

Disposal of Long-Lived Highly Radioactive Wastes in France: An IEER Evaluation

BY ARJUN MAKHIJANI AND
ANNIE MAKHIJANI¹

France is often held up by nuclear power advocates in the United States and elsewhere as a model of energy development, not only because it gets almost 80 percent of its electricity from nuclear power plants, but also because it reprocesses most of its spent nuclear fuel to extract plutonium for reuse as fuel. Yet, France has a considerable volume of long-lived, highly radioactive waste that is slated for disposal in a deep geologic repository, including vitrified high-level waste from reprocessing, unprocessed uranium spent fuel, unprocessed mixed oxide (MOX) spent fuel, and some other long-lived wastes of lower specific activity.² MOX spent fuel arises from the use of reprocessed plutonium as a reactor fuel.

The 1991 French law on nuclear waste mandates, among other things, investigation of deep geologic disposal. In 2003, the Institute for Energy and Environmental Research (IEER) was retained by the Comité local d'information et de suivi (CLIS) of Bure to conduct an evaluation of French geologic repository research program for disposal of high-level radioactive wastes. The CLIS is an official stakeholder group, consisting of local and national elected officials and non-government leaders.³ It is funded by the French government, to provide input and advice to the process of site characterization and research.

The site being investigated by ANDRA (Agence nationale pour la gestion des déchets radioactifs), the French nuclear waste agency, is located near Bure, a village in eastern France, not far from the German and Swiss borders. (See SDA vol. 7 no. 4 for a map.) The area is known as the Meuse-Haute Marne region, after the two major rivers, the Meuse and the Marne, that drain it. The Bure site is the French counterpart



VERONIQUE PAUL GRAPHIX IMAGES/ANDRA

Inside the “experimental niche” of the underground research laboratory of ANDRA, France’s nuclear waste agency. The actual laboratory, now under construction in Bure, France, will be used to assess the feasibility of a deep geological waste repository in the region. A scientific team led by IEER performed an independent evaluation of ANDRA’s repository research program.

A Readiness to Harm The Health Effects of Nuclear Weapons Complexes

BY ARJUN MAKHIJANI¹

On September 29, 1957, at 4:20 p.m., an enormous explosion in a tank containing highly radioactive waste occurred in the Mayak nuclear weapons plant in the southern Ural mountains of the Soviet Union. The fallout plume spread strontium-90 and other dangerous radionuclides over about 15,000 square kilometers, which remain contaminated to this day.

Food stores were closed, and more than 1,000 tons of food dumped. Farming was stopped for more than two decades on about 150,000 acres. More than 10,000 people were relocated, and their empty homes were torn down and buried as radioactive waste. Yet, none of the residents were told why. The Soviet government covered up the accident, only acknowledging the devastation in June 1989 as the Cold War was ending.²

Surprisingly, the West assisted the Soviet government in its cover-up. In 1976, Soviet dissident biologist Zhores Medvedev published an article in the *New Scientist*, a British science magazine, about the

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of the U.S. Yucca Mountain site. It is the only site currently being investigated in France, since research into granite sites was suspended in the year 2000 due to intense local opposition. Interestingly, U.S. research into granite sites was suspended in 1986, apparently due to political opposition,⁴ after which Yucca Mountain was named as the only site.

The purpose of the IEER project was to evaluate ANDRA's research program for characterizing the site. Since the goal is to contain wastes for periods extending out to hundreds of thousands of years (to the time of the highest dose), the research program into the engineered barriers, the geological setting, and the combination of the two must be robust and thorough enough to provide reliable estimates. IEER was not charged with determining whether the site was suitable for high-level waste disposal. The overriding goal of the project was to determine the adequacy of the research program for making a reliable statement about the performance of the proposed system when the research was complete. If ANDRA's research program was found to be deficient in some respects, IEER was further charged with making recommendations to improve the program so that a reliable statement could be made about the feasibility of using the site for geologic isolation of high-level waste.

We are summarizing the results of the evaluation in this article since the principles of evaluation of a geologic isolation system are the same everywhere. Interested members of the public in other countries as well as agencies charged with characterizing sites might find the process of IEER's evaluation as well as its results useful in their own situations.

The Isolation System

The main way that nuclear waste disposal in a deep geologic repository is likely to affect people far into the future is via contamination of water used for drinking, farming, and other purposes that could lead to the ingestion of radionuclides. The threat is from very long-lived radionuclides, with half-lives in the thousands to millions of years.

No repository program has ever claimed that perfect isolation of the waste from the human environment (groundwater and surface water first of all) is possible. The goal therefore is to limit the peak radiation dose to levels considered socially acceptable today as expressed in present-day radiation protection standards. Typically, the peak radiation dose is expected to occur hundreds of thousands of years into the future.

The French guidelines for research require that the peak dose be limited to 25 millirem per year. The U.S. Environmental Protection Agency standard for Yucca Mountain limits dose to 15 millirem per year for the first 10,000 years, which is far earlier than the expected peak dose time. The time limitation for a dose limit well before peak dose is expected to occur was invalidated by a federal court, since it was explicitly in contrast to a recommendation of a National Research Council study that advocated the approach of peak dose limitation.⁵

A geologic isolation system consists of:

- ▶ A deep underground excavation dug into a suitable geologic setting ("host rock");

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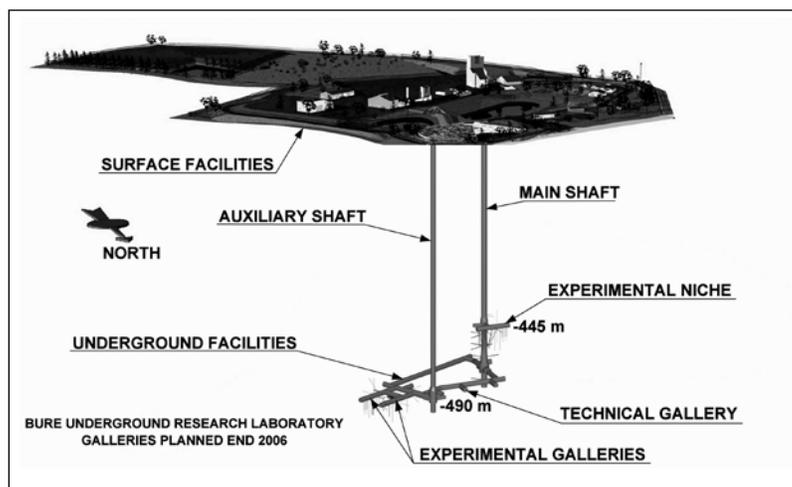
- ▶ Waste packages, which consist of the materials in which the radioactive waste is encapsulated and packaged;
- ▶ Other engineered barriers around the waste packages to retard the movement of radionuclides once they leak from the packages;
- ▶ The materials used to backfill and seal the excavated zone once the waste has been emplaced in it; and
- ▶ The surrounding (“far-field”) geologic system that retards the movement of radionuclides once they have been released from the waste packages and other barriers in the “near-field.”

An assessment of the performance of a geologic isolation system therefore consists of understanding the properties of each of these components and most importantly how they would function together over long periods of time to meet the goal of limiting radiation doses hundreds of thousands of years into the future. Research into the characterization of a site and its associated isolation system must ensure that the necessary data are gathered about the site, that experiments are done on the waste packages and other materials, such as seals, both in laboratories and in-situ, and that a suitable model for estimating performance that is validated by real-world data and experience is created.

Evaluating Repository Research

A crucial problem for research is that the model must estimate performance not of the natural setting but of a geologic system that has been considerably disturbed by a large excavation, which may induce fractures not originally present, by the introduction of (thermally) hot wastes, and by the addition of various backfill materials and seals. Hence, the system being modeled is no longer the original geologic system, but a profoundly perturbed system. (The perturbed zone is called the “Excavation Damaged Zone” or EDZ, for short). Further, given the long periods of time involved, *climate change* as well as the possible impacts of deliberate or inadvertent *human intrusion* after institutional memory of the disposal is lost must also be taken into account. Estimation of performance of a system under these conditions with some confidence poses challenges that are, in many ways, unparalleled in scientific research.

In the specific case of the Bure site, the host rock is argillite, a hard rock consisting of clayey minerals, carbonates (mainly calcites), and quartz. The in-tact rock is not very porous, leading to expectation of diffusive flow in the absence of fractures and in the absence of



Schematic of the underground research laboratory at Bure, also showing the experimental niche. Construction of the underground lab is scheduled to be completed in March 2006. Many experiments are already taking place in the lab.

disturbance by mining. Such flow would be very slow and the expected travel time of radionuclides released from waste packages could be very long.

However, the IEER team’s evaluation of (i) the documents, (ii) argillite rock properties under conditions of heat and humidity, and (iii) the research done to model the site performance indicated that the actual conditions prevailing in an actual repository could be very different from diffusive flow. Failure of certain components, notably repository seals, could result in rapid (in geological terms) transport of radionuclides to the human environment.

ANDRA’s own estimate of dose under conditions of seal failure was higher than the allowable limit of 0.25 millisieverts (25 millirem) per year. In this context, IEER concluded that ANDRA’s scenario for human exposure was not necessarily conservative, in that doses to an autarchic farmer family (also called “subsistence farmer family”) using groundwater in certain locations could be even higher than the dose at the surface water outcrop estimated by ANDRA. This finding and other aspects of IEER’s evaluation of ANDRA’s research program resulted in a number of overall recommendations as well as specific detailed recommendations for the research program.

IEER’s overall conclusion was that any statement regarding the feasibility of constructing a geologic isolation system was premature as of early 2005, and that research over a period of many years would be required before a scientifically reliable statement could be made. At the time this issue of SDA went to print, ANDRA was preparing its recommendation regarding further work at the site and the French Parliament is due to consider the status of the site and further research in 2006.

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IEER did not endorse further research or stopping further research, but made its recommendations about the research program that should be pursued in case the French Parliament decided to authorize continued work at the site.

The areas that the IEER team⁶ evaluated in terms of their implications for research on geologic isolation were:

- ▶ Climate change, human intrusion, the choice of scenarios regarding who would be exposed in the future, and methods for making performance estimates more robust in the face of large uncertainties.
- ▶ Rock mechanics, including tests to determine the nature of the damage caused by the deep underground excavation and the research program needed to test the materials and methods by which the repository would be sealed after waste emplacement.
- ▶ Thermal aspects, including modeling, laboratory and in-situ research needed to test for the effects of

putting high-temperature waste in emplacement tunnels, effects which include the potential for creation of secondary fissures and local boiling of water due to heat in the waste.

- ▶ Source term, waste matrix, and near-field geochemistry, covering the various kinds of waste proposed for disposal.
- ▶ Hydrogeological aspects, including the nature of expected flow of water in the undisturbed and perturbed host rock, and the determination of the size and number of fractures in the host rock.
- ▶ Minerological research required to support characterization of the geologic past of the site.
- ▶ Seismic issues, including the criteria and the nature of research needed to determine design basis earthquakes.

IEER presented its final report to the CLIS in January 2005. Note that all statements below about the status of ANDRA's work are as of January 2005.

OVERALL MAJOR FINDINGS

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IEER found that ANDRA's research program is fine in some areas, satisfactory in others, and deficient or lacking in some cases.

1. In several detailed areas such as source term characterization, rock mechanics, and general climate change research (the BIOCLIM program), ANDRA research program as carried out or intended is state-of-the-art.
2. There are institutional structures for scientific oversight of ANDRA's work. This is an important safeguard. The provision for the CLIS, a body constituted under the French nuclear waste law, to commission its own independent review provides one layer of independent oversight. Indeed, because the IEER review was implemented outside the context of a body constituted by ANDRA or the French government, it can be considered a level of independent oversight that is unusual in repository programs.
3. ANDRA's research program is not transparent enough to allow independent judgments to be made on many aspects of the program in a timely fashion.
4. Although ANDRA's screening calculations done in Dossier 2001 Argile* for using a low diffusion coefficient indicate compliance with the dose guideline, the scenario "altéré" does not. Specifically, the dose limit may not be met for the case when the seals fail, indicating an excessive dependence on a single element of the isolation system. This indicates that ANDRA needs to pay more attention to the source term element of its program as an element of its conceptual model. Overall, the performance assessment, even at the initial stages of methodological screening estimation, should be robust in the sense that it depends on multiple barriers and multiple lines of argument.

5. ANDRA still has a great deal of essential research work to complete in the repository host rock in a number of different areas. ANDRA has not even elaborated a detailed program in some areas, such as in situ waste form research.
6. A scientifically sound overall performance assessment to determine the feasibility of constructing a repository for geologic isolation at the Bure site is not possible based on the present state of research. There are many critical elements of the research program that are incomplete in essential ways or have not even begun. For instance, before any such statement can be considered scientifically sound, ANDRA would have to address elements such as:
 - a. Research on seals within the host rock after in situ characterization of that rock
 - b. Characterization of small fracture networks and bedding planes that could be significant for creating a realistic evaluation of the EDZ
 - c. Gas generation and its relationship to fractures.

Further, rock mechanics and thermal pulse research has many components that are deficient or missing. This is a crucial problem in ANDRA's research program plan, given the central role that the EDZ and repair of the EDZ is expected to play in performance assessment. Reducing uncertainties in the performance would require far more research in these areas, and in some respects, the specifics of the research would have to be different from the ones that ANDRA now plans (for instance, in the area of seals). Much work on the coupling of various detailed elements remains to be done, for instance in the coupling of EDZ-induced fractures to natural fractures and of the source term to the near-field geochemistry.

* Dossier 2001 Argile, sur l'avancement des études & recherches relatives à la faisabilité d'un stockage de déchets à haute activité et à vie longue en formation géologique profonde. Partie A et Partie B. Châtenay-Malabry: Agence nationale pour la gestion des déchets radioactifs, Décembre 2001.

OVERALL MAJOR RECOMMENDATIONS

1. There should be continuing independent scientific oversight of ANDRA's program, should the French Parliament decide to continue research beyond 2006.
2. ANDRA should post all documents relating to its research program (performance assessment, raw data from the core library, seismic data that it is using to characterize the site, borehole data) on its website as soon as the data are validated for internal use. Models should also be publicly accessible, with all the assumptions about parameters and uncertainties, so that independent review is easier and more efficient. Detailed and current results of planning, scheduling, research, modeling, and performance assessment should also be easily available to the public.
3. Given the uncertainties in regard to the development of the EDZ and in its performance, a conceptual model that assumes a reduction of the source term, for instance, by redesign of the waste canisters (and/or by other means), should be developed and a research program based on it should be created. A canister redesign program may involve investigation of more durable waste packages, different repository thermal characteristics, and different near-field geochemistry. ANDRA does not have such a program at present.
4. ANDRA should implement a detailed program of underground research in the underground laboratory planned in the host rock at the repository horizon. It should elaborate a research program in areas where none now exists and spell it out. Several aspects of such an underground research program, such as extended heater tests and in situ testing of waste canister and host rock interactions will take considerable time.
5. ANDRA should develop a strategy designed to address the uncertainties in each specific field as well as in its overall research program and its performance assessment.

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One reason for high dose estimates in one of the scenarios related to ANDRA's assumption that relatively large amounts of radionuclides would be released from the waste packages. At this point, a decision could be made to strengthen the research into the waste packages, including adoption of new concepts for waste packages that would be far more durable, along the lines of design chosen by the Swedish geologic isolation program. The latter has a goal for the waste containers to last for one million years under specified hydrogeologic conditions. In this case, the waste containers themselves could contain the waste and keep radiation doses low far into the future. The host rock serves as a back-up to the waste package system, providing some insurance against non-compliance in case the estimation process is incorrect or if future conditions are different than those assumed in the models.

The redundancy approach, in which the geologic system serves as a back-up to the engineered containment system, would also serve to mitigate the effects of climate change, in case they turn out to be more severe than assumed. ANDRA had endorsed the redundancy approach discussed here in an early phase of its work, but abandoned it in a later phase. Another example of how the initial framework or initial assumptions might foreclose necessary research options was in the area of water flow. ANDRA's assumption of a diffusively dominated regime (very slow transport of radionuclides) could preclude any discussion of the potential significance of advective flow in a fracture network representation of the host rock (much faster radionuclide transport).

The IEER team gave considerable thought to the structure of scientific decision-making in the program. What is the process, for instance, by which a program might conclude that a site is unsuitable or an approach

to designing waste packages must be revisited? At the early stages in a site characterization program, it is unlikely that adequate data will be available to resolve which of various conceptual models of the site is most appropriate (e.g., is flow in the host formation advectively or diffusively dominated?). Where alternative models cannot be excluded, and especially if the alternatives have very different implications for performance, it is important that those alternatives should be carried through an iterative procedure and in particular that site characterization activities should be prioritized to distinguishing which of the alternatives is applicable.

At the Bure site, many essential aspects of site characterization ranging from heater tests to EDZ characterization in the host rock at the repository horizon had not yet begun as of January 2005. As a result, the ANDRA program of site specific research was estimated by IEER to be in a preliminary phase that would require considerable iterative work before a sound scientific determination of site suitability or even feasibility can be made. The IEER report was oriented towards specifying the types of research that will need to be done in that iterative process.

The iterative process of characterization and assessment should continue through at least to the stage when permission is sought to emplace waste in a constructed facility. This is because the process of construction may itself reveal properties of the host rock or the EDZ that has previously been unrevealed, unless of course some feature of the site that would disqualify it in all reasonable conceptual designs is identified at some prior stage.

In any site investigation program, decisions are made at successive phases as to whether to proceed at the site with either the original or modified design or to abandon the site and begin afresh. As the proposer continues

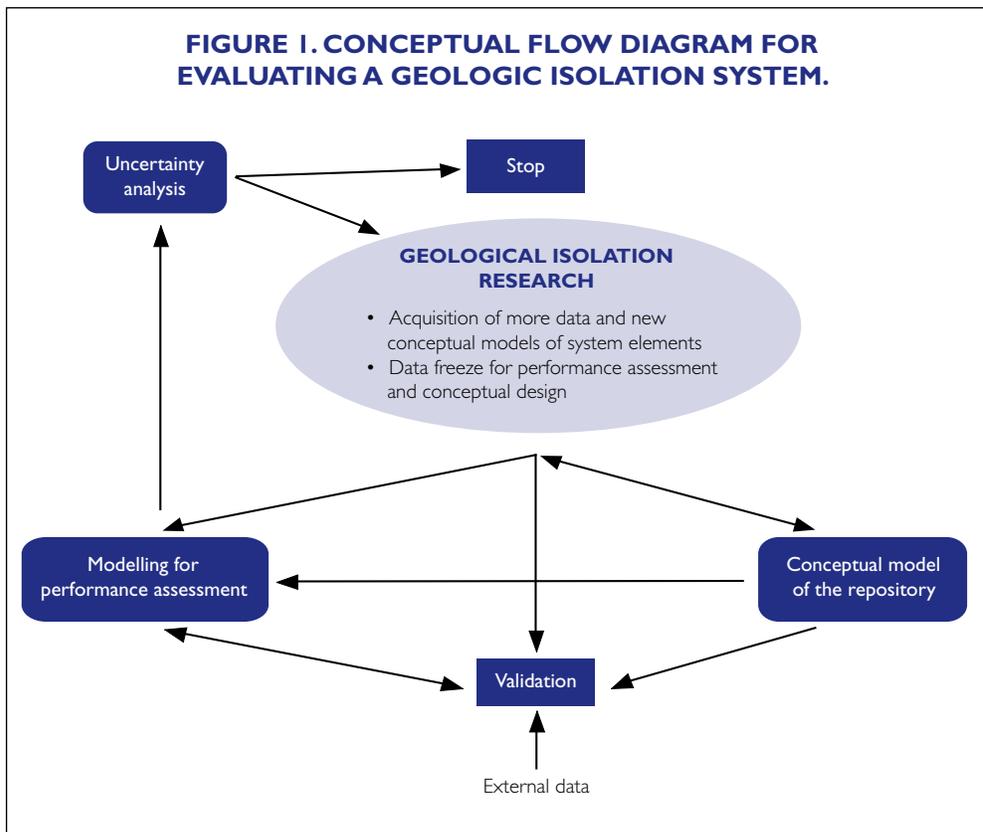
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further into the site investigation process, the resource investment in the site increases markedly. Large investments tend to become a factor in decisions for investing more, since the reluctance to abandon a site increases in relation to the material resources and professional judgments that have been invoked in investigating site suitability. This tendency is likely to be more marked if no other site is being characterized for comparison. A tendency to freeze a conceptual model and conceptual design in the face of indicated problems in a performance assessment could have a markedly deleterious impact in defining the subsequent phases of site

characterization in any repository program. Periodic scientific review that has within its mandate the ability to make a scientific judgment about the technical merits of continuing investigation of a site could reduce the risks of failure and also reduce the opposite risk that an inappropriate site would be chosen for disposal because of the investment of resources that has been made in it.

The IEER team prepared a flow diagram (Figure 1) of the various stages in repository research, emphasizing that it should be iterative. Several rounds of research should be expected in a complex project, with an overall assessment being prepared at for each round, based on a consistent set of data taken from a well-identified phase of the research (“data freeze”). The diagram also shows the point in each iterative step at which research could be stopped if the site was found unsuitable.



1. The article is based on IEER’s report *Examen critique du programme de recherche de l’ANDRA pour déterminer l’aptitude du site de Bure au confinement géologique des déchets à haute activité et à vie longue*, January 11, 2005. Specifically considerable portions of it are drawn from the preface and main summary and recommendations section. The full report in French is at www.ieer.org/reports/bure/1204index.html.
2. France has a different waste classification system than the United States. A large volume of wastes deriving from commercial nuclear power is slated for deep geologic disposal in France. In the United States, waste classification is not as stringent and a far broader category of waste can be disposed of in shallow land burial.
3. The non governmental stakeholders include people from commerce, industry, agriculture, trade unions, and environmental as-

sociations. ANDRA is also represented. The president of the CLIS is the préfet of the Meuse département. (A préfet is the executive branch head of the government of a département in France. A French département is a unit of government somewhat in between a county and state government in the U.S. Préfets are appointed by the Interior Minister.) The mission of the CLIS is to inform the public and its members on the activities taking place at the laboratory and to report on the research conducted and the results obtained. The web site of the CLIS is www.clis-bure.com. ANDRA’s web site is www.andra.fr.

4. The U.S. search for an Eastern, granite site was suspended two weeks after a White House meeting that opponents had with an aide to then-Vice-President Bush, who was at the start of his presidential campaign and presumably had voters in New Hampshire high on his list of priorities for his path to the nomination. The Department of Energy denied that political pressure had a role in the sudden cancellation of an Eastern repository site. Eliot Marshall, “Nuclear Waste Program Faces Political Burial,” *Science*, Vol. 233, 12 August 1986, pp. 835-836.
5. In August 2005 the U.S. EPA proposed a dose limit of 350 millirem per year beyond 10,000 years. This dose limit greatly exceeds the radiation protection limit of 100 millirem per year for the public from all sources. IEER’s press release on the proposed standard is at www.ieer.org/latest/yuccaepapr0805.html
6. The IEER team consisted of: Arjun Makhijani, Ph.D., Project Director, Professor Jaak Daemen, Ph.D. (rock mechanics), Professor George Danko, Ph.D. (thermal effects), Professor Rod Ewing, Ph.D. (waste packages and near-field characterization), Detlef Appel, Ph.D. (hydrogeology), Yuri Dublyansky, Ph.D. (mineralogy), Professor Gerhard Jentzsch, Ph.D. (seismology), and Horst Letz, Ph.D. (seismology). Annie Makhijani was the Project Coordinator and provided radiochemistry and other research support for the project. She was principal translator of the report (from English to French). Translation review was done by Annike and Jean-Luc Thierry.

accident. Instead of denouncing the callous cover-up of the Soviets, however, the chairman of the United Kingdom Atomic Energy Authority, Sir John Hill, and other British experts dismissed the story as “rubbish” and “scientific fiction.”³

The CIA also helped the cover-up. According to a 1959 CIA document, the agency knew that an accident had occurred that resulted in food stores being closed. The resulting food shortages created lines that were “reminiscent of the worst shortages during World War II.” They also knew that high officials had been “wearing small radiation counters” while the public had no protection.

Yet, the CIA did not publicize the accident, even though it occurred during the height of the Cold War and at a time that both sides took every opportunity for propaganda advantage. The U.S. government did not condemn the Soviets for the secrecy and destruction of homes without informed consent. Was it because officials in the West feared that the public might raise questions about the possibility of a similar explosion in France, the United Kingdom, or the United States?

Indeed, since the dawn of the atomic age, millions of people in other parts of the world have been affected by bomb production and testing. American, British, French, and Soviet soldiers were ordered to participate in atomic war exercises. Children in the United States have seen their risk of cancers rise from drinking milk contaminated with fallout from atmospheric nuclear tests. Conditions for uranium miners in India are lamentable, and who knows what damage has been caused by nuclear weapons in China, Israel, North Korea, and Pakistan?

Few nuclear-weapon states have provided much information about the harm caused by their nuclear weapons establishments. For example, information about the intense fallout from French nuclear tests in Polynesia is coming to light only this year. The typical reaction of these establishments has been to deny damage, cover up problems, and simply assert national security requirements to be taken on trust, promulgated by fiat, or both.

The problem is by no means at an end, even leaving aside plans in the United States and other nuclear-weapon states to make more nuclear weapons. For example, poor radioactive waste disposal practices throughout the Cold War threaten some of the most important water resources in the United States. These include putting high-level liquid radioactive wastes from reprocessing into tanks that have leaked a million gallons into the ground near the Columbia River and dumping plutonium-laden wastes into unlined pits above Snake River

Plain Aquifer, southeastern Idaho’s sole source aquifer.

Avoiding and Permitting Fallout

Efforts to keep damaging information about nuclear weapons hidden from the public began early. The very first nuclear test on July 16, 1945, led to severe fallout and hot spots of radioactive contamination 32 kilometers from the site. The affected people were not informed even after the bombings of Hiroshima and Nagasaki, nor were they evacuated. A fallout cloud hung over much of southeastern New Mexico in the days following the test, but even 60 years later, there has been no official investigation of the health effects. Col. Stafford Warren, a medical doctor in the Army who was the chief of radiation safety for the test, recommended that future tests should not be done within 240 kilometers of human habitation. The recommendation was ignored, with tragic effects.

In 1950, the United States had considered setting up a weapons testing site in North Carolina at a coastal location that would have allowed most fallout to land in the ocean. Instead, the United States chose to set up a continental nuclear weapon test site in Nevada with the knowledge that a western location would blow fallout over most of the country. The federal government risked the health of its citizens in large part to make life more convenient for weapons scientists at New Mexico’s Los Alamos National Laboratory and to avoid the political difficulties of acquiring coastal private property through eminent domain.

When the site became operational, tests were conducted when the wind blew away from Las Vegas and Los Angeles. The result was ubiquitous fallout over most of the rest of the continental United States. The government reassured a skeptical public that it would provide ample warning of any dangers. Yet, it did not share the results of its 1950 research, which had shown that milk would be contaminated by fallout. Cows would eat grass on which iodine-131, an intensely radioactive fission product, had been deposited. The iodine-131 would concentrate in the milk. Growing children who drank the milk would get large doses of radiation to their thyroids, creating a risk of cancer and other thyroid diseases.⁴

Rather than address these realistic concerns, the military dismissed them. The opinion in military circles was that the public in the United States had a “hysterical and alarmist complex” about radiation that needed to be corrected to enable the United States to proceed with its testing activities. In internal documents, Department of Defense officials said the process of correction “would be a matter of reeducation over a long period of time.”

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Poor radioactive waste disposal practices throughout the Cold War threaten some of the most important water resources in the United States.

The objective was in direct contradiction to the advice given by Warren in July 1945: the “reeducation” was supposed to go on until “the public will accept the possibility of an atomic explosion within a hundred or so miles of their homes.” At that point, the establishment of a test site in the continental United States would no longer be a problem.⁵ People would then “feel at home with neutrons trotting around” and presumably become comfortable with nuclear tests nearby. It was after all, as the safety preparations were being done in December 1950, “the most important angle to get across.”⁶

The cover-up was a spectacular success, although the fallout was intense. After two nuclear tests (Shot Harry and Shot Nancy), 1,420 lambing ewes and 2,970 lambs in Nevada, Utah, and Arizona died of severe radiation injuries.⁷ In the lawsuit that followed,⁸ the government’s representatives provided what the judge nearly 30 years later concluded was “false and deceptive” representations, withheld information, and provided other information “in such a manner as to be deceitful” and, in sum, “manipulated” the court by “convoluted actions.”

In 1997, when the National Cancer Institute acting under congressional directive assessed milk contamination, it found that fallout from the tests would eventually cause between 11,000 and 212,000 thyroid cancers. The cancer risk fell primarily to those who had been children, with girls being at twice the risk of boys. A large portion of the milk supply of the continental United States had been poisoned with iodine-131, with no action being taken to protect it. Those who believed that they were leading healthy farm lives by drinking fresh milk got the highest doses.

An atomic Kodak moment was playing out in a parallel political and economic universe in the very same period. The photographic film company found its film was getting fogged because the corn husks it was using to make packaging had become contaminated with fallout. Kodak threatened to sue. The government quickly provided data on anticipated patterns of fallout to Kodak and the rest of the photographic film industry so they could protect their products.⁹ Was it because Kodak knew too much? Was it because film was more precious than milk?

As a way to avoid publicity and lessen the political consequences, the United States and other countries also often tested weapons in areas home to foreign subjects or minority populations. The United States located its test sites in the Marshall Islands and on land claimed by the Western Shoshones in Nevada. The Soviets located

their major test site in the land of the Kazakhs, near Semipalatinsk. The British conducted their tests on native lands in Australia and on Christmas Island in the Pacific. The Chinese located theirs on minority lands in western China. The French test sites were in the colonies in Algeria and Polynesia.

According to France’s conservative newspaper, *Le Figaro*, although fallout was anticipated and the genetic risk for the native population was considered greater than that for the general French public, “a preventive relocation of the people of the Gambiers [archipelago] was ruled out for political and psychological reasons.” Further, the evacuation of old people and children “who comprised a large fraction” of the population was considered “the most difficult,” so they were left in the path of the fallout.¹⁰

To be sure, the cover-ups were not entirely successful. Public protests in the 1950s and concerns about contamination of mother’s milk and baby’s teeth with strontium-90 were central to the Partial Test Ban Treaty, which the Soviet Union, United Kingdom, and the United States signed in 1963.

In a real, practical sense, the first arms

control treaty was an environmental one. Yet, China and France did not sign. The French did not stop atmospheric testing until 1974; the Chinese did so in 1980.

Moving tests underground did not end the problem, even though it did greatly mitigate the problem of radiation doses from short-lived radionuclides such as iodine-131. Large amounts of plutonium, iodine-129, cesium-135, and other longlived radionuclides remain underground at the test sites. They possess the potential for migration into water bodies in the long term. No cleanup method has yet been devised.

The frequent claims of safety and lack of deleterious health effects of nuclear tests are perhaps most clearly contradicted by military plans to use fallout as a terror weapon. The fallout from the first ever underwater test at Bikini in July 1946 was so ubiquitous and so insidious in its effects that the Joint Chiefs of Staff evaluation of the military aspects of the tests concluded that fallout may constitute a weapon of war. Of the long-term effects of the radioactivity, the 1947 evaluation stated that the contaminated areas:

irregular in size and shape, as wind and topography might form them, would have no visible boundaries. No survivor could be certain he was not among the doomed, and so added to every terror of the moment, thousands would be stricken with the fear of death and the uncertainty of the time of its arrival.¹¹

Public protests in the 1950s and concerns about contamination of mother's milk and baby's teeth with strontium-90 were central to the Partial Test Ban Treaty.

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Overall, estimates of cancer fatalities due to the global radiation doses from the atmospheric nuclear testing program of the five nuclear-weapon states that are parties to the nuclear Nonproliferation Treaty and that are also the only permanent members of the UN Security Council, which gives them veto power over global security decisions, run into hundreds of thousands between the start of testing in 1945 and the end of the 21st century.

There are considerable uncertainties in the risk of cancer death from exposure to low levels of radiation, but all careful scientific evaluations, including the most recent ones, have concluded that every increment of exposure to radiation produces an incremental risk of cancer. The range of estimates of cancer deaths as a result of testing fallout, using the official U.S. Environmental Protection Agency cancer risk coefficients, is between about 200,000 to more than half a million.¹² The number of cancer cases, including thyroid cancer, which has a low fatality rate (about 5 percent), would be considerably greater. No sound global estimate of cancer incidence is possible because no study comparable to the 1997 U.S. National Cancer Institute study has been carried out on a global scale. Indeed, even the thyroid cancer risk in Canada due to testing in Nevada has not been evaluated, although it is apparent from the National Cancer Institute study as well as the similar dietary patterns between Canada and the United States that people in several parts of Canada would have been significantly affected.

Further Dangers

That was not the only damage caused by nuclear weapons establishments. There are many other examples. Some from the United States include:

- ▶ From the 1940s into the 1970s, more than 23,000 people were subjected to radiation experiments, many

without their informed consent. They were administered by the Atomic Energy Commission (AEC), the Department of Energy, the Department of Defense, NASA, and the Department of Veterans Affairs for purposes including determining the biology of radiation intakes, developing radiation weapons, and determining radiation's effects on military personnel performance on the battlefield. One experiment involved feeding oatmeal with radioactive trace elements to more than 100 boys at a Massachusetts school. Others included testicular irradiation experiments on prisoners to determine what doses induce sterility and experiments on pregnant women. In 1993, after learning of a particularly troubling series of experiments involving the injection of plutonium into unknowing subjects, then-Secretary of Energy Hazel O'Leary remarked, "The only thing I could think of was Nazi Germany."¹³

- ▶ A quarter of a million armed forces personnel participated in nuclear weapons tests in the United States alone. They were marched into ground zero, they scrubbed plutonium from the decks of contaminated ships, and they flew planes through the mushroom clouds to sample them and to test how pilots might function in a nuclear war environment. It took until the end of the 1980s for the U.S. government to recognize the harm and begin a compensation program.
- ▶ During the Cold War, more than half a million weapons complex workers in the United States were exposed to radioactivity and chemicals in the course of their work. In the early decades, many were exposed without proper information or training, with authorities sometimes hiding the risks so that hazard duty would not have to be paid, among other reasons.¹⁴ The atomic weapons establishment did not actually calculate radiation doses to workers received

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SDA READER COMMENTS

"Thank you for the latest issue of *Science for Democratic Action* [Vol. 12, No. 3, June 2004]. It is very useful. We will be sending it to our Minister of Defense and Minister for Disarmament and Arms Control as part of our efforts to get New Zealand more active internationally in highlighting the risks of DU. Also, thanks . . . for a very amusing Dr Egghead section."

— Alyn Ware, International Association of Lawyers Against Nuclear Arms, Aotearoa-New Zealand

"I saw the article earlier today and it looks great. ["Cash Crop on the Wind Farm," *Science for Democratic Action* vol. 12 no. 4, October 2004.] We're always looking for good materials to take to events and send to people seeking good wind energy information."

— Sarah Johnson, Windustry, Minneapolis, USA

"We will use [*Science for Democratic Action*] to try to educate our immediate population, as we are in the heart of uranium mining, and a very high grade at that. So, we would love to receive anything that will help us with our educating. Thanks for your support."

— Linda Murphy, Inter-Church Uranium Committee Educational Co-operative, Saskatoon, Canada

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due to inhalation and ingestion, even though data were being collected and analyzed in the form of urine samples. Congress passed a compensation program for nuclear weapons workers in October 2000.

- ▶ During the 1950s, it was well known that exposure to radon and its decay products in unventilated mines was a health hazard and increased the risk of lung cancer, but the AEC, the Department of Energy's predecessor, did not require that the mines be ventilated, choosing instead to emphasize production.¹⁵

Even today, people who live along the Savannah River and use its water downstream of the Savannah River Site, a nuclear weapons materials plant, are drinking water contaminated with tritium, which is radioactive hydrogen. This contamination level is at about 5 percent of the present-day drinking water standard. However, these standards are set for a grown male, called "standard man," and they do not consider the effects of radioactive water on developing fetuses. They do not consider miscarriages and other noncancer effects. No removal is planned of the source of the tritium contamination, which lies in the unlined pits and trenches where radioactive waste was dumped in cardboard and wooden boxes. Unless the long-lived and especially risky wastes, such as liquid highlevel wastes in tanks, are recovered and stabilized and isolated from the human environment, the risks will persist.

Hundreds of thousands of people have been similarly affected in other nuclear-weapon states. The main difference between them and the United States has been that the United States has been more open and hence has, under public pressure, acknowledged a wider scope and depth of harm, although that task is still far from done. India has strict secrecy laws surrounding its nuclear

weapons activities, much like France and the United Kingdom. The least is known about China, Pakistan, Israel, and North Korea.

It is a remarkable fact of nuclear weapons history and radiation risk that every nuclear weapon state has first of all harmed its own people in the name of national security. For the most part, they have done so without informed consent.

Nor is the damage confined to nuclear-weapon possessors. Uranium for nuclear weapons was mined in many non-nuclear-weapon states. France got its uranium in large measure from its colonies, where working conditions in mines were—and continue to be—scandalous. The United Kingdom got its uranium partly from Namibia. The Soviets got much of their uranium from vast operations in Eastern Europe, notably in East Germany and the former Czechoslovakia. Health and environmental problems have typically been serious, so far as independent evidence indicates, but have usually been officially denied.¹⁶

The statement of then-Deputy Secretary of Energy W. Henson Moore at Rocky Flats in June of 1989 at the end of the Cold War was a kind of mea culpa about this. Nuclear weapons production, he told *The Washington Post*, has been "a secret operation not subject to laws... no one was to know what was going on." He added that "the way the government and its contractors operated these plants was: This is our business, it's national security, everybody else butt out." The "everybody else" he was referring to was not a foreign power, but the people of the United States. Other countries have not had a comparable confession, although their nuclear establishments have been as high-handed and their people have likely suffered similar kinds of consequences.

In a reverse of the doctors' dictum to "first do no harm," nuclear weapons establishments have first

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Thank you very much.

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We are grateful to our foundation funders, too, listed on page 2.

HARM

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harmed the people of their own countries, as well others around the world. They have shown a readiness to harm. Given the nature of the problem and its main sources, the permanent members of the UN General Assembly and the UN Security Council should call for a global truth commission to investigate the harm that nuclear weapons production and testing have done and continue to do to people all over the world.



1. A slightly different version of this article first appeared in the July/August 2005 issue of *Arms Control Today*, a publication of the Arms Control Association (ACA), www.armscontrol.org.
2. International Physicians for the Prevention of Nuclear War (IPPNW) and Institute for Energy and Environmental Research (IEER), *Plutonium: Deadly Gold of the Nuclear Age* (Cambridge: IPPNW Press, 1992), chap. 4.
3. Ibid.
4. Pat Ortmeier and Arjun Makhijani, "Worse Than We Knew," *Bulletin of the Atomic Scientists*, November/December 1997.
5. IPPNW and IEER, *Radioactive Heaven and Earth: The Health and Environmental Risks of Nuclear Weapons Testing in, on, and Above the Earth* (New York: Apex Press, 1991), chap. 4.
6. Barton C. Hacker, *Elements of Controversy: The Atomic Energy Commission and Radiation Safety in Nuclear Weapons Testing 1947–1974* (Berkeley, CA: University of California Press, 1994), p. 43.
7. Philip L. Fradkin, *Fallout: An American Nuclear Tragedy* (Tucson, Arizona: University of Arizona Press, 1989), p. 148.
8. IPPNW and IEER, *Radioactive Heaven and Earth*, p. 59.
9. Ortmeier and Makhijani.
10. "Polynésie: Le Mensonge Nucléaire," *Le Figaro*, May 19, 2005.
11. IPPNW and IEER, *Plutonium*, p. 143 (U.S. Joint Chiefs of Staff evaluation of the 1946 tests at Bikini Atoll).
12. The total committed dose equivalent to the global population through the year 2100 is estimated at 544 million person-rem. IPPNW and IEER, *Radioactive Heaven and Earth*, p. 37. The doses are much larger if estimated for longer periods, mainly due to the very long-lived radionuclides, of which the most important is carbon-14, which gets into food and becomes incorporated into our bodies and all ecosystems. Carbon-14 has a half-life of 5,730 years, meaning that significant amounts will remain for tens of thousands of years in the atmosphere in the form of radioactive carbon dioxide, to be taken up by plants. Carbon-14 also occurs naturally, created mainly by the interaction of cosmic rays with nitrogen in the atmosphere.
13. Arjun Makhijani and Ellen Kennedy, "Human Radiation Experiments in the United States," *Science for Democratic Action*, vol. 3, no. 1 (Winter 1994).
14. Arjun Makhijani, Bernd Franke, and Hisham Zerriffi, "Preliminary Partial Dose Estimates From the Processing of Nuclear Materials at Three Plants During the 1940s and 1950s," 2000, available at <http://www.usatoday.com/news/poison/uranium.htm>.
15. Arjun Makhijani and Lisa Ledwidge, "Back to the Bad Old Days," *Science for Democratic Action*, vol. 11, no. 4 (September 2003).
16. Arjun Makhijani, Howard Hu, and Katherine Yih eds., *Nuclear Wastelands: A Global Guide to Nuclear Weapons Production and Its Health and Environmental Effects* (Cambridge, MA: MIT Press, 1995 and 2000), chap. 5.

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I Dreamt a Bomb

BY OMAR MCCRAY

As the bomb blasted, a cloud formed a monstrous cloud.
towered over the largest tower.

a cloud never seen before,
with the blink of an eye i seen nothing but red,
bodies on the floor.

i was lost, afraid, horrified,
glooming scenes of death blurred my vision.

where's my mom? where's my dad? where's the arms
i just had?

with the blink of an eye, the clouds began to spread,
force feeding all those who bled,
shedding hopeless tears of a scenery not common to me.

the blast, the suffocating clouds, bodies
some torn to pieces,
mothers, fathers, aunts, uncles, nephews, nieces
scattered all about.

i wanna wake up, from this horror of a nightmare,
scared crying wanting mommy,
seeing babies lying in streets,
no noses, some with no faces, arms adjacent to their feet.

i have no arms to carry the helpless child crying,
i have no strength within me to give hope to
the woman dying.

with the blink of an eye, i awake from a dream
too surreal to be real,
in the coldest sweat running down my neck,
as my dilated eyes struggle to open,
i hear constant beepings, children weeping,

where am i, i wonder to myself.
as my eyes wandered around the room
noticing what was going on,
i realized that both of my arms
were gone.

Omar McCray is a member of SANITY, Students Against Nuclear Insanity and for Tomorrow's Youth.

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