FACING REALITY

Nuclear Weapons "CLEANUP"

Prospect Without Precedent

FACING REALITY reports are published under the auspices of the Council on the Department of Energy's Nuclear Weapons Complex, an initiative of the Tides Foundation's Project for Participatory Democracy. An Advisory Committee oversees each publication.

NUCLEAR WEAPONS "CLEANUP," the fourth in a series of Council publications, was preceded by *FACING REALITY: The Future of the U.S. Nuclear Weapons Complex;* a companion *Citizens' Guide to the Future of the U.S. Nuclear Weapons Complex;* and *BEYOND THE BOMB: Dismantling Nuclear Weapons and Disposing of their Radioactive Wastes.*

Cleaning up after nuclear weapons production is an enormous and costly task. Large quantities of waste and many contaminated buildings and sites will remain hazardous for centuries or even tens of millennia. *Dealing with these realities is a prospect without precedent in human history.*

In the past, Department of Energy environmental policies have been cloaked in secrecy. Many decisions were made that proved detrimental to citizens living near the cleanup sites. Secretary of Energy Hazel O'Leary is making significant efforts to provide information to the public and to consult with citizen groups and independent scientific experts. This progress comes at a time when the Administration is recommending significant reductions in DOE's cleanup budget. We argue for reconsidering that intended action. Delaying cleanup will increase long-term costs as well as human and environmental risks.

This document presents principles to guide action and attempts to present complicated problems in understandable ways, emphasizing what we know and do not know about cleaning up nuclear wastes. The report is intended for policymakers and citizens groups concerned about the future of the U.S. Nuclear Weapons Complex.

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Nuclear Weapons
"CLEANUP"

Contents

This report is based upon published government documents and the research efforts of many independent experts and organizations. Cooperating in producing the current report have been many members of the Military Production Network, a national alliance of organizations working to address issues of nuclear weapons production, waste, and contamination.

Review Committee for this Report:

Drew Caputo, Natural Resources Defense Council, Washington, DC

Sharon Carlsen, Associate Director, Nuclear Safety Campaign, Seattle, Washington

Brian Costner, Director, Energy Research Foundation, Columbia, South Carolina

Lisa Crawford, President, Fernald Residents for Environmental Safety and Health, Ross, Ohio

Tim Connor, Associate Director, Energy Research Foundation, Spokane, Washington

Beatrice Brailsford, Program Director, Snake River Alliance, Idaho

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Bill Mitchell, Director, Nuclear Safety Campaign, Seattle, Washington

Gerald Pollet, Executive Director, Heart of America Northwest, Seattle, Washington

Robert Schaeffer, Public Policy Communications, Belmont, Massachusetts

Lynne Stembridge, Executive Director, Hanford Education Action League, Spokane, Washington

F. Ward Whicker, Professor, Department of Radiobiology, University of Colorado, Fort Collins, Colorado

---

Writer and Editor – **Peter Gray**

Public Education Consultant – **Robert Schaeffer**

Secretary to the Council – **Richard Boone**, Director of the Project for Participatory Democracy, The Tides Foundation, San Francisco, CA

Names of organizations are for identification purposes only.

Introduction

A half century of U.S. nuclear weapons research, development, testing, and production has left behind tremendous quantities of some of the most persistently dangerous substances ever identified. Community and worker health, clean air, and safe drinking water are all at risk from contamination caused by leaking waste containers, underground toxic plumes, and airborne radiation from nuclear warhead production. Some wastes are so poorly stored that spontaneous explosions are possible that could lead to major releases of radioactivity.

The Department of Energy (DOE) Environmental Management office, commonly called its "cleanup" program, is charged with addressing these threats in order to protect present and future generations from radioactive contamination. ***That task, at more than a dozen major sites and many smaller ones around the country, is a prospect without precedent in human history.***

The word "cleanup" brings to mind mops, buckets, and brooms . . . and a job that has a recognizable beginning and end. However, little of the DOE's environmental work resembles familiar household or even industrial cleaning tasks.

The United States learned a painful lesson in this respect after it tested the effects of atomic bombs on naval vessels in the South Pacific in 1946. For months after the detonations, tens of thousands of sailors scrubbed, sandblasted, and treated the ships with chemicals. Many of these "cleanup workers" were exposed to high doses of radiation. In spite of all that effort and risk, more than 60 ships could not be salvaged and instead were scuttled or used for target practice.

Buildings, machinery, and land at all of the DOE's major nuclear weapons plants and labs pose similar decontamination difficulties. But the bomb factories cannot be towed offshore and sunk, and no simple formula exists for deciding what should be done at each site.

There are several scientific reasons for the difficulty of nuclear weapons site cleanup. Radioactivity cannot be destroyed by chemical processing or high temperatures. At best it can be contained and stored for the centuries or millennia necessary for it to decay naturally. Because radioactive isotopes can be dangerous in tiny quantities, special care will be required to protect workers and public health over the long-term.

Radioactivity cannot be destroyed by chemical processing or high temperatures. It must be isolated for the centuries or millennia necessary for it to decay naturally.

The physical challenge of monitoring and safeguarding these materials is exacerbated by an inferior management system that has operated since the 1940s in a culture of Cold War secrecy. Many DOE contractors and officials have had long careers in nuclear weapons production. They have little experience with openness, little inclination toward environmental work, and often lack the willingness to consult with others. Oversight has been inadequate, and contracting practices often encourage inefficiency and mismanagement.

The DOE cleanup requires a national commitment equivalent to that which created the nuclear weapons legacy.

Environmental performance is difficult to measure compared to the production of nuclear materials and bomb components. That problem is compounded by failures and scandals at former production sites. Meanwhile, recent political changes are increasing the pressure to reduce other federal expenditures in order to pay for tax reductions and additional military spending. Waste management and cleanup programs have become tempting targets for draconian budget cuts.

A basic social contract is also threatened by proposals to eliminate or circumvent Executive Order 12088, which requires the DOE to request funding sufficient to meet its binding compliance agreements with states and tribes. Budget cuts now under consideration will severely compromise the DOE's ability to meet its legally mandated commitments.

Arbitrary reductions in DOE environmental projects will increase the likelihood of further offsite contamination and make many current problems even worse. If cleanup work is cut back or delayed, the long-term costs in human health and taxpayer dollars will be much higher. Even in the short run, savings might not materialize if citizens, states, and Native American tribes bring successful lawsuits to force the federal government to fulfill its environmental commitments.

Instead of supporting across-the-board spending cuts, policy-makers must recognize that the DOE cleanup requires a national commitment equivalent to that which created the nuclear weapons legacy. Politically and technically, the challenge for the future is at least as complicated as the work of the past. A similar degree of resolve, both moral and financial, is necessary to attain success.

Energy Secretary Hazel O'Leary has begun to reform the DOE and focus its resources on scientifically sound environmental policies. Across the country, citizens are becoming involved for the first time in a process to decide what to do about waste and contamination. These initiatives deserve to be strengthened, not undermined. Nuclear weapons cleanup is a societal obligation that must be protected from the political winds of the moment.

PART ONE: The Enormous Challenge

We are faced with a dilemma: While experts agree that cleaning up nuclear wastes is a monumental undertaking, the public remains largely uninformed about the extent and depth of the problems. This section attempts to describe the uniqueness and scale of the task, the importance of taking action now, and the issue of cleanup costs.

Most of the radioactive waste, spent nuclear fuel, and surplus plutonium created by nuclear weapons production is still stored at DOE sites.

A Vast Threat

In terms of the quantity and virulence of its wastes, the DOE legacy is in a class of its own (see Appendices A and B for an overview). The cleanup effort faces uncertainties about waste containment and about the health effects of radioactive pollutants. Possible wars, societal breakdowns, or natural calamities are unpredictable. Therefore the disposition of long-lived radioactive materials requires special attention.

Government bears an extra responsibility because nuclear weapons production imposed risks on citizens without their consent. During the Cold War, nuclear weapons complex workers and the public were unknowingly exposed to risks through routine operations, accidents, and deliberate releases of radioactive and toxic materials. In many cases, exposures were hundreds or even thousands of times higher than the levels officially deemed "tolerable" at the time.

During the century since high-energy radiation was first identified, its health effects, especially at low doses over long exposure periods, gradually have been recognized as more serious than previously believed. This trend is one reason for extra caution in handling and storing waste. The eventual genetic and immune system effects from chronic radiation exposure are not fully understood, nor are the biological interactions among radioactive and toxic pollutants.

Given the clear health and environmental risks, steps taken now to minimize the spread of contamination will be a much better investment than assuming that spilled waste can be cleaned up later. The best available scientific assessments indicate that the total harm from these contaminants is not likely to be reduced by spreading them across large populations or long time periods.[1]

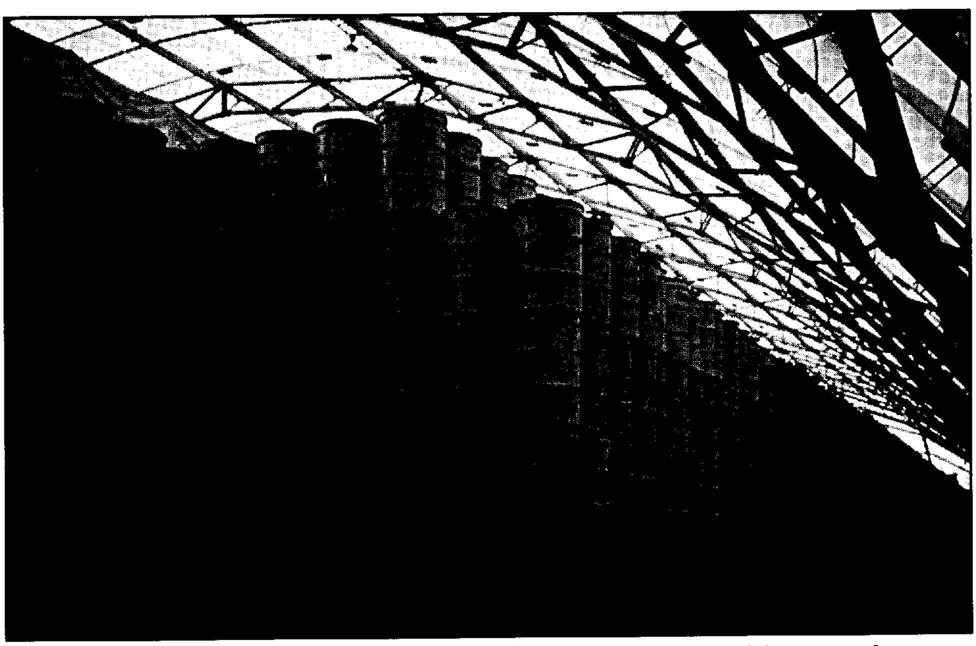
Overt abuse of the public trust is diminishing, but enormous problems remain. Most of the radioactive waste, spent nuclear fuel, and surplus plutonium created by nuclear weapons production is still stored at DOE sites. Little of this material is in a stable form suitable for long-term storage, and some of it poses immediate as well as long-term risks of accidents and leaks.

Steps taken now to minimize the spread of contamination will be a much better investment than assuming that spilled waste can be cleaned up later.

Trying to reduce current costs has become attractive to the current Administration and many Congressional leaders in order to fund proposed tax reductions. However, the costs of long-term cleanup obligations will only rise if neglect leads to radioactive releases. As contaminated facilities deteriorate, the danger of serious accidents is also likely to grow. These conditions will also increase health risks to workers and to populations near cleanup sites.

Destination Unknown

Radioactive wastes from nuclear weapons production are in tanks, drums, bins, boxes, piles, ponds, trenches, silos, and pits at dozens of mill sites, factories, and labs scattered across the country. There has been some progress toward putting waste into forms suitable for "permanent" storage, but underground repositories proposed for waste disposal have been delayed by many years and continue to face serious technical questions and political opposition.



Peter Gray photo

Plutonium-contaminated wastes are stored in tens of thousands of drums inside temporary structures such as this one at the Idaho National Engineering Laboratory.

Clear and Present Dangers

The following are a few examples of the many radioactive waste and contamination problems at U.S. nuclear weapons production sites:

- The DOE stores about 3,000 tons of highly radioactive spent nuclear fuel at sites in **Idaho, South Carolina, Tennessee**, and **Washington**. Most of this material is in storage pools, some of them more than 40 years old, that were not designed for the long term. Many of the pools are susceptible to leakage and earthquake damage. Some spent fuel is corroding, increasing the risk of an accidental nuclear chain reaction, or "criticality."[2]
- At the **Hanford, Washington** site, 67 high-level waste tanks, each containing about one million gallons, are known to have leaked into the surrounding soil.[3] Many automatic leak detectors are malfunctioning. Some of the waste tanks are at risk of disastrous explosions. Hanford has a backlog of about 1,500 maintenance projects on its 177 high-level waste tanks.[4]
- More than 500,000 55-gallon drums (or their equivalent) of "transuranic" waste, containing more than 10 tons of plutonium, are stored in **California, Colorado, Idaho, Nevada, New Mexico, Ohio, South Carolina, Tennessee**, and **Washington**. Similar volumes of transuranic waste have been buried in shallow pits or trenches. This waste, a dangerous contaminant, is in interim storage with inadequate protection from natural and human events.[5]
- In addition to the plutonium classified as waste, contained in weapons, removed from dismantled warheads, or contained in spent fuel, the DOE has about 26 tons of plutonium scrap, solutions, and other forms known as "residues" in storage designed for weeks or months rather than years. The DOE has compiled a list of 46 "most significant vulnerabilities" involving leftover plutonium, at sites in **California, Colorado, New Mexico, Ohio, South Carolina, Tennessee**, and **Washington**. Potential fires, explosions, containment failure, and criticality accidents pose serious risks to workers and the public.[6]
- Concrete walls surrounding intensely radioactive waste stored at the **Idaho National Engineering Laboratory** are likely to fail in the event of an earthquake. The waste was converted to a dry form for "permanent" storage 30 years ago, but now must be extracted and repackaged, a costly and hazardous process that might begin in 1998.[7]
- The U.S. Environmental Protection Agency has found plutonium contamination, at levels 16 to 160 times higher than "normal background" (which exists primarily due to atmospheric nuclear testing) in a public park next to an elementary school near the **Lawrence Livermore National Laboratory** in **California.**[8]
- The **Fernald, Ohio** plant released at least 500 tons of toxic uranium dust into the surrounding air and water. During much of the 1980s this known contamination was kept secret.[9] It still poses hazards to nearby communities.
- The DOE was recently forced to provide drinking water lines to homes near the **Paducah Gaseous Diffusion Plant** in **Kentucky**. Wells there had been contaminated by a 1,300-acre underground plume of Technetium-99, a uranium decay product. The plume is migrating toward the nearby Ohio River at the rate of several inches per day.[10] Nationwide, the DOE has identified more than 5,700 plumes of various kinds of contamination under and near its sites.

DOE's Cleanup Sites (Fiscal Year 1995 funding levels)

Major Operating Sites: (On-site budget total about $5,346 million)

Site	State	($millions)
Hanford	Washington	1,577
Savannah River	South Carolina	735
Oak Ridge	Tennessee	572
Rocky Flats	Colorado	644
Idaho National Engineering Lab	Idaho	483
Fernald	Ohio	291
Waste Isolation Pilot Plant	New Mexico	182
Los Alamos Lab	New Mexico	179
West Valley	New York	127
Livermore Lab	California	89
Portsmouth Gaseous Diffusion Plant	Ohio	79
Paducah Gaseous Diffusion Plant	Kentucky	78
Nevada Test Site	Nevada	65
Sandia Lab	New Mexico, California	54
Mound Plant	Ohio	48
Pantex	Texas	45
Argonne Labs	Idaho, Illinois	32
Brookhaven Lab	New York	24
Battelle Lab	Ohio	20
Kansas City Plant	Missouri	13
Pinellas Plant	Florida	9

Formerly Utilized Sites Remedial Action Program* (FUSRAP: $74 million)

Site	City	State
CE Site	Windsor	Connecticut
Madison Site	Madison	Illinois
W.R. Grace & Co.	Baltimore	Maryland
Chapman Valve	Indian Orchard	Massachusetts
Shpack Landfill	Norton	Massachusetts
Ventron	Beverly	Massachusetts
General Motors	Adrian	Michigan
Latty Ave. Properties	Hazelwood	Missouri
St. Louis Airport Site	St. Louis	Missouri
St. Louis Airport Vicinity Site	St. Louis	Missouri
St. Louis Downtown Site	St. Louis	Missouri
Maywood Site	Maywood	New Jersey
Wayne Site	Wayne	New Jersey
Middlesex Sampling Plant	Middlesex	New Jersey
DuPont & Co. Site	New Brunswick	New Jersey
B&L Steel	Buffalo	New York
Colonie Site	Colonie	New York
Niagara Falls Storage Site	Lewiston	New York
Ashland 1 Site	Tonawanda	New York
Ashland 2 Site	Tonawanda	New York
Linde Air Products	Tonawanda	New York
Seaway Industrial Park	Tonawanda	New York
Associated Aircraft	Fairfield	Ohio
B&T Metals	Columbus	Ohio
Baker Brothers	Toledo	Ohio
HHM Safe Co.	Hamilton	Ohio
Luckey Site	Luckey	Ohio
Alba Craft	Oxford	Ohio
Painesville Site	Painesville	Ohio
Aliquippa Forge	Aliquippa	Pennsylvania
C.H. Schnoor	Springdale	Pennsylvania

* FUSRAP Sites were primarily used for small-scale research and production work during the Manhattan Project.

Sources: Fiscal Year 1995 Environmental Management Appropriations data, Department of Energy and Office of Management and Budget, Dec. 20, 1994; Administrative Record Requirements for FUSRAP (Formerly Utilized Sites Remedial Action Program) overview document, U.S. DOE, April 1994.

Uranium Mill Tailings Remedial Actions (UMTRA: $101 million)

Numerous sites in Arizona, Colorado, Idaho, New Mexico, North Dakota, Pennsylvania, Utah, Washington, and Wyoming

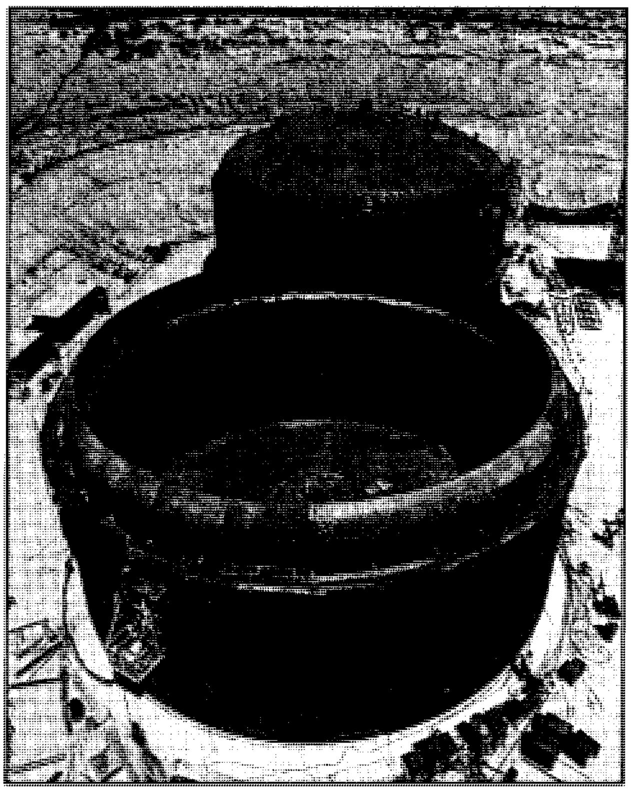
The quantity of nuclear waste, the hazards of handling it, and the difficulty of establishing permanent disposal sites for even a fraction of it means that society will be burdened with these materials for a long time. The best hope appears to be to contain the waste in order to minimize its health threats now and avoid creating costly problems later. When radioactive waste is handled and packaged, however, the tools, clothing, and containers used in the process typically become contaminated and themselves eventually become waste. Buildings, machinery, soil, and sediment that become contaminated usually cannot be cleaned and must be treated as radioactive waste, adding to disposal problems.

Waste has been stored in "temporary" containers that corrode and leak within a few years or decades.

Because the DOE and its predecessor agencies made naive assumptions about final disposal, waste has been stored in "temporary" containers that corrode and leak within a few years or decades. Contamination is extensive at many sites, and is always costly and difficult to remove.

Despite extensive contamination at many sites, there are some cleanup success stories that should be used as instructive models. However, no universal formula can work under the unique conditions at each contaminated site. Waste characteristics as well as local geography, ecology, and land use patterns require site-specific cleanup planning.

Under the most optimistic view, only a small fraction of total waste will be in long-term storage within several decades. Most of the waste will remain in "interim" storage, in containers that will wear out long before the waste loses its radioactivity. Given such problems, action should be guided by principles reflecting the scale of the issues.



U.S. Department of Energy photo

Million-gallon storage tanks for highly radioactive waste under construction in 1985 at Hanford, Washington.

Why "Cleanup" is a Massive Problem

These factors place the DOE cleanup in a class by itself:

1. Extremely dangerous materials

- Nuclear weapons production has created large quantities of highly radioactive materials that are not found in nature.
- Minuscule quantities of materials such as plutonium can be dangerous.
- Some materials will keep their radioactive potency for tens of thousands of years.
- Virtually all major DOE facilities are now on the Superfund list of the nation's most contaminated sites.

2. Inadequate scientific foundations

- Interactions among radioactive and toxic materials are poorly understood.
- There is no consensus on which research to do, who should do it, and how it should be done.
- Many cleanup technologies are new and unproven.

3. A history of secrecy and deception

- Public distrust runs deep.
- Institutions for citizen involvement are in their infancy.
- Entrenched contractors and bureaucrats resist change.

4. Difficulty of setting cleanup goals and priorities

- There is no national, regional, or even site-by-site consensus on "how clean is clean."
- It is unclear how cleanup goals are set.
- The rationale for deciding where and when to use cleanup resources is not explicit.

5. Inadequate contracting system

- Expertise, incentives, and contract enforcement in the DOE complex are not well suited to environmental work and public participation.
- Contractors' conflicts of interest undermine accountability and effective cleanup.
- Incentives often favor expensive projects rather than meaningful performance.
- Incentives have failed to improve performance when contractors have been able to manipulate the system for profit.

The first and most important principle should be a rule similar to the physicians' commandment to do no harm: ***Avoid spreading contamination.*** Citizens near sites such as Hanford in Washington State have expanded on this principle by asking that the DOE follow a rational sequence for dealing with radioactive wastes:

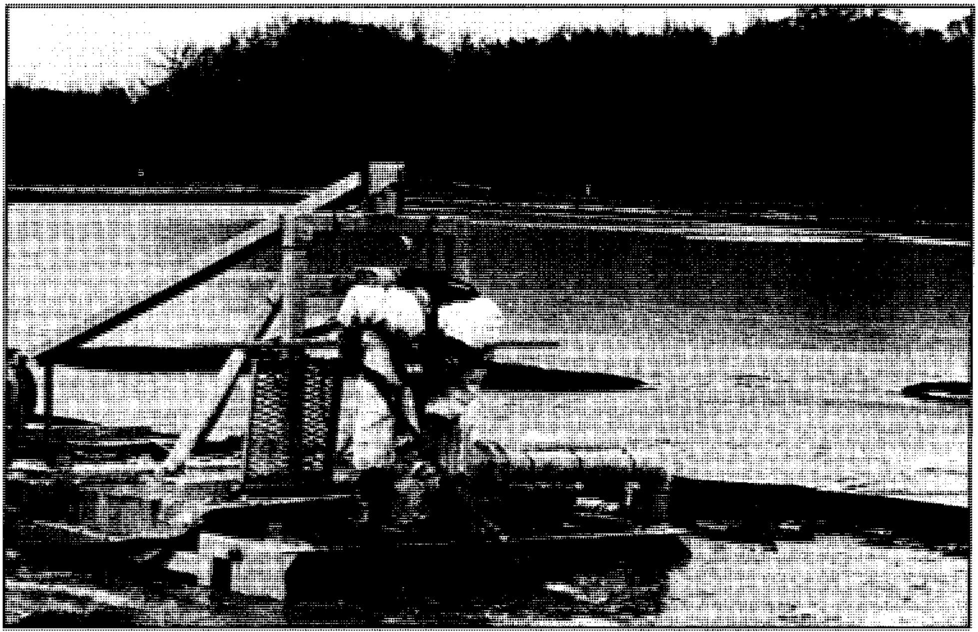
1) identify and characterize the materials;
2) isolate them from the environment;
3) stabilize and consolidate them to make future releases less likely; and
4) store and monitor the materials at the sites where they were generated.

Committing to Action Now

Sound environmental practices throughout the nuclear weapons complex will require dramatic institutional changes as well as many billions of dollars. The costs for waste management and cleanup of DOE sites during the next several decades have been estimated at several hundred billion dollars. This price is high, but it should be kept in perspective. Today the United States spends 250 billion to 300 billion dollars per year to protect itself from largely hypothetical external threats. Budget allocations for defending against the known internal threat of radioactive contamination are about 40 times smaller than for the military. If the problems are neglected, the costs to taxpayers, as well as the risks to workers and communities, will quickly escalate. The adage equating an ounce of prevention with a pound of cure is particularly apt in the case of radioactive waste.

Some problems will defy "engineering solutions."

This necessary national commitment of resources brings to mind an Environmental Manhattan Project, but that comparison should not be taken literally. Some problems will defy "engineering solutions." Even where technical solutions are available, decision-making partnerships between government, citizens, workers, and independent experts will be needed in order to proceed. In the past, citizens, particularly those living near DOE sites, have been excluded from consultative and decision-making roles. Informed and constructive participation of citizens is not only possible, it is essential. An open debate with shared responsibility for the outcome is the first step toward matching federal resources to the legitimate expectations of people who will live with the results and uncertainties of the decisions.



U.S. Department of Energy photo

A cleanup worker dredges the Pit 5 radioactive waste dumpsite at Fernald, Ohio.

A balancing act

While the goals, standards, and funding for cleanup cannot be determined through scientific research alone, a less than comprehensive and carefully planned approach could waste resources in several ways. If cleanup contractors have too much influence, decisions are likely to be biased toward the most elaborate and expensive projects, rather than toward efforts that are most effective in reducing risk. Several major DOE cleanup projects have been plagued by mismanagement, undermining the entire program's credibility. On the other hand, if contamination is viewed as a limited problem in someone else's backyard, cleanup is likely to be neglected. Such an underinvestment will lead to additional damage and more costly problems later.

If contamination is viewed as a limited problem in someone else's backyard, cleanup is likely to be neglected.

The quantities, characteristics, and locations of the DOE's waste inventories are known with widely varying degrees of accuracy, and the process of setting cleanup goals and priorities is not fully developed. This is because there are many uncertainties. For example, a major accident such as a high-level waste tank explosion might heavily contaminate large regions and cause many fatalities. The DOE has rightly treated the possibility of such an accident as an "urgent risk." But less dramatic "slow-motion accidents" are happening already, as radioactive and toxic materials seep out of their containers or dumpsites and spread through the environment.

Costs in Perspective

While the costs of containing, repackaging, and monitoring the vast inventory of dangerous materials left by nuclear weapons production seem staggering, they cannot be avoided. In fact, the bulk of the costs will be spread across several decades, making the annual expenditure small compared to many other national programs.

For example, the United States is now spending about $270 billion per year on military programs, even though the primary justification for such a large diversion of resources—the Soviet Union—is gone. Weapons with no plausible military mission cost the nation far more than DOE's $6 billion annual environmental management budget.

Many other national commitments have had costs in the range of the DOE cleanup. For example (in estimated 1994 dollars):

- Nuclear weapons production consumed about $375 billion.
- The direct, immediate cost of the Vietnam War was about $600 billion.
- $100 billion was spent on the Apollo space program.
- The B-2 bomber will cost more than $45 billion for 20 aircraft.
- Building the federal highway system required about $1,000 billion.

Managing radioactive waste and cleaning up contamination should be seen as an investment in the health of present and future generations. While difficult to trace, the additional commerce and industrial efficiency attributable to the highway system are widely recognized as substantially outweighing the construction costs. Similarly, the benefits of avoided health risks (including possible public health disasters), of land and ecosystems that do not become heavily contaminated, and of protracted legal battles that do not take place—are difficult to estimate in cash terms. However, adequate investment and responsible handling of radioactive materials can lead to benefits that far exceed the costs.

Environmental remediation projects can reduce public radiation exposures, but could also increase health and safety risks to workers. Workers' exposures can be reduced by improving worker safety standards and enforcement under the DOE's Office of Environment, Safety and Health. Workers should also be given better information and training, and more say over workplace conditions. Technological innovations might also improve health and safety conditions, through using robotics to handle wastes, for example.

Some former weapons plants and sites probably should not be used by humans in the foreseeable future. In some cases, instead of tearing down buildings at great expense, with likely risk to workers and generation of large quantities of waste, it might be more feasible to fill and encase the buildings with concrete, seal in contamination as well as possible, and prevent human access indefinitely.

Some areas of land might be too polluted for homes or farms, and trying to clean them might expose workers to radiation, spread contamination, and damage ecosystems. Often such sites now serve as *de facto* wildlife preserves, and perhaps should be given that status officially. For example, at the Savannah River Site a large pond that was used for reactor cooling water now contains sediment contaminated with radioactive cesium. Draining and dredging the pond would be expensive, could expose workers to radiation, and could destroy a valuable resource for migratory birds and other animals. A better solution might be to physically restrict public access near the pond for about 100 years, allowing most of the cesium to decay away. However, such a decision is not the DOE's alone. It would require the cooperation of regulatory agencies and citizen advisory boards, using the best available knowledge of risk comparisons and of realistic prospects for preventing access to contaminated areas.

In some cases the best solution might be to leave materials in place and restrict land use.

Hasty cleanup efforts, particularly those undertaken without independent review, can actually spread contamination. At the Rocky Flats Plant, one of the largest off-site releases of plutonium stemmed from the removal of soil from a contaminated area within the site. This cleanup was the result of a "risk-based" priority-setting process. It failed because the potential for dust to be scattered by high winds typical at the site was not taken seriously.

At best, cleanup might restore a site to a pristine condition, usable for any purpose. Since many sites requiring cleanup probably cannot be returned to a "green field" state at any reasonable cost, an intermediate goal might be to identify maximum acceptable levels of contamination in order to reach regulatory compliance or be considered safe for certain kinds of usage. However, the regulatory framework for radioactive substances in the environment is incomplete and inconsistent.[11] Regulation must somehow account for the various biological pathways and potential for biological damage of the many different radioactive materials.

Welcome Changes at DOE

Among current Cabinet officials, Energy Secretary Hazel O'Leary appears the most committed to policies of accountable government. DOE reform efforts that deserve strong support include:

- **Public Involvement** – A series of frequent public hearings, extension of institutions such as Site Specific Advisory Boards, and better responsiveness toward citizens are solid first steps toward building trust and utilizing outside perspectives.
- **Openness Initiative** – Many historical documents have been declassified, and current activities are becoming more accountable.
- **Contracting Reform** – The DOE has initiated changes designed to increase competition, save taxpayer dollars, and encourage environmental professionals rather than weapons producers to do environmental work.
- **Improved Internal Oversight** – DOE has promised to hire several hundred project engineers to oversee cleanup contractors.
- **Whistleblower Initiative** – Officials at DOE headquarters and at some major sites have adopted a policy of "zero tolerance for retribution" against employees who call attention to safety problems or mismanagement.
- **Ending Production and Testing** – Secretary O'Leary has supported the nuclear testing moratorium and has recognized that the country does not need to rush into building a New Production Reactor for making more tritium. Such a project would create additional waste to be managed for centuries.

While these initiatives help the United States adjust to the end of the Cold War, their long-term success is far from automatic. An entrenched bureaucracy continues to oppose reform, and only a fraction of DOE's secret documents have yet been declassified. Weapons contractors such as Lockheed and Martin Marietta repeatedly receive environmental management contracts at major sites. Weapons designers, particularly at the Los Alamos and Lawrence Livermore National Laboratories, continue to lobby for research and development of new warheads. A combination of military, business, and political interests persist in a form of "industrial socialism." Those in government who seek reform deserve active support from citizens, policymakers, and the news media.

The DOE "Cleanup" Budget

DOE's Environmental Management (EM) budget grew rapidly after the end of the cold war. Some of this expansion reflects a change in national priorities from making nuclear arms to cleaning up after them and watching over their radioactive and toxic leftovers. Funding increases, however, do not always reflect changes in activities. Much current EM work was previously part of "Defense Programs" (DP) and would have continued in any case.

Examples of programs that have largely shifted from DP to EM with little change in mission include: 1) **Waste Management** (transferred from DP to EM beginning in the 1980s); 2) **Facility Transition** (primarily consists of maintaining obsolete buildings to prevent them from releasing contaminants or putting future cleanup workers at risk); 3) **Uranium Enrichment Decontamination and Decommissioning** (indicating official recognition that some of these huge plants will not be operated again); 4) **Environmental Restoration** (increases in this category – the actual "cleanup" part of the budget – largely reflect DOE's obligation to begin complying with the same regulations that govern other polluting industries).

DOE's Environmental Management Budget

(millions of 1995 dollars)*

Activity	FY90	FY91	FY92	FY93	FY94	FY95
Waste Management	1,548	2,344	2,732	3,577	3,115	3,090
Environmental Restoration	780	1,265	1,265	1,984	1,896	1,914
Facility Transition	0	0	0	19	695	848
Technology Development	218	271	336	388	411	419
Uranium Enrichment D&D	0	0	0	0	296	301
Program Direction	16	37	27	54	95	85
Corrective Activities	124	216	134	66	27	27
Transportation Management	14	17	21	21	20	21
Prior Balances and Efficiency Savings	0	-18	-28	-196	-187	-567
TOTAL	**2,701**	**4,132**	**4,752**	**5,914**	**6,368**	**6,138**

* 3.5% average inflation rate applied over the period.

Source: DOE budget data, 1994. Minor discrepancies are due to rounding and changes in budget categories.

Guidelines for Action

Cleanup action must proceed subject to an honest understanding of what is and is not known, with full disclosure to stakeholders, and with their participation in the planning and implementation process. The DOE's environmental programs should follow these guidelines:

- Treat waste as if final disposal methods will never be available.
- Avoid creating new waste.
- Invest in research to support realistic risk comparisons as they relate to cleanup at individual sites.
- At each site, with stakeholder participation, determine "how clean is clean" and establish guidelines to determine when that goal has been reached.
- Determine whether a particular site should be decontaminated, given current knowledge of probable risks and costs. Consider alternative scenarios for future land use.
- First clean up contamination that either poses immediate risks or could be costly and hazardous later if neglected.

In 1988 the DOE estimated a total cleanup cost of $66 billion to $110 billion. Some recent analyses project eventual costs exceeding 300 billion dollars.

Calculating the Costs

About six billion federal taxpayers dollars per year are now directed toward the DOE's environmental management program. Estimates of the total cost of coping with the Cold War's radioactive legacy have escalated rapidly. In 1988 the DOE estimated a total cleanup cost of 66 billion to 110 billion dollars.[12] Some recent analyses project eventual costs exceeding 300 billion dollars.[13] As mandated by Congress, the DOE is expected to publish a "Baseline Environmental Management Report" by the end of March 1995 that will provide new cost estimates, perhaps as high as one trillion dollars, for a range of cleanup scenarios.

Unanticipated future problems at DOE sites could increase cleanup costs. On the other hand, new technologies might reduce dramatically the costs of some projects. By definition, both of these factors are unpredictable. Unfortunately, recent Administration proposals to reduce the DOE Environmental Management budget by about 4.4 billion dollars during the next five years are likely to jeopardize the nation's investment in more efficient cleanup methods while increasing the potential for costly accidents.

Aside from political pressures that often work against taking a rational long-term view, several variables affect the difficulty and cost of waste handling and decontamination:

- **Waste characteristics** – During the Cold War, the compositions and locations of wastes that were stored, dumped, or buried often were not recorded accurately. Now there is uncertainty about chemical interactions among waste forms and about the rates at which contamination spreads.
- **Radiation standards and regulations** – This is another way of considering the question, "How clean is clean?" Levels of "acceptable risk" near waste storage sites are unclear, as are the regulations governing residual contamination allowed after cleanup. For example, the government is currently considering "acceptable" lifetime cancer risks in the range of one in 10,000 to one in a million, a 100-fold disparity.[14]
- **Contracting** – Costs can be reduced if procurement contracting is reformed in order to increase competition, penalize waste and fraud, bring in environmental professionals, and clearly specify performance standards.
- **Research and Technological development** – Unforeseen advances might lead to better and cheaper waste disposition and environmental cleanup methods. "Hard science" can also provide a basis for comparing environmental programs. It should offer not only numbers but measures of the uncertainty in those numbers. Research directed toward reducing uncertainty could reduce costs by helping prevent wasted cleanup effort in some cases and excessive risks in others.

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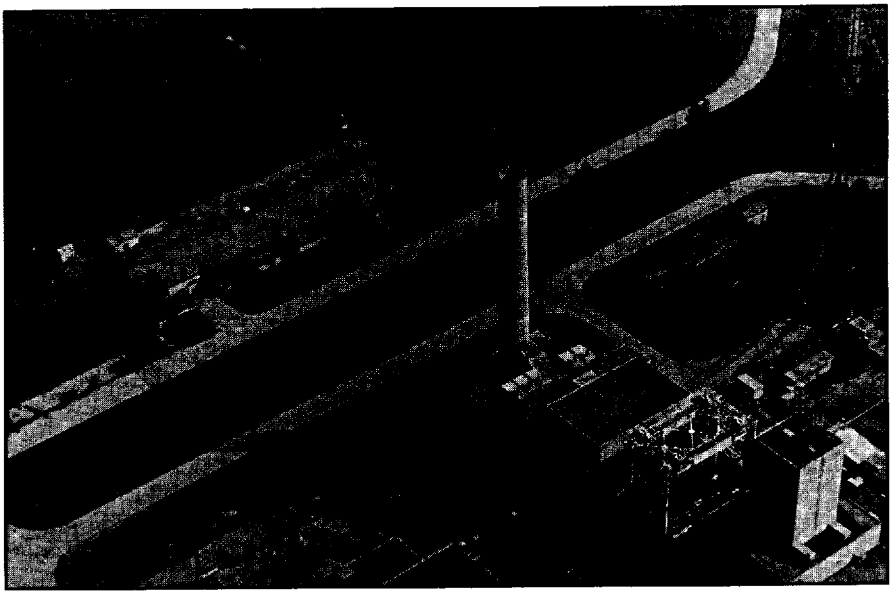

Robert Del Tredici photo

Hundreds of facilities such as this obsolete plutonium production reactor in South Carolina require costly maintenance, then decontamination and dismantlement.

- **Future land use decisions** – Cleanup resources might be used more effectively if citizens, regulators, and the government could agree that some contaminated sites should be fenced off indefinitely or restored for limited use. Environmental restoration costs as well as waste volumes are influenced strongly by decisions about future land use. Depending on whether land is decontaminated for restricted or unrestricted uses, cleanup could generate from two million to 30 million cubic meters of additional waste, in other words from 2.5 to nearly 40 times the current inventory.[15]

The risk of a massive misallocation of resources, and the fact that the burden of waste and contamination was created in the name of national security, mean that effective cleanup is a national responsibility and an obligation to aid those who now face hazards.

PART TWO: Improving our Chances of Success

Many factors can contribute to more effective cleanup. This section deals with three critical issues: the danger of over-reliance on current risk assessment methods and the need to improve them; the importance of contracting and procurement reforms; and the value and necessity of informing and involving citizens in key decisions.

Risk assessment should be approached with healthy skepticism, and it must be performed in the true scientific spirit of openness to responsible criticism.

Risk Assessment

Recently, "risk assessment," an attempt to quantify and compare the health and safety effects of various waste and contamination scenarios, has been promoted for measuring the likelihood of health and environmental harm, and for setting priorities for the use of limited resources. In the abstract, this approach has promise. In reality, however, priority rankings based on seemingly quantifiable differences between the worker and public risks associated with thousands of waste sites could be meaningless.

Risk assessment should be approached with healthy skepticism, and it must be performed in the true scientific spirit of openness to responsible criticism. Understanding the risks imposed upon human populations by a particular waste dump or contaminated site is complicated and fraught with uncertainty. Often the physical characteristics of the radioactive or toxic materials are not well understood, nor are the durability of containers, the various biological pathways, or future land use patterns. The wide variety of contamination problems, as well as natural and demographic features at each

DOE site, undermine the notion that a standardized, risk-based ranking of projects is the best way to bring efficiency and wisdom to cleanup management.

Some combinations of events are nearly impossible to anticipate, and the likelihood of accidents is often underestimated. Every step in risk assessment entails uncertainty and the possibility of faulty or value-laden assumptions.

With so much uncertainty in the data and its interpretation, many citizens fear the possibility of risk-based decisions that would favor foregone conclusions by the government, lead to neglect of environmental work at some major sites, or ignore social and land use issues missing from "scientific" analyses. For example, current risk-based approaches to priority setting sometimes assume no changes in population distributions. This can impart a short-term bias to cleanup decisions and increase long-term costs and risks.

Even the best risk numbers can rarely be trusted to within ten percent and often they are uncertain by a factor of two or more.

There remains a wide range of legitimate disagreement over how to interpret imprecise risk estimates, particularly when large populations are exposed to low doses over long periods. There is also no accepted mathematical model for comparing voluntary and involuntary risks. Even the best risk numbers can rarely be trusted to within ten percent and often they are uncertain by a factor of two or more. This uncertainty means that as a way of setting goals and priorities for environmental remediation, risk assessment cannot substitute for efforts to build a political consensus based on realistic estimates of human health threats.

When risk assessment is used to help make cleanup decisions, policy-makers and stakeholders should ensure that several key guidelines are followed:

- All risk numbers must be accompanied by data references, explicitly stated assumptions at each stage of estimation, and descriptions of both uncertainty and the sources of uncertainty. The methods used in calculating risk, as well as the interpretation of results, must be subject to open review, a key element of science at its best. This approach is essential not only to gain public understanding and cooperation, but to guide research that might improve accuracy.
- Risk assessment should be seen as one of many tools for decision-making, rather than as a source of final authority.
- Contractors who have a financial stake in the outcome of cleanup decisions should not perform risk assessments. While no responsible researcher is likely to deliberately falsify data, unconscious biases could affect assumptions and the interpretation of results. Even the appearance of a conflict of interest is likely to lead to delays and public opposition that could be avoided by assigning research work to a truly independent entity.

"Risk Communication" and Public Trust

The relatively new field of "risk management" has often been seen by the nuclear industry as primarily a matter of "risk communication." According to this approach, if only everyone could be convinced that radiation hazards are small compared to voluntary hazards such as cigarettes or automobiles, then the public would accept those risks and cooperate with the projects in question. This approach has failed consistently.

Systematic abuse of the public trust during the Cold War has given citizens ample reason to question simple assertions about the hazards they are asked to bear. Too often, "public participation" has consisted of site managers developing their preferred plans, then presenting them in a public meeting and saying, in effect, "If you don't like this, come up with something better." Citizens, who have had neither the time nor resources to explore alternatives, usually object to this way of reaching decisions. Plant managers often seem to see any opposition as proof of public naiveté, and sometimes try to avoid further public involvement. Only by accepting shared responsibility for decisions can government, contractors, workers, and citizens attain mutual trust.

The White House and Congress have failed to exert meaningful control over contractors, leaving this handful of private entities to operate as a kind of "shadow government."

Contracting Reform

The Role of Contractors

The nuclear weapons complex is dominated by large contractors that specialized in weapons production and now operate under too little DOE control or outside oversight. A system of minimal governmental control was established in the late 1940s by the Atomic Energy Commission, which believed that this would encourage contractor initiative and responsibility. Instead, inadequate oversight led to waste and mismanagement that continues today. Contractors too often specify what the DOE needs to buy and the department serves as a passive benefactor. A continuation of this system will increase health and safety hazards and waste billions of dollars.

The DOE spends about 16 billion dollars annually on contractors that manage and operate its various sites. More than 60 percent of these funds have gone to the top five contractors. Each received from 1.3 billion to 2.9 billion dollars in fiscal year 1993.[16] Most of the DOE's top environmental contractors are also contractors for nuclear weapons production work.

The White House and Congress have failed to exert meaningful control over contractors, leaving this handful of private entities to operate as a kind of "shadow government." Contractors have lobbied for profitable projects, influenced members of Congress, written official reports, developed policy positions, and contributed to the excesses of the Cold War. Dominant DOE contractors have grown too comfortable in a system allowing little or no competitive bidding. They rarely pay penalties for mismanagement or even for serious legal violations.

Official secrecy, lack of competition, weak oversight, and cost-maximizing profit incentives have all contributed to waste and inefficiency. Now that the DOE's mission is changing from nuclear weapons production to waste management and cleanup, the same contractors continue to dominate. Their inefficiency is worsened by their inexperience in cleanup work. The culture and skills of weapons production are not suited to the technical and public aspects of environmental work.

The culture and skills of weapons production are not well suited to the technical and public aspects of environmental work.

Since the late 1980s, when accumulated waste and contamination began to receive serious attention, there have been numerous cases of environmental mismanagement and incompetence. Prime contractors at several major sites have been forced to leave in disgrace, disrupting cleanup work and generating costly court cases.[17] Headline stories about cost overruns and lack of progress have fueled concern in Congress about the value of the entire program.[18] Ironically, if this bad press leads to major budget cuts or a shift of funds back to "defense programs," thus causing a sacrifice of environmental management reforms, cleanup will become even more costly and hazardous in the long run.

Secretary O'Leary and her staff have begun a contracting reform initiative in an attempt to cope with widespread inefficiency and abuse. The DOE is now hiring up to 1,200 qualified professionals to manage contractors and to measure their performance. For its procurement reform to be successful, the DOE also needs to:

- **Increase oversight** – The DOE's contractor employees outnumber its government staff by up to 40 to one. The federal staff is too small to adequately monitor contracts for waste and fraud. The Government Accounting Office also estimates that the total cost of an average federal employee is about 40 percent (or $50,000 per year) less than a contractor. In a recent letter to the Office of Management and Budget, Assistant Secretary of Energy Thomas P. Grumbly wrote:
  "*Our contractors are currently in control of our program planning and management processes, and we do not have adequate project management mechanisms that are run and overseen by qualified and capable federal employees.*"
- **Frequently re-compete prime contracts** – A distinct possibility of not having contracts renewed is a necessary incentive for better performance. Some contractors have managed the same sites for decades.

- **Eliminate self-evaluation** – Contractors have undue influence over their award fees. Firms should not be allowed to write their own performance evaluations or control their work plans. Under the priciple that sunlight is the best disinfectant, projects and performance measures must be developed publicly; contractors must be evaluated against an established baseline; and performance must be subject to public review and comment before award fees are granted.
- **End site monopolies** – Instead of giving one large contractor control over each major site, DOE managers reporting to headquarters should assume that role. By dividing the work into well-defined tasks when possible, competition would not be limited to the few contractors that can afford to go through a complicated proposal process and then take on massive projects.

  However, subcontracting is not a panacea. Oversight is needed in order to prevent pyramiding of labor surcharges. Direct control over subcontractors is also necessary for reversing the deterioration of worker health and safety that is already apparent at many sites.[19] High employment turnover increases accident rates. The DOE must resolve the conflict between procurement reform and the risk of losing long-term employees who retain an institutional memory of the hazards at each site.
- **Bring in environmental professionals** – Contractors must demonstrate successful experience in managing environmental projects. Success at a Superfund site, however, does not imply success in handling nuclear waste or plutonium.
- **Reward efficiency and innovation** – The DOE has typically used a "cost-plus" fee structure, which gives contractors incentives to maximize costs (including excessive layers of overhead) in order to maximize profits. This is the opposite of competitive market conditions, where profit depends on minimizing costs. The DOE should reward contractors for finding more efficient methods of reaching specific objectives, perhaps by splitting the savings with them. However, constant oversight is necessary to counter contractors' temptations to overstate time and money requirements in order to win awards for "saving money" later. The DOE's Inspector General has already reported such cases of corrupting the system at sites in Idaho and Nevada.[20]

Information and Public Involvement

A Heritage of Secrecy

Shortly after World War II the existence of the nuclear weapons program was acknowledged, but virtually no information about its waste and contamination problems was released. Citizen pressure, media attention, and lawsuits by public interest groups brought a major wave of revelations during the late 1980s. Under the Clinton Administration's

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"openness in government" policy, DOE Secretary O'Leary released significant volumes of previously secret information in 1993 and 1994. A litany of carelessness, blithe assumptions, and illegal activities has now been revealed.

History shows that the closed, unaccountable Cold War institutions that successfully created a massive nuclear arsenal performed poorly in health, safety, and environmental protection. Weapons production bureaucracies have continued to demonstrate that they cannot do effective cleanup work or spend public money wisely unless they are closely supervised. Recently, however, important steps have been taken to introduce public scrutiny to the cleanup process.

Advisory boards play a vital role in risk assessment and planning.

Site-Specific Advisory Boards

One effective approach to openness, the Keystone Dialogue, was initiated in 1991.[21] In the interests of resolving disputes over how to prioritize the nation's federal facility cleanup responsibilities, representatives from federal agencies, state regulatory officials, Native American leaders, and national and local environmental organizations were brought together. In 1993 the dialogue members published an interim report recommending public access to information, stakeholder involvement in decision making, and equitable resource allocation among sites.

Several federal agencies including the DOE and the Department of Defense have begun to implement the main recommendations of the 1993 report. Establishment of Site Specific Advisory Boards (SSABs) was recommended as a crucial first step. SSABs have been set up at many major sites.

Peter Gray photo

The Rocky Flats Plant near Denver, Colorado has large accumulations of plutonium scrap, contaminated production equipment, and plutonium-contaminated waste.

Advisory boards play a vital role in risk assessment and planning, site by site. But citizens who work with SSABs need technical assistance and access to information in order to effectively be involved in decision-making.

Some additional elements of democratic process are also needed to address nuclear waste and contamination:

- **First things first** – DOE managers have sometimes presented a limited, self-selected range of options, and inadequate time and information for making decisions. This approach, described as "decide, announce, defend," has undermined public trust. Broad consensus is necessary on how decisions will be made. Without that foundation, agreement on policy outcomes is unlikely.
- **Public Education** – The release of information on the nuclear weapons complex during the Clinton Administration is a welcome change, but it presents new problems. People living near DOE sites often have difficulty comprehending huge quantities of technical documents. SSABs are beginning to fill the information gap, but coordination among sites is inconsistent, leading to and redundant effort on broad issues such as risk assessment. One solution might be to establish a national technical advisory panel that could provide information and training, as well as help the SSABs work together. A joint venture of government and private philanthropies to sustain such an information effort could be credible and effective.
- **Decision-making role at every stage** – Citizens and independent experts must have their concerns taken into account during all phases of decision-making. This will not only build trust and understanding but could help identify faulty projects before large sums of money are wasted. Activists have already saved billions of taxpayer dollars by blocking ill-conceived projects such as the "grout vault" disposal plan at Hanford.
- **Fairness** – Institutions for public involvement must be designed carefully in order to give voice to a wide range of ideas and concerns. The DOE term "stakeholder" must cover the spectrum of people affected by decisions, not just those who have strong financial interests.
- **Oversight costs** – Private industries are typically required to set aside about 2-4 percent of any cleanup budget to pay for regulatory oversight. DOE cleanups, which are more complicated and more prone to abuse, have paid for oversight at rates 4-8 times lower.[22]
- **Procurement and contracting information** – Requests for proposals, contracts, bids, award fee schemes, and incentive structures should be made public. Planning documents that describe the logic behind projects should be formulated using independent suggestions and then be made available to all interested citizens.

Activists have saved billions of taxpayer dollars by blocking ill-conceived projects.

PART THREE: Summary of Recommendations

The environmental legacy of the nuclear arms race will require a national commitment comparable to that devoted to producing the weapons themselves. The reform initiatives announced by Energy Secretary O'Leary are unique. They deserve strong support, but more policy changes are needed. A sound cleanup policy should contain the following elements:

The environmental legacy of the nuclear arms race will require a national commitment comparable to that devoted to producing the weapons themselves.

Basic Goals

- Recognize that "cleanup" largely consists of containing and monitoring large inventories of waste for the indefinite future. Waste should be identified, isolated, stabilized, and monitored to the best extent possible, with recognition that permanent repositories might not be available for many decades.
- At each site, with stakeholder participation, determine "how clean is clean" and establish guidelines to determine when specified goals have been reached.
- Decide whether particular sites should be decontaminated, given current knowledge of probable risks and costs. Consider alternative scenarios for future land use.
- First clean up contamination that either poses immediate risks or could be costly and hazardous later if neglected.
- Use a technology development strategy that encourages innovation and utilizes existing environmental expertise. Research should emphasize putting waste into relatively stable forms for interim storage, rather than on rushing ahead with permanent repositories. "Interim storage" of waste should be managed under more conservative and realistic assumptions about the feasibility of permanent disposal. On-site storage methods should reflect the likelihood that permanent repositories will not open for many decades. Research into efficient decontamination and environmental remediation is also needed.
- Develop an enforceable mechanism to ensure that federal commitments to environmental management and to honoring the terms of existing cleanup agreements are kept.
- Recognize and account for the eventual waste and contamination when considering any nuclear weapons development, testing, or production program.

Costs

- Resist pressures to transfer cleanup funds to meet other projected budgetary needs. Cleanup is an enormous task and delay will only increase dangers to humans and the environment, and will dramatically increase long-term costs.
- Increase funding for oversight of DOE programs by the Environmental Protection Agency, Occupational Safety

and Health Administration, states, and tribes. Regulatory oversight is a sound investment in preventing mismanagement and waste. Its cost should be built into every cleanup project.

- Promote full, consistent public involvement in decisions regarding risk, land use, and the sequence of restoration activities. Costs have often been increased by a secretive process that suffers from a narrow perspective and leads to decisions that are subject to legitimate dispute.

Avoiding Misuse of Risk Assessment

- Acknowledge the current limits of scientific knowledge and place a higher priority on basic research to support better risk assessment and decision making. A truly scientific approach depends upon open debate among well informed independent reviewers, as well as adequate funding for basic research.
- Invest in research to support realistic risk comparisons as they relate to cleanup at individual sites.
- Award risk assessment contracts to entities other than those with a financial stake in the outcome of cleanup decisions.

Contracting Reform

- Overhaul DOE contracting practices in order to attract qualified environmental professionals and combat waste and mismanagement.
- Reassert DOE managerial control over contracting practices, the scope of work, and over tasks that entail a contractor conflict-of-interest, such as risk assessments, financial auditing, and performance evaluations.
- Do not place too much reliance on subcontracting to cure DOE's procurement problems. Subcontracting can improve efficiency in some cases, but it can also add costly layers of overhead and threaten worker health, safety, and institutional memory.
- Frequently re-compete contracts for environmental work, with aggressive oversight to prevent systematic abuses and a "multiplier effect" on labor charges and other costs.
- Develop sound alternatives to "cost-plus" fee structures, which encourage contractors to maximize costs in order to maximize profits. The DOE should reward contractors for finding more efficient methods of reaching specific objectives, perhaps by splitting the savings with them. This too will require constant oversight in order to prevent abuse.

Public Involvement

- Provide the means for reaching a broad consensus on how decisions will be made. Without this crucial step, there is little prospect of agreement on the decisions themselves.
- Give the public consistent access to information, training in how to interpret it, and a stronger system of public involvement in setting cleanup priorities and standards.

Citizens and officials who are working on behalf of present and future generations to take responsibility for the nuclear weapons legacy deserve the full support of the nation.

- Ensure strong oversight by citizens and independent experts at all stages of cleanup decision-making. Citizen involvement must be ensured through advisory boards and other mechanisms, as outlined in the Keystone Dialogue report.
- Design institutions for public involvement carefully in order to give voice to people with a wide range of ideas and concerns, not just those who have strong financial interests.
- Write planning documents that describe the logic behind projects and the rationale for contract provisions. This material should utilize independent suggestions and it must be made public.
- Expand the release of documents on current operations as well as historical data.
- Re-examine assumptions about what needs to be classified, in light of the end of the Cold War.

Containing radioactive waste for the long term, cleaning up contamination, and gaining public trust are daunting tasks, but they are not impossible, nor are they beyond the grasp of democratic process and cooperation. A problem 50 years in the making will not be solved overnight, but the first steps toward openness, accountability, and rational decision-making are beginning to bear fruit.

Citizens and officials who are working on behalf of present and future generations to take responsibility for the nuclear weapons legacy deserve the full support of the nation.

APPENDIX A: Elements of the Problem

A Pyramid with a Uranium Foundation

Designing, manufacturing, and testing nuclear weapons requires a vast and complicated industrial enterprise. The United States designed dozens of different nuclear warheads and bombs, manufactured about 70,000 of them in total, exploded more than 1,000 in tests, and had standing arsenals of as many as 32,500 weapons.[23] The flow of raw and processed materials through the nuclear weapons complex can be visualized as a pyramid with a base of uranium ore and a relatively small volume of final weapon components at its peak.

By splitting uranium and other elements into highly radioactive isotopes (versions of natural elements distinguished by their atomic weights), nuclear reactors created wastes with radioactivity roughly 1,000 times greater than that of the raw material. The accumulations of waste from nuclear weapons production can be measured in terms of their physical volume, radioactivity (in curies, a measure of the number of radioactive disintegrations per second), or potential threat to human health and the environment.

Uranium Ore

The foundation of the production complex is the uranium ore that was mined for military purposes. Hundreds of mines and several dozen mills were devoted to nuclear weapons production from 1942 until 1971. More than 99 percent of this ore ended up as uranium mill tailings, a sandy material that was left in open piles. Mill tailings containing radioactive and toxic metals constitute about 90 percent of the DOE's total waste volume – roughly 45 million cubic meters (or about 1.5 billion cubic feet)[24] of pulverized rock left in open piles – enough material to make 17 piles the size of the largest Egyptian pyramid.[25] Many millions of dollars have been spent to prevent tailings from being dispersed by wind and water, and to reduce risks where this radioactive material was used in construction.

Uranium Metal

About 250,000 metric tons[26] (the metric ton, 1,000 kilograms or 2,205 U.S. pounds, is used throughout this document) of uranium were extracted from the ore, forming the next level of the pyramid. Several factories, including the heavily contaminated Fernald Plant near Cincinnati, Ohio, were devoted to uranium refining and metallurgy. These facilities produced fuel elements and "targets" for use in reactors, and they made uranium hexafluoride that was fed into enrichment plants.

Highly Enriched Uranium

Roughly half of the total uranium purchased by the government went through a costly "enrichment" process in order to concentrate the less common and more unstable "fissile" form called uranium-235, which can support a nuclear chain reaction in a weapon or reactor. About 1,000 tons of highly-enriched uranium (or HEU, generally containing more than 90 percent U-235) were produced by three plants at Paducah, KY, Portsmouth, OH, and Oak Ridge, TN. These are among the largest structures ever built. HEU is more radioactive than natural uranium, and as a crucial weapons ingredient it poses additional safety and security problems. About 75 percent of U.S. HEU was used directly in weapons, and most of the remainder was used as fuel for reactors used in naval propulsion and plutonium production. Enrichment caused extensive contamination and left behind tens of thousands of tons of unstable uranium hexafluoride stored in steel cylinders. Simply maintaining the buildings, machinery, and uranium storage tanks and vaults until they are dismantled is an expensive commitment.

Plutonium: Smaller Product, More Radioactivity

At higher levels of the weapons complex pyramid, the physical quantity of product material is smaller, but the radioactivity of the products and their associated wastes increases dramatically.

About half of the Atomic Energy Commission's uranium was not enriched, but was made into fuel for nine plutonium production nuclear reactors at Hanford in Washington state. Some HEU, along with large quantities of the "depleted" uranium byproduct of enrichment, supplied another five large production reactors at the Savannah River Site in South Carolina. Depleted uranium is somewhat less radioactive than the natural or enriched forms, but all uranium is a toxic heavy metal.

Plutonium is not available naturally and must be created by irradiating uranium in nuclear reactors. All nuclear reactors, including those dedicated to making plutonium, release energy by splitting uranium into a wide variety of isotopes, most of which are unstable and highly radioactive. Spent fuel discharged from reactors is among the most radioactive material on the planet.

The government produced about 100 tons of plutonium for weapons between the early 1940s and the late 1980s. Water from the Columbia and Savannah Rivers that was used to cool the 14 U.S. production reactors while they operated became contaminated with radioactive byproducts. Obsolete reactors will be expensive and hazardous to decontaminate and decommission. Meanwhile, the reactors must be maintained and guarded.

Eight chemical processing buildings known as canyons, each 800 to 1,000 feet long, were used to extract plutonium and uranium from reactor discharge material. By the end of the 1980s, these plants had generated an inventory of more than 100 million gallons of "high-level waste" (HLW). This material represents the great majority of total DOE waste radioactivity.[27] The primary constituents of HLW have decay half-lives of about 30 years, which means that the waste's radioactivity will decrease by a factor of 1,000 after 300 years. Even then, however, HLW will be very dangerous to any unshielded people who might come in contact with it, especially in the concentrated forms in which it is likely to be stored.

Weapons-related high-level waste has been stored in large steel tanks and bins at Hanford, Savannah River, and the Idaho National Engineering Laboratory. These tanks were not designed for long-term containment. Many have corroded and leaked. Unanticipated chemical reactions in some tanks, along with hydrogen gas generated by radioactive decay, have created the potential for explosions that could spread intensely radioactive fallout over wide areas. A mixing pump installed in the highest-risk tank at Hanford has reduced the chances that it will explode, but several other tanks remain risky.

A Multi-Thousand-Year Commitment

Coping with the byproducts of plutonium production has consumed billions of dollars, but most of the work lies ahead. Most plutonium scrap, residues, and plutonium-contaminated wastes have not been put into relatively stable forms suitable for long-term storage, and no final repository has yet proven technically and politically acceptable. Surplus plutonium components will also cause headaches for the conceivable future.[28] This synthetic metal, crucial to nearly all modern nuclear weapons, requires 24,000 years for its radioactivity to decay by half, causes cancer in tiny quantities if inhaled as a dust, and can ignite spontaneously when exposed to air. If more than a few kilograms are placed in close proximity, plutonium will begin a chain reaction that emits intense radiation. Plutonium must also be guarded carefully against theft.

Tritium: Fancier Bombs and More Waste

Other nuclear weapon ingredients have left additional legacies of waste and contamination. Less than 200 kilograms of tritium, a highly radioactive gas used to multiply the explosive power of weapons, are estimated to have been made in the United States during the Cold War. Tritium is highly radioactive, and hundreds of thousands of curies[29] of it were routinely released to the air and water around the Savannah River plant where it was manufactured, increasing the radiation exposure to citizens in a large region. Tritium production required the equivalent of at least one large reactor running full time for more than 30 years, generating many thousands of tons of extremely radioactive waste.[30]

Other Materials

In addition to the radioactive raw materials, final products, and wastes generated by reactors and chemical separation plants, the nuclear weapons complex used, dumped, and released into the environment many toxic metals, solvents, and acids. Beryllium, for example, is a key component of many nuclear weapons, and it is extremely toxic. The government purchased between 40,000 and 120,000 tons of lithium concentrate and enriched most of it in order to extract about 400 to 1,500 tons of Lithium-6 metal, a relatively rare non-radioactive isotope used in tritium production and directly as a weapon ingredient. Lithium processing is said to have required most of the entire world's stockpile of mercury during the 1950s.[31] According to DOE estimates, more than 1,000 tons of mercury, a poisonous heavy metal, have been released into the environment around Oak Ridge, Tennessee. At many sites, toxic organic solvents were dumped onto or injected into the ground and have contaminated groundwater aquifers.

APPENDIX B: Kilograms and Curies

Quantity of Process Material

Material	Kilograms
Uranium Ore	60,000,000,000
Natural Uranium**	250,000,000
Natural Lithium**	22,000,000***
HEU+	1,000,000
Lithium-6	390,000***
Plutonium	100,000
Tritium	180

Waste Radioactivity

Process	Curies*
Uranium Milling	109,000
Uranium Enrichment	17,500
Fuel/Target Fabrication	1,594,000
Target Irradiation	788,000++
Reprocessing	1,042,084,000
Parts Mfr., Assembly	4,745,000
Research and Testing	2,386,000++

Sources: *Nuclear Weapons Databook, Vol. II*, Natural Resources Defense Council, 1987; US Department of Energy; "Integrated Data Base for 1993," DOE/RW-0006, Rev. 9 (Draft), March 1994.

* One curie represents 37 billion radioactive disintegrations per second.

** Uranium or lithium metal equivalent.

*** These are considered minimum estimates–actual quantities could be higher.

+ Highly enriched uranium.

++ Wastes in these categories include significant quantities of "Materials Not Categorized as Waste." Some of these materials were formerly considered economically recoverable, but with the end of the Cold War they are likely to be redesignated as waste.

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17. See, for example, "Showdown at Rocky Flats," by Barry Siegel, *Los Angeles Times Magazine*, Aug. 8, 1993.
18. Fiascos involving the new managing contractor (Fluor Daniel) at Fernald were reported on the front page of the June 30, 1994 *The Wall Street Journal.*
19. *"Checking its Common Sense at the Door": FERMCO's Abuse and Mismanagement of its Contract with the U.S. Department of Energy*, Fernald Atomic Trades & Labor Council, 1994.
20. Report on Inspection of the Cost Reduction Incentive Program at the Department of Energy's Idaho Operations Office, Office of the Inspector General, U.S. Department of Energy, July 1994.
21. Formally called the Federal Facility Environmental Restoration Dialogue Committee, the Keystone Dialogue is a federal advisory committee to the Environmental Protection Agency.
22. *Facing Reality: The Future of the U.S. Nuclear Weapons Complex*, P. Gray, ed., Tides Foundation, 1992, p 29.
23. "Nuclear Notebook," *The Bulletin of the Atomic Scientists*, May/June 1994, p 62, and Nov./Dec. 1994, p 58.
24. Estimate derived from *Nuclear Weapons Databook II*, Natural Resources Defense Council, p 80, 82.
25. The Khufu Pyramid covers 13 acres at its base and is 482 feet tall.
26. Metal equivalent, derived from *Nuclear Weapons Databook II*, p 80.
27. Derived from DOE Integrated Data Base, 1993, DOE/RW-0006, Rev. 9 (draft), March 1994.
28. *Beyond the Bomb: Dismantling Nuclear Weapons and Disposing of their Radioactive Wastes*, P. Gray, ed., Tides Foundation, January 1994.
29. The curie represents the radioactivity of one gram of pure radium, or 37 billion disintegrations per second.
30. Derived from *Nuclear Weapons Databook II*, p 179-180, and *World Inventory of Plutonium and Highly Enriched Uranium 1992*, by Albright, Berkhout, and Walker, 1993, pp 33, 34.
31. *Citizen's Guide to Oak Ridge*, The Oak Ridge Education Project, 1992, p 7.

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