Boston College Environmental Affairs Law Review

Volume 9 | Issue 1 Article 14

1-1-1980

Radioactive Waste: Politics, Technology, and Risk by Ronnie D. Lipchutz

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Recommended Citation

Dr. George J. Goldsmith, *Radioactive Waste: Politics, Technology, and Risk by Ronnie D. Lipchutz*, 9 B.C. Envtl. Aff. L. Rev. 251 (1980), http://lawdigitalcommons.bc.edu/ealr/vol9/iss1/14

BOOK REVIEW

RADIOACTIVE WASTE: POLITICS, TECHNOLOGY, AND RISK. By Ronnie D. Lipschutz. Ballinger Publishing Company, Cambridge, Massachusetts, 1980. 246 pp.

*Reviewed By Dr. George J. Goldsmith**

This book, written under the auspices of the Union of Concerned Scientists, takes a detailed look at one of the most vexing difficulties facing the entire nuclear enterprise, the safe-handling and disposal of radioactive waste. One might wonder why this waste problem is unique among the many varieties of industrial garbage society is required to manage. This is because it involves social, political, and environmental concerns that range far beyond those encountered by the management of other hazardous wastes, affecting matters such as war and peace and our obligations to future generations.

The advent of nuclear power in the wake of diminishing worldwide fossil fuel resources has created exciting new possibilities for providing energy adequate for the continued growth and expansion of our technological society. As with most technological innovation, however, its introduction is accompanied by problems, many of which have not been dealt with previously. In spite of thirty-five years of experience with military applications and nearly twenty-five years of commercial electric generation, some of these problems remain unsolved. They largely are associated with the unique health hazard caused by radiations from the radioactive

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substances which constitute the nuclear fuel and waste products. These insidious and mysterious invisible rays are capable of producing life threatening damage to living things, damage which usually does not become evident until long after exposure. The damage can manifest itself in several different ways depending on the severity and circumstances of human exposure. In its most acute form, at high dosage, radiation can cause death within days or weeks; at lower dosage, various forms of cancer can appear some years later; and any level of exposure of that segment of the population capable of reproduction can create a finite probability for creating genetic damage which will affect future generations.

This very real hazard coupled with attitudes originating from the manner in which nuclear energy literally burst into public awareness gives rise to a very high level of anxiety toward nuclear installations. Public awareness of the feasibility of nuclear energy arose with the incredible devastation wreaked upon Hiroshima and Nagasaki at the end of World War II; and hence there is an indelible impression on the entire world of its horrendous explosive potential. This connection remains in spite of the well-established fact that no nuclear generating plant or propulsion system can become a nuclear bomb. The fear of explosion coupled with the mystery surrounding biological damage from invisible, unsensed radiations has created an understandable aura of confusion over nuclear energy.

The nuclear industry is required, in response to the hazards and to these emotional factors, to design and construct systems which possess a degree of reliability against failure from all causes, human and natural, far more rigorous than heretofore encountered in more conventional installations. This industry, which has grown up about military and civilian demands for nuclear systems, and which has enjoyed a unique partnership with government, is faced with multiple, and sometimes conflicting challenges. Ever since the oil embargo of 1973 it has been under heavy pressure from several quarters to expand as rapidly as possible so as to reduce our reliance on imported oil. Expansion, on the other hand, has been inhibited by escalating costs, uncertainties over future demand for electricity, public resistance exacerbated by episodes such as the failure at Three Mile Island, and the frightening aspect of the proliferation of nuclear weapon capability throughout the world. These negative pressures have caused many to argue that the overall risks of nuclear energy outweigh the benefits and that the entire enterprise should be dismantled. It is quite clear, however, whatever the future may hold over the long term, our present commitments, military and civilian, insure that nuclear weapons systems, nuclear propulsion systems, and nuclear electric generation systems will be with us for some time to come.

Among the many problems faced by all these applications of nuclear energy, the safe management of waste products remains one of the most intractable. While the basic requirements on the disposal of these wastes are similar to those associated with other toxic materials—essentially that they must be disposed of in such a way that they cannot contaminate the environment beyond some established safe limit—their containment poses special difficulties. These arise from the following conditions: the toxicity of radioactive wastes often bears no relation to the amount of material; some materials remain hazardous for years, in some cases for millennia; some continue to generate considerable quantities of heat for years after disposal; their presence cannot be detected without the use of special instruments; the amount of environmental contamination which constitutes an "established safe level" is a matter of heated controversy; disposal by dilution does not always work because of chemical and biological concentration mechanisms, or because of excessively high levels of radioactivity; and some of the radiations are so penetrating as to constitute a hazard even when separated from the environment by closed containers, or other material barriers.

Radioactive waste is generated throughout the entire nuclear fuel cycle from mining, through fabrication of fuel elements, in operation of the reactor, and in all other activities associated with nuclear reactors. Wastes are classified on the basis of the intensity of their radioactivity, and sometimes, as well, on the basis of the kind of radiation they emit and on their chemical form. The unit of radioactivity is the *curie* defined as being a rate of disintegration equal to that of one gram of radium, 37 billion disintegrations per second. The kinds of radiation that might be emitted, depending on the particular radioactive nucleus, are termed alpha particles, beta particles, and gamma rays. These radiations differ in size, in electrical properties, and most significantly in the context of the waste problem, in their biological effectiveness and ease with which they can be contained. Alpha particles are the nuclei of helium atoms and have so little penetrating power that they can be stopped by a sheet of cardboard. Beta particles, high speed electrons, are moderately penetrating, requiring a few centimeters of material to stop them. Gamma rays are similar to x-rays, and require heavy shielding. As a rule the alpha-emitting substances are those of high atomic number: actinides such as thorium and uranium, and the transuranium elements such as neptunium and plutonium. Beta and gamma rays are given off by some of these heavy elements as well as by nearly all the other radioactive nuclear species.

An important characteristic in addition to the kind of radiation that is emitted by a particular nucleus is its half life. When a radioactive nucleus emits radiation it is transmuted to a different nuclear species, usually nonradioactive and of a different element. The rate at which this happens is determined by two factors: the transition probability and the number of radioactive atoms present. The transition probability is a constant quantity, characteristic of the specific transmutation. As the process proceeds, however, the *number* of radioactive nuclei in a given sample decreases and hence the rate decreases geometrically. Since, in principle, in a process such as this, it would take an infinite time for all the nuclei to be transmuted, it is better described by the time required for half the original nuclei to decay—the half-life. An important consequence of the radioactive decay mechanism is that for a given amount of radioactive material, the specific activity (e.g., the number of *curies* per gram of material) varies inversely as the half life. The shorter the half life, the greater the activity, but of course for a shorter time. Half lives range from small fractions of seconds to billions of years.

A broad classification of radioactive wastes divides them into either of two categories: low-level, less that one *curie* per cubic foot, and high-level which may average thousands of *curies* per cubic foot. Evaluation of the hazard created by these wastes is complicated because the biological effectiveness of the radiation depends on the energy of the radiations, their specific properties, the age distribution of the exposed population, and the part of the body which is exposed. For example, while it is easy to contain alpha radiation, it can produce a very high density of damage in any living matter. A microscopic particle of an alpha-emitting substance lodged in lung tissue has a very high probability of creating a cancer in its vicinity, while a sealed jar full of the same substance may be quite safe to handle. Whatever the details, the major problem with radioactive waste is clearly associated with the fuel used in nuclear reactors since they represent the source of all the high-level waste. It is this problem that constitutes the chief thrust of Lipschutz' *Radioactive Waste.*

The preparation of fuel elements for reactors starts with the mining of uranium ore containing about 0.2 percent uranium. After refining to remove the uranium, the residual material called "tailings" remains slightly radioactive so that the radiation background in the vicinity of a tailings dump is many times normal background. Most of the radioactivity from these tailings originates in radon gas which diffuses into the atmosphere.

Until 1966 these materials were widely employed as land fill in building projects. It was subsequently ascertained that the risk of lung cancer in populations residing in the vicinity of these mine tailings is twice that of the general population. The quantity of tailings continues to grow as mining operations continue. Today it amounts to nearly 200 million tons. Its disposal as low level waste requires that it be appropriately sealed off from the environment, and obviously not used as land fill or for any other purpose which would result in exposure of unprotected persons.

After the refinement process the concentrated uranium is then treated chemically and put through a process which increases the concentration of the fissile uranium isotope, U^{235}, from 0.7 percent to about 3 percent. Most of the remaining uranium is non-fissile U^{238}. It is then fabricated into fuel rods enclosed in a protective sheath. Low level wastes are produced throughout this procedure, many of which have very long lifetimes. While the management of these wastes has not been entirely free of health threatening episodes, there are no especially formidable obstacles to its safe disposal. All that is required is ensurance that established procedures are strictly adhered to.

Once the fuel rods are introduced into the reactor, and the fission process initiated, an entirely new set of conditions arise. Fission, through the splitting of U^{235}, produces fission fragments, nuclei of lighter elements, most of which are highly radioactive. Excess neutrons also generated during fission either produce more fission to keep the chain reaction going, or are captured by the non-fissile U^{238} which makes up most of the fuel element. Upon capture of a neutron the U^{238} decays rather quickly in two steps to fissile plutonium which is then available for participation in the chain reaction. In reactors currently in use for the commercial production of electricity, the rate of buildup of fission fragments at the expense of U^{235} and plutonium, exceeds the rate of production of new plutonium. Eventually the fuel rods become incapable of sustaining the reaction, and they must be replaced. At this point they are extremely radioactive from the large burden of fission fragments and plutonium that they contain. Current practice involves the annual change of one third of the approximately 100 tons of fuel in each reactor. At the moment of shutdown, the radioactivity in the spent fuel rods amounts to about 150 million *curies* per ton. This much radioactivity will generate, on its own, about 1.5 million watts of heat per ton! The rods are placed in storage pools at the reactor site while the initial short-lived, very high level, activity decays away. After six months, the radioactivity is reduced to about 4 million *curies* per ton, and the heat generation to about 20 kilowatts per ton. The radioactivity continues to decay, but at a slower rate with a half-life for the major beta emitter of about thirty years, and for the most important alpha emitter, plutonium (Pu^{239}), of 22,400 years.

The contents of these spent fuel rods will remain dangerously radioactive for millennia and they must be prevented from intruding into the environment through leaching into underground or surface water, or from mixing or exposure through human activities, the action of wind or earthquake, or by means of biological processes. Since the thousand year time frame exceeds that of any political institution that we are aware of from historical experience, the wastes also must be secure against the dissolution of these institutions as we know them. Obviously, given these circumstances, they cannot simply be dumped into landfill, even into that which may be designated for other sorts of hazardous waste. Nor is it possible to package them and store them in vaults even though the quantity may not be too large to manage in this manner. The combination of heat and radioactivity would destroy any container fairly quickly.

It would appear that one obvious way to reduce the magnitude of the problem would be to reprocess the spent fuel rods to remove the valuable uranium and plutonium. This would reduce the effective dangerous lifetime from millennia to centuries. Reprocessing is well within the present state of the art, and has, in fact, been carried out in the United States in the past, and is currently in operation in Europe. It is, however, a very complicated and dangerous procedure both technically and politically. The processing plant itself must, first of all, maintain the same level of integrity that is required of the disposal system. It has to be automated, fail-safe, and resistant to damage by natural disasters, war, insurrection, sabotage, or terrorism. Second, reprocessing would produce a large inventory of plutonium, a substance fairly easily made into a nuclear bomb. This inventory would contribute greatly to the danger of proliferation of nuclear capability around the world. And third, there is presently little economic incentive to proceed with reprocessing.

Even should reprocessing become feasible, it would not eliminate the problem of waste disposal. The remaining fission products would still constitute a serious hazard. Several solutions to this have been suggested and are under study for disposal of wastes in whatever form they may ultimately appear: burial in deep ocean trenches, in salt mines, in deep rock formations; disposal on the polar ice caps where they would melt their way beneath miles of ice; rocketing into the sun or out of the solar system; transmutation by neutron bombardment unto less harmful isotopes; deposition in managed mausolea either in isolated desert locations or in mountain caves.

Of these methods, the most attractive is deposition in deep geologic formations, either salt or rock. It is of course essential that the location of the deposit and the characteristic of the site be such as to exclude absolutely the possibility of migration of the material. An initial effort to develop a storage facility in a salt mine beneath Lyons, Kansas was frustrated when it was discovered that the region had been penetrated in a random fashion by unknown numbers of exploratory drill holes. West Germany does currently operate a salt mine storage facility. It is very difficult, however, to predict beyond any doubt the continued integrity of a deep storage site over so long a time, even where the presence of salt indicates the absence of water over long geologic periods. Burial, under most circumstances, also would demand retrievability, especially if the material were to contain fissile substances. Thus it would be important that storage areas not be vulnerable to seal-off by tectonic action.

Polar ice cap disposal appears on first look to be a neat solution since one would anticipate that the fuel containers would melt their way to bed-rock and be subsequently sealed off by refreezing of the overburden. To risk contaminating this virgin region of the world now considered to be a wasteland, but which may become of great economic and social value in the future, is unthinkable—and forbidden by international agreement. The other methods are similarly fraught with technological, economic, and political difficulties.

No waste disposal method has been implemented by the U.S. government up to the present. Several different options are under study, but in spite of frequent declarations by the Department of Energy that an operating waste program is imminent, there is no firm plan. It is anticipated that suitable sites for mined repositories will be located and one will be selected by some time between 1982 and 1985. The first repository would then be ready to receive waste in the early to mid 1990's. Even this plan, however, continues to be under heavy attack by members of Congress, competing government agencies, and by various private and public interest groups. In the meantime spent fuel rods are stored in pools of water on the site of the individual installations. These, however, are becoming filled, and even with reconfiguration of the storage to increase capacity, some facilities are close to their limit. A government sponsored program to establish a managed temporary storage facility at some central location, the so called "Away From Reactor Program" (AFR), is not yet under way. Time is running short, and pressures to solve the waste problem are mounting out of fear that it may turn out to be the Achilles Heel of the nuclear industry.

In the meantime both military and civilian programs continue to accumulate and store large volumes of high level waste. The military program has experienced some episodes of environmental contamination through leakage from their high volume storage tanks at the Richland, Washington site. Plans to reduce the volume of waste and to encapsulate it in glass or ceramic matrices to make it safer to manage and easier to store remain stalemated. This is in part because of a current government moratorium on the operation of reprocessing plants, a decision arising out of our choice to take the lead in minimizing opportunities for the proliferation of nuclear capability. The situation is both confused and alarming.

Ronnie Lipschutz' book takes the reader step by step from a clear discussion of the nature and hazards of radioactivity; through a description of the nuclear fuel cycle; to a detailed account of the history of radioactive waste management. He then considers in some detail the options for waste management and analyzes the present government programs. In his final chapter he outlines requirements and suggestions for a successful program.

The book is written for the layman in a narrative style which is both clear and easy to read. His facts are well documented and the entire presentation is up to the high technical calibre we have come to expect from the agency that sponsored the book, The Union of Concerned Scientists. This organization is widely recognized as a very responsible advocate of safe practices within the nuclear establishment, and has been an extremely successful gadfly in promoting vastly improved criteria for safer reactor design.

In the light of this, it is disappointing to find so cynical a tone in Lipschutz' presentation. The writing is filled with not-so-subtle implications of the wickedness of government and industry in neglecting the public welfare for the sake of expediency and profit. While to some degree this may be true, it does not seem necessary to find a new manifestation of Satan lurking around each bend. The writing also tends frequently to cliches and to gratuitous opinions, many of which are not especially relevant to the matter at hand. There are occasional slips in technical accuracy, none of which, however, detract significantly from the overall accuracy of the account. The appendices contain many useful data including a description of waste management programs in other countries. There is a thorough, but somewhat awkward-to-use, set of references arranged in alphabetical order by major author or sponsoring group, an exhaustive bibliography, and a very useful glossary.

The book offers the interested layperson a clear picture of a complex problem, and en route gives much insight into the principles and practices of nuclear energy. It also can serve as a useful reference to the details of a serious unsolved problem which demands a prompt, thoughtful solution.