabitants of high radiation areas show average or better health and cancer rates (*8*).

Following Roentgen's 1895 x-ray discovery, low-dose radiation (LDR) was found to produce immunological stimulation, curing infections and inflammatory diseases and enhancing physiological conditions (*9*); by the 1920s, it was found to prevent and cure some cancers (*10*). We referenced [notes (*21*–*22*) in our Policy Forum] information that relevant mechanisms are being elucidated: Radiation produces consistent biphasic responses in vivo: on immune cells and molecules; transcription factors; and enzymes, genes, and intercellular communications; etc. LDR responses are consistent with medical and health benefits (*7*). Antibiotics have largely replaced LDR therapies (*11*), but positive LDR effects on biology and health remain. Oak Ridge hospital facilities successfully exposed patients at moderate dose rates for hours and low dose rates for days (*12*). LDR, including radon therapies, is applied worldwide, with physicians' prescriptions, and is covered by medical insurance.

Commenters objected to our asserting that LDR is essential to life. But relevant, confirmed, uncontroverted data show detrimental health effects and biological functions when organisms are "protected" from background radiation (*13*) and in experiments using potassium with potassium-40 removed, e.g., in the Oak Ridge calutrons (*14*). [Signed]

References

1. See, for example, M. Levenson, F. Rahn, "Realistic estimates of the consequences of nuclear accidents" (Electric Power Research Institute, Palo Alto, CA, 1980), and the 48 references therein.
2. E.g., R. S. Yalow, *Mayo Clinic Proc.* **69**, 436 (1994).
3. For example, A. Berrington, S. C. Darby, H. A. Weiss, R. Doll, *Br. J. Radiol.* **74**, 507 (2001).
4. U.S. Nuclear Regulatory Commission (NRC), NUREG/CR-6672 (NRC, Washington, DC, 2000).
5. Principles and Application of Collective Dose in Radiation Protection (Report 121, NCRP, Bethesda, MD, 1995).
6. Evaluation of the Linear-Nonthreshold Dose-Response Model for Ionizing Radiation (Report 136, National Council on Radiation Protection and Measurements, Bethesda, MD, 2001).
7. S. Kojima, H. Ishida, M. Takahashi, K. Yamaoka, *Radiat. Res.* 157, 275 (2002). This and other supporting research is available at http://cnts.wpi.edu:9000/rsh/dd3/_database.jsp. J. Muckerheide, Ed., *Low Level Radiation Health Effects: Compiling the Data* (Radiation, Science, & Health, Inc., Needham, MA, ed. 2, 1998) (searchable by author and by topic, with annual update supplements).)
8. See M. Tubiana, *Radiat Environ. Biophys.* **39**, 3 (2000), and other reports on variations in natural background radiation available at http://cnts.wpi.edu/rsh/docs/background.html.
9. See A. Richards, *Science* **42**, 287 (1915), and other early 20th century low-dose studies on physiological responses described at http://cnts.wpi.edu/rsh/docs/earlystudies.html.
10. S. Russ, H. Chambers, G. M. Scott, *Proc. R. Soc. London* **92**, 125 (1921), and other early LDR therapeutic data available at http://cnts.wpi.edu/rsh/docs/earlyimmune.html.
11. LDR is still sometimes used when antibiotics and antiinflammatories fail, e.g., in some arthritic conditions, and radon therapies are used extensively and successfully by medical direction in Europe, Russia, and elsewhere. LDR had 95% success treating gas gangrene, largely eliminating any amputation, whereas current practice is to amputate and use antibiotics, with 30-70% mortality (*15*).
12. Human radiation studies: Remembering the early years, Oral history of pathologist Clarence Lushbaugh, M.D., conducted 5 October 1994 (Report DOE/EH-0453; DE96-009839, Department of Energy, Washington, DC, 1995) (available at http://tis.eh.doe.gov/ohre/roadmap/histories/0453/0453d.html).
13. H. Planel *et al.*, *Health Phys.* **52**, 571 (1987).
14. T. D. Luckey, *Radiat. Res.* **108**, 215 (1986).
15. J. F. Kelly, D. A. Dowell, *Radiology* **37**, 421 (1941).

16. The authors are all members of the National Academy of Engineering, but this statement does not constitute an official statement of the academy. James Muckerheide, Director of the Center for Nuclear Technology and Society at Worcester Polytechnic Institute, and Massachusetts State Nuclear Engineer, contributed to authoring this response.

von Hippel letter excerpts:

Chapin *et al*. assert that "no airplane, regardless of size, can fly through such a wall" ["the reinforced, steel-lined 1.5-m-thick concrete walls surrounding a nuclear reactor"]. Sandia National Laboratory, whose report Chapin *et al.* cite as evidence of this assertion, has already disputed the relevance of its report to this conclusion (*1*). Also relevant to the overall question of the risks from aircraft crashing into nuclear power plants is the conclusion of a recent Nuclear Regulatory Commission (NRC) report on the potential risks to the spent fuel pools that adjoin U.S. nuclear power reactors: "1 of 2 [large] aircrafts are large enough to penetrate a 5-foot-thick reinforced concrete wall" of a pressurized water reactor spent fuel storage pool, potentially causing it to be "so damaged that it rapidly drains and cannot be refilled from either onsite or offsite resources." (*2*.

The authors cite the UN's review of the consequences of the Chernobyl accident as the basis for their assertion that "no increase in mortality or cancer due to irradiation of the public have been observed." However, that report shows an up to a 25-fold increase in the incidence of childhood thyroid cancers in cities in the most contaminated regions of Belarus and concludes that "there can be no doubt about the relationship between the radioactive materials released from the Chernobyl accident and the unusually high numbers of thyroid cancers observed in the contaminated areas during the past 14 years" (*3*, Table 57, p. 504).

The public fear of the risks from ionizing radiation may be disproportionate. However, this fear is reinforced by a learned distrust of reassurances from the nuclear industry. This article by 19 mostly retired nuclear-industry leaders does nothing to remedy that situation. Contrary to the implied conclusion of their Policy Forum piece, the U.S. government should require strengthened protections against and preparations for emergency response to terrorist attacks on U.S. nuclear power reactors.

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Brenner letter excerpts:

With regard to potential terrorist scenarios involving a nuclear power plant, the authors are correct to point out that the very thick walls of the containment vessel make the nuclear core an unlikely target. They do not, however, address the more pertinent issue of the spent fuel-rod storage pools, which are located adjacent to most commercial reactors (*1*). These spent fuel storage facilities typically contain amounts of radioactivity comparable to that in the reactor core itself. Typically, the fuel rods are stored under water and in nonhardened buildings; often they are on upper floors. The issues relating to the possibility of a plane- or missile-based attack on a spent-fuel pool or the possible theft of a spent fuel rod for use in a "dirty bomb" seem much more relevant than the unlikely scenario of an attack on a nuclear reactor core.

In terms of the radiological risks from the low levels of radiation that might be produced in a radiological terrorism incident, the authors present a one-sided perspective. Indeed, the biological effect of low levels of radiation are hard to quantify because the individual risks are small, but there is little evidence that low doses of radiation are actually beneficial, as the authors suggest….the risk probably goes down proportionately, but is unlikely to actually reach zero.

Chapin *et al*. suggest that no significant increase in mortality or cancer has been observed from the radiation from the 1986 Chernobyl accident…It is only 16 years since the Chernobyl accident, which, based on the A-bomb survivor experience (*4*), is still too early to expect significant radiation-related increases in solid cancers. Most of any potential increase in cancer rates in individuals exposed in 1986 would not be expected to appear until 25 to 50 years after the accident (*4*).

Yes, the cancer risks from very low doses of radiation are probably very small. But nuclear terrorism could result in large numbers of people being subject to these very small risks. That's why it may represent a significant public health concern.

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Lyman letter excerpts:

As president of an organization criticized for exaggerating the danger of a terrorist attack on a nuclear power plant ("Nuclear power plants and their fuel as terrorist targets," D. M. Chapin *et al*., Policy Forum, 20 Sept., p. 1997), I would like to outline the technical basis for our concern. Chapin *et al*. selectively invoke "a few simple scientific and engineering truths" to assert that nuclear plants are essentially invulnerable to attack. In fact, the issues they raise are far from simple and cannot be so neatly resolved.

Today's nuclear plants are vulnerable to common-mode failures, such as station blackout events, that could result in core damage in as little as 2 hours (*1*). Terrorists could exploit these weaknesses to maximize the severity of an attack.

The 1979 Three Mile Island (TMI) accident has little bearing on this scenario because operators were able to restore core cooling before the core became fully molten. With time, a molten core will indeed cause rupture of the reactor vessel, an event that was observed in a dramatic test at Sandia National Laboratories in 2000 (*3*). In contrast to the sequence of events at TMI, if terrorists were able to seize the control room and remote shutdown panels during an attack, they could prevent operators from taking timely corrective action.

The security around nuclear power plants is not commensurate with the consequences of a terrorist attack. The cost of additional protective measures is small compared with the benefits of risk reduction. To ignore the dangerous potential of such events, as Chapin *et al*. would do, can only lead to uninformed and irresponsible policy decisions.

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