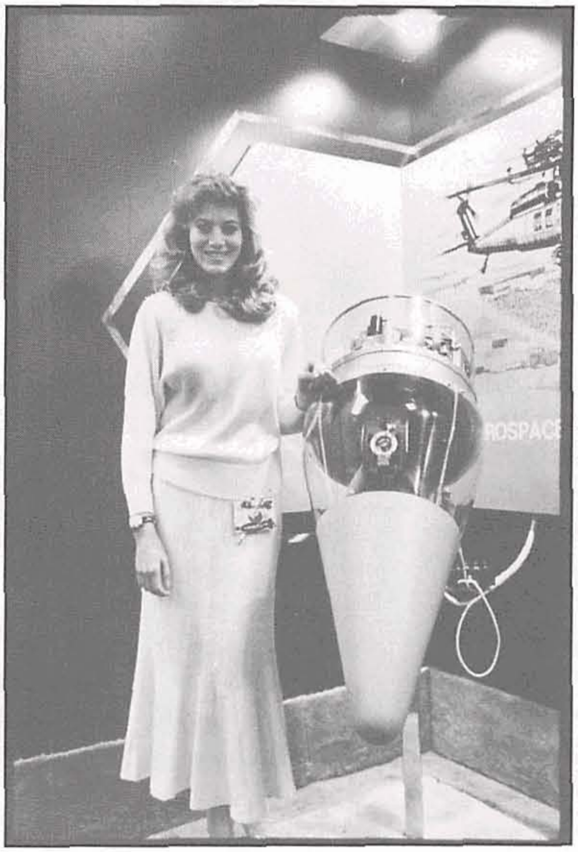
SCIENCE FOR DEMOCRATIC ACTION

an ieer publication

Volume 2, Number 3 Fall 1993



Complex 21: More bombs, anyone?

A terminal guidance system displayed by a Goodyear sales representative. U.S. Army Weapons Bazaar, Washington, DC, 1986

FROM THE BOOK
AT WORK IN THE FIELDS OF THE BOMB
BY ROBERT DEL TREDICI,
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Planning Complex 21: How Many Nuclear Weapons Is Enough?

Arjun Makhijani

Existing facilities to build nuclear weapons in the United States are, by all accounts, obsolete, unsafe and polluting. In September and October of 1993, the Department of Energy (DOE) is holding hearings on its environmental assessment of Complex 21, the new nuclear weapons facilities that it plans to build to sustain the nuclear arsenal well into the twenty-first century. By January of 1995, the DOE will have prepared a Programmatic Environmental Impact Statement on the "reconfiguration" of the nuclear weapons complex, called the R-PEIS, and made its final decisions regarding what plants are to be built where.

The entire exercise is based on an assumed number of nuclear

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EDITORIAL

Reactor Reincarnation

J. Robert Oppenheimer, the scientific director of the Manhattan Project, was one of the witnesses of the awesome first nuclear explosion in the New Mexico desert in 1945.

The experience led Oppenheimer to recite a line from Hindu scripture, "Now I am become Death, the destroyer of worlds." Little did he realize that nuclear reactors would one day achieve reincarnation, a time-honored Hindu belief. Moreover, like the reincarnation of Hindu thought, which stems from a failure to be good (only saints are delivered from the miseries of the cycle of births and deaths), reactors seem to be reborn according to their *karma*; if they are bad and have been punished by cancellation, they come back.

Shippingport

The most common civilian reactor type, the pressurized light

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THIS IS YOUR LAST ISSUE UNLESS...

(DETAILS ON BACK COVER)

Complex 21

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warheads required for the *long-term* security of the United States in the post-Cold War era. This number has enormous financial, security and non-proliferation implications. It has been decided on in secret by the Department of Defense (DoD) and DOE.

There are several ways to estimate the number of nuclear weapons that the DoD and the DOE plan to retain for the long term, all of which point to about 5,000. One way to estimate this number is to consider DOE plans to begin producing more tritium by about the year 2010. That is part of the assumption the DOE is using in the preparation of the PEIS. Tritium is a radioactive gas used in nuclear warheads; it has a half-life of about 12 years. The U.S. stopped producing tritium at the end of the 1980s, when its nuclear arsenal consisted of about 20,000 warheads. The stock of tritium in these warheads would be sufficient to last until 2010 (about 2 half-lives) but only if the arsenal is cut to about one fourth of this size. That would mean new tritium requirements by about 2010.

Planned arsenal maintenance requirements also point to a large number of warheads. In a briefing given to some members of the Military Production Network on August 27, 1993, Howard Canter, Deputy Assistant Secretary responsible for planning the DOE weapons complex, stated that in the past the objective for arsenal maintenance was for the DOE to rebuild each year about five percent of its total number of warheads. He said that planning for Complex 21 is based on a figure substantially less than five percent per year, though the exact figure is classified. He also indicated that it would require industrial-scale facilities to accomplish the job. Since rebuilding a few dozen weapons a year could be carried out in laboratory-scale facilities, the requirement of an industrial-scale plant indicates a rebuilding requirement on the order of a hundred or more weapons per year. This means an arsenal of several thousand weapons.

> *Consideration of U.S. defense and deterence needs in post-Cold War era indicates that an arsenal of 5,000 nuclear weapons is far too large.*

The Pentagon view also appears to be represented in a 1992 work by Thomas Reed, former Secretary of the Air Force, and Michael Wheeler, who has been a special assistant to three chairmen of the Joint Chiefs of Staff. This report concluded that the U.S. should maintain a "strategic weapons inventory number-

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SCIENCE FOR DEMOCRATIC ACTION

Science for Democratic Action is published three times a year by the Institute for Energy and Environmental Research,
6935 Laurel Avenue, Takoma Park, MD 20912
Phone: (301) 270-5500 FAX: (301) 270-3029

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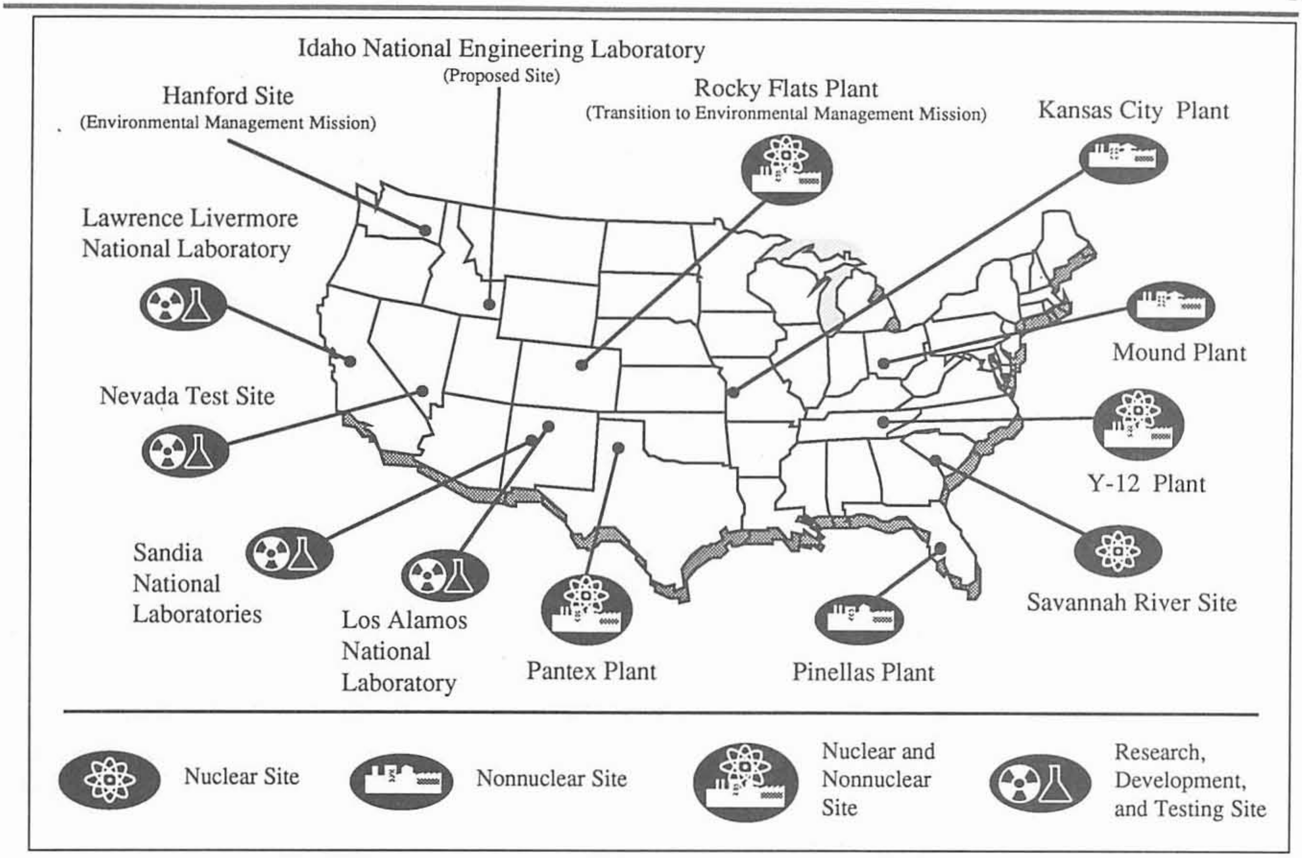

This map represents some of the options the DOE is considering for the R-PEIS (Complex 21).

Complex 21
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ing in the 5,000 range (plus or minus 20%)."[1]

The decision is *not* about how many weapons are needed now, during the transition to the post-Cold-War era. The current capacity for dismantling warheads is so limited that even existing commitments for dismantlement will not be met for many years. Instead, the most crucial aspect of the decision is what the strategic basis for long-term planning should be, and whether it is prudent to continue actively deploying nuclear weapons, given the current world situation.

An arsenal of about 5,000 warheads will require large and expensive full-scale production and processing facilities, including a tritium production reactor or accelerator and substantial facilities for rebuilding weapons. The costs of such a nuclear weapons complex will run into tens of billions of dollars. Yet, consideration of U.S. security in the post-Cold War era indicates that an arsenal of 5,000 nuclear weapons is far too large. A different basis for planning Complex 21 could achieve security and environmental goals while minimizing unnecessary public expenditures.

Target List Approach

One point of departure is to ask what the targets are for U.S. nuclear weapons today. In the past, a large arsenal was justified partly by the presence of large numbers of multiple-warhead, land-based missiles in the Soviet Union that could, in theory, be launched in a surprise preemptive first strike. But these are all to be dismantled. Another plan targeted Soviet tactical nuclear capabilities. Tactical nuclear weapons are also being almost completely eliminated, by reciprocal, unilateral moves undertaken by both the U.S. and Russia.

Another long list of non-military targets during the height of the Cold War was based on a principal objective of U.S. nuclear war plans: the destruction of the Soviet urban-industrial base.

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Thomas C. Reed and Michael O. Wheeler, *The Role of Nuclear Weapons in the New World Order*, January 13, 1992, p. iv.

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Today, this would be regarded as inappropriate because nuclear weapons have become more politically difficult to use: tens of millions of dead have become unacceptable "collateral damage." Even for the school that believes in the utility of nuclear weapons in diplomacy—a highly dangerous long-term proposition which causes more and more countries to desire and acquire nuclear weapons—there are few specific targets today. The main function of the arsenal in the post-Cold-War era for this diplomacy school would be to achieve a more diffuse, general deterrent effect.

The Minimalist School

Various figures for the size of a post-Cold War deterrent arsenal have been put forth by what one might call a minimalist school. For instance, Herbert York, the first director of the Lawrence Livermore National Laboratory, where nuclear weapons are designed, has suggested that 100 weapons would be sufficient; so has Robert MacNamara, Secretary of Defense to Presidents Kennedy and Johnson.

One interesting concept from the minimalist school is called "non-weaponized deterrence," put forth recently by George Perkovich of the W. Alton Jones Foundation. This requires no standing arsenal of nuclear weapons, but only the capability for making them as its source of deterrent power, similar to the deterrence regimes that exist with respect to biological and chemical weapons.

In part, "non-weaponized deterrence" relies on the fact that nuclear warheads can be made quickly under conditions of emergency. During World War II, when no one knew how to make them, when the materials were not available, and when the technology and even much of the science was not proven, it took just over three years to make the first nuclear bomb. Today, this might take a few days to a few months depending on the materials and facilities available at the start of the crisis. In the meantime, all nuclear weapons could be disarmed and put under international control. A policy of non-weaponized deterrence would have obvious advantages for achieving progress on non-proliferation goals when the Non-Proliferation Treaty is reviewed by its signatories in 1995. It is also a useful bridge concept to universal nuclear disarmament.

General LeMay's plan with 750 warheads would have converted the Soviet Union into "a smoking, radiating ruin at the end of two hours."

The LeMay Criterion

Those who believe in a powerful force of nuclear weapons might look to General Curtis LeMay for inspiration as to a reasonable upper limit for a U.S. nuclear arsenal. He was clearly a man who did not pussyfoot around with weapons of mass destruction. He oversaw the massive fire bombing of Tokyo during World War II, for instance. About 100,000 people perished in that conflagration in one night.

In the mid-1950s, LeMay was at the helm of the Strategic Air Command (SAC), which was responsible for carrying out U.S. strategic nuclear war plans, if so ordered. SAC had developed an "optimum" plan for a nuclear war against the Soviet Union. It called for a huge, simultaneous strike, that would turn the Soviet Union into "a smoking radiating ruin at the end of two hours."[2] SAC estimated that 750 strategic nuclear weapons would be required for this task.

More recently, many studies, such as the one recently completed by the relatively conservative Center for Strategic and International Studies, have concluded that about 1,000 nuclear weapons would be sufficient for maintaining the U.S. in an unquestioned superpower role. Such thinking is evidently in direct contrast to that of the Pentagon, which seems to want to retain about as many weapons as current U.S. commitments would allow.

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[2] War planning document as quoted in David A. Rosenberg, "'A smoking Radiating Ruin at the End of Two Hours': Documents on American Plans for Nuclear War with the Soviet Union, 1954-55," *International Security*, vol. 6, no. 3, Winter 1981/1982, p. 11.

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Implications of Arsenal Size

Any arsenal in the range of zero ("non-weaponized deterrence") to 1,000 would mean that no production facilities would be required apart from some laboratory-scale facilities similar to ones already in existence (although these would need to be refurbished for environmental and safety reasons). No new tritium production would be required for about five or more decades. At 100 warheads, existing stocks of tritium would suffice for a 100-weapon arsenal for well over three-quarters of a century. That is beyond the planned life of Complex 21 itself. Similarly, facilities required for rebuilding less warheads would be minimal for an arsenal of 1,000 weapons or less.

In contrast, an arsenal of 5,000 weapons would require planning for new tritium production facilities to begin by about 1996. An industrial-scale plant would be needed for rebuilding warheads, according to the DOE. All this would entail huge expenditures.

There is an urgent need for a national debate about the appropriate size of the U.S. arsenal in the post-Cold War era, but current plans for an arsenal of about 5,000 warheads are excessive. They do not appear to be part of any coherent strategy other than to provide for continuing expenditures on nuclear weapons production technologies. Nor do they adequately take into account the deleterious effect on global nonproliferation goals of creating a new nuclear weapons production complex. Plans for Complex 21 should be scrapped in favor of a focus on the goal of cleaning up the legacy of past production, without the distraction of building unneeded new production facilities and managing the radioactive wastes that these will generate. The DOE's Reconfiguration Programmatic Environmental Impact Statement should include comparative assessments of the impact of smaller arsenals—down to zero—even though these are not a part of the current official "weapons guidance" from the Pentagon.

Reincarnation
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water reactor, was born out of a design used for naval propulsion. The very first civilian reactor, built at Shippingport, Pennsylvania, was actually born as an aircraft carrier reactor in 1952 and killed by the Pentagon in 1953. It was reincarnated as a demonstration civilian power plant at Shippingport under the guidance of Admiral Hyman Rickover.

The gas-cooled reactor

The latest gas-cooled reactor designs came from an idea of Edward Teller for an "inherently safe" reactor. It evolved into a successful research reactor design and then into a commercial power reactor design. A power reactor of this design was built at Fort St. Vrain in Colorado and was an economic and technical lemon, junked before its time. It came back reincarnated as a tritium production reactor (the Modular High Temperature Gas Reactor or MHTGR) in the 1980s for the U.S. military.

With the end of the Cold War, the need for new tritium has evaporated, since the number of weapons in the arsenal has been decreasing and old tritium can be recycled from one warhead to another (see accompanying article, "How Many Weapons is Enough?"). The MHTGR has now come back as a dual-purpose reactor to "burn" excess plutonium and produce tritium. And by the way it will also generate some electricity.

Since the DOE has no active plans to order an MHTGR for construction in the U.S., General Atomics—the reactor vendor—is proposing that the U.S. give "foreign aid" to Russia so that the Russians could buy and build one using a check issued in the United States. Reincarnated reactors give birth to reincarnated checks.

Liquid-metal-cooled reactors ("breeder" and "fast" reactors)

In the first decade after World War II, when uranium was scarce, breeder reactors were regarded as the design of choice by many or most analysts. These reactors would convert uranium-238 into plutonium-239. Uranium-238,

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while far more abundant than uranium-235, cannot be used to drive power reactors or bombs because it cannot sustain fission chain reactions. But uranium-238 can be converted into plutonium-239 in a nuclear reactor that contains uranium-235 (or plutonium-239) to drive the chain reaction. This possibility gave rise early on in the nuclear age to the pro-nuclear vision of a "magical," endless energy source.

The breeder reactor was pushed out by Rickover's light water reactor (to the consternation of many) at Shippingport, but nonetheless received funding for research and demonstration projects throughout the world. None have operated well and many have been shut down due to technical problems.

The most common design of breeder reactor, the Liquid Metal Fast Breeder Reactor (LMFBR), uses as a coolant liquid sodium, which explodes on contact with moist air or water. Moreover, some breeder reactors can have accidental nuclear explosions, unlike light water reactors. Breeders also gave rise to concerns about proliferation, since their use would put increasingly large amounts of plutonium into circulation in the civilian economy, leading to a kind of plutonium population explosion.

Economic problems and security concerns put an end to the U.S. breeder program in the early 1980s; opponents thought the reactor was dead. Yet it is now being reincarnated as the Advanced Liquid Metal Reactor, or ALMR. Its purported function is to "burn" plutonium; a design that was once to create plutonium is now being promoted as a way to destroy it. Of course, the reactor can still be used to produce more plutonium, if desired.

Even nuclear bombs can be reincarnated as reactors. One proposal from the Lawrence Livermore National Laboratory advocated an underground "reactor." This reactor would require about twenty thousand nuclear explosions of one kiloton each per year to generate electricity equivalent to just one nuclear power plant. This scheme would require two million nuclear explosions annually to produce the same amount of power as nuclear power plants in the U.S. The proposal appears dead for now; the nuclear deities have announced no reincarnation date as yet.

Breeder reactors give rise to concerns about proliferation, since their use would put large amounts of plutonium into circulation.

Relying on new reactors to deal with plutonium would be expensive and take a long time to accomplish the job. They would create more nuclear waste, including long-lived fission products and decommissioning wastes.

Energy production from plutonium is not economical. Contrary to early estimates, uranium has turned out to be significantly cheaper and more plentiful fuel than plutonium. It is more expensive to use plutonium as an energy source in reactors even when it is given away as surplus from military uses. This seeming paradox arises from the fact that plutonium must be processed to make it suitable for use in reactors. Plutonium processing must be done remotely in costly facilities because it is far more radioactive and dangerous than uranium.

Despite the pro-nuclear rhetoric, these various reincarnated reactors will not be able to deal with military surplus of plutonium in a way that minimizes costs and environmental damage while maximizing security and non-proliferation objectives. Rather the true rationale for these reactors appears to be the transmutation of taxpayer dollars into government-issue pork (GIP).

Arjun Makhijani

NEW VIDEO

A new video on testing, ***Bound by the Wind,*** is out. $49. Call 415-468-7469.

Report on the IEER Technical Training Workshop

Ellen Kennedy

On June 4 and 5, IEER hosted a workshop in Washington, D.C. on nuclear waste issues. About 30 activists from around the country attended, primarily from the Military Production Network. Participants deciphered government graphs, solved math and science problems based on real disposal sites, got a political update on cleanup, and even composed some poetry.

The central purpose of the workshop was to equip activists with the technical know-how to wade through confusing government documents. Don Hancock of the Southwest Resource and Information Center helped IEER's president, Arjun Makhijani, explain the fission process and other nuclear reactions, units of radioactivity and how to make heads or tails of scientific notation. Participants were given rigorous problem sets based on actual data from documents of the Department of Energy, Nuclear Regulatory Commission, National Research Council of the National Academy of Sciences, and the EPA.

The workshop also sought to improve the way activists express their understanding of nuclear waste issues. Margaret Carde of Concerned Citizens for Nuclear Safety showed segments of a televised debate in which she took on a scientific consultant for the Department of Energy. Carde and workshop participants critiqued the clips and discussed how to prepare for future debates.

Robert Alvarez of the U.S. Senate Government Affairs Committee summarized nuclear waste clean-up policy on Capitol Hill. He advised participants on upcoming legislation and strategies for affecting policy making.

Finally, workshop participants plumbed their creative depths to crystallize scientific concepts learned in the workshop through drama, poetry, games and other artistic means. Bill Weida of ECAAR was voted the "techno-weenie beatnik" wonder for his inspiring adaptation of Poe's "Nevermore." Participants whirred about the room as electrons, jumped through sheets of paper as beta (not alpha) particles, and proved that learning—even about topics like nuclear waste—can be fun.

Participants were enthusiastic about the workshop and expressed interest in future ones. One participant explained, "as our role in these issues increases...there is a proportional need for technical comprehension of the problem. The training goes a long way toward balancing our activism with our ability to provide credible direction."

IEER will conduct two additional technical training workshops for members of the

See "Workshop"—p. 12

SELECTED IEER WORK

- Project to support grassroots groups working on nuclear weapons production, testing and clean-up issues.
- Portsmouth Residents lawsuit, for neighbors of this DOE uranium enrichment facility.
- Outreach on protection of the ozone layer.
- Rongelap Rehabilitation Project to assess the habitability of Rongelap Atoll.
- Mound lawsuit for neighbors of the DOE's Mound Plant, near Dayton, Ohio.
- Production of *The Nuclear Power Deception*, a book on nuclear power issues.
- Production of source-book on global environmental and health effects of nuclear weapons production for IPPNW.
- Work on clean-up and decommissioning issues for Native Americans for a Clean Environment.

A SPECIAL PIN-UP FOR TECHNO-WEENIES

by Kevin Gurney

DCFs

The techno-weenie centerfold in this issue presents more useful information on many radioactive materials commonly found in nuclear weapons, nuclear power plants, and/or radioactive waste. This information can be used to calculate the internal radiation dose to the body (or a particular organ) due to a **single** or **continuous intake** of radioactive material.

An example of a single intake might be the consumption of a single glass of water contaminated with radioactive material. A continuous intake could result from living near a nuclear facility known to chronically contaminate the air that you breathe every day over weeks, months or years. Single intakes tend to be associated with accidents or unusual conditions while continuous intakes occur over the course of an individual's daily life.

In both single and continuous intakes, the dose received is due to the energy imparted to internal organs such as the lung, thyroid or bones. The most crucial piece of information when performing such a calculation is the dose conversion factor, or "DCF". Dose conversion factors for inhalation (breathing) and ingestion (eating and drinking) are shown in the centerfold table.[1]

Strictly speaking, DCFs are the radiation dose, given in units of rems or sieverts (1 sievert equals 100 rem), received due to the inhalation or ingestion of a given quantity of radioactivity, given in units of becquerels or picocuries (0.037 becquerels equals one picocurie). So, the DCF converts an amount of radioactivity into a dose. Since each radionuclide emits different amounts of radiation, the DCF depends on the radionuclide.

The DCF values used for regulatory purposes are derived from a combination of experimental data and mathematical models. The experimental data has been used to estimate the dose that different human organs would receive if exposed for a given period of time to various radioactive materials. A mathematical description of the flow of radioactive material in the human body then assists in determining how much time such materials would spend in proximity to each exposed organ. As a result, each organ in the body has a different DCF for a chosen radionuclide. Combining the DCFs for each critical organ in a particular way gives the "effective dose."[2]

To determine if a person has received a radiation dose above a recommended limit, a single DCF, pertaining to a particular organ or the "effective" DCF, is used. The organ chosen is then referred to as the "standard-setting organ". The centerfold table lists the standard-setting organ for each radionuclide.

The DCF for a given radionuclide also depends on how easily that radioactive material passes through the body. For inhaled materials, this is indicated by the solubility of the radioactive material.[3] For ingested material, this is indicated by the **uptake fraction**; the fractional amount taken up by the blood from the small intestine.

As mentioned in the last issue of *Science for Democratic Action* (volume 2, number 2), the solubility of radioactive material is a reflection of how likely it is to dissolve in water. The less soluble a given amount of inhaled or ingested material, the more difficult it is for your body to remove it. Therefore, most insoluble material spends more time in your body and has more time to do damage. This explains why, for most radionuclides, insoluble forms have greater DCFs than less soluble forms.

By the same logic, radionuclide forms with smaller uptake fractions will spend less time in the body. This will generally result in less damage and a smaller DCF.

Radionuclide	Solubility[4]	Dose Conversion Factor INHALATION (millirem/pCi)	Standard Setting Organ	Uptake Fraction[5]	Dose Conversion Factor INGESTION (millirem/pCi)	Standard Setting Organ
Hydrogen-3 (Tritium)	vapor	0.0000000640	effective	1.00	0.0000000640	effective
Strontium-90	insoluble	0.00130	effective	0.01	0.0000120	effective
	soluble	0.00269	bone surface	0.30	0.00155	bone surface
Technetium-99	somewhat soluble	0.00000833	effective	0.80	0.00000146	effective
	soluble	0.00000914	remainder[6]			
Ruthenium-106	insoluble	0.000477	effective	0.05	0.000262	remainder[6]
	somewhat soluble	0.000118	effective			
	soluble	0.0000562	effective			
Iodine-131	soluble	0.00108	thyroid	1.00	0.00176	thyroid
Cesium-137	soluble	0.0000319	effective	1.00	0.0000500	effective
Barium-140	soluble	0.00000374	effective	0.10	0.0000977	remainder[6]
Lanthanum-140	somewhat soluble	0.00000485	effective	0.001	0.00000844	effective
	soluble	0.00000345	effective			
Polonium-210	somewhat soluble	0.00858	effective	0.10	0.00190	effective
	soluble	0.00940	effective			
Radium-226	somewhat soluble	0.00858	effective	0.20	0.0253	bone surface
Radium-228	somewhat soluble	0.00477	effective	0.20	0.0215	bone surface
Thorium-230	insoluble	3.22	bone surface	0.0002	0.0133	bone surface
	somewhat soluble	7.99	bone surface			
Thorium-232	insoluble	18.5	bone surface	0.0002	0.0685	bone surface
	somewhat soluble	41.1	bone surface			
Nat. Uranium[7]	insoluble	0.125	effective	0.002	0.0000249	effective
	somewhat soluble	0.00747	effective	0.05	0.00396	bone surface
	soluble	0.0381	bone surface			
Plutonium-239	insoluble	3.04	bone surface	0.00001	0.000651	bone surface
	somewhat soluble	7.81	bone surface	0.001	0.0651	bone surface
				0.0001	0.00651	bone surface
Plutonium-241	insoluble	0.0659	bone surface	0.00001	0.0000129	bone surface
	somewhat soluble	0.155	bone surface	0.001	0.00129	bone surface
				0.0001	0.000129	bone surface
Americium-241	somewhat soluble	8.03	bone surface	0.001	0.0670	bone surface

Dose conversion factors can be found in U.S. Environmental Protection Agency, *Limiting Values of Radionuclide Intake and Air Concentration and Dose Conversion Factors for Inhalation, Submersion and Ingestion.* Federal Guidance Report No. 11, September 1988. EPA-520/1-88-020.

[2] It is also important to note that the DCFs presented here are representative of an "average adult".

[3] The assumed particle size is also a consideration. In the values presented in the centerfold table, a 1 micron AMAD (activity median aerodynamic diameter) is assumed.

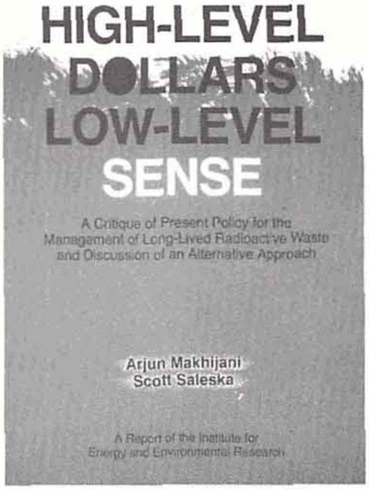
[4] In existing regulations, solubility is listed as "class Y", "class W" and "class D". These correspond to "insoluble", "somewhat soluble", and "soluble".

[5] The uptake fraction is the fractional uptake from the small intestine to the blood.

[6] "Remainder" represents the dose to tissue other than gross specified organs.

[7] Natural uranium is assumed to be made of equal activity of U-234 and U-238.

RECENT PUBLICATIONS



High-Level Dollars, Low-Level Sense

A Critique of Present Policy for the Management of Long-Lived Radioactive Waste and Discussion of an Alternative Approach

by Arjun Makhijani and Scott Saleska

Radioactive wastes contain materials that remain hazardous for up to millions of years. The authors explain inconsistencies in the waste regulations, expose the industry's tactics, and propose an alternate unified approach to the problem.

High Level Dollars, Low-Level Sense *is a devastating analysis of the attempt to manage radioactive wastes generated by the production of nuclear power and nuclear weapons . . . . Makhijani and Saleska have written what might well stand as the epitaph of nuclear technology.*

—Barry Commoner, Center for Biology of Natural Systems, Queens College

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Plutonium

Deadly Gold of the Nuclear Age

by International Physicians for the Prevention of Nuclear War and IEER

The Cold War is over, yet production of plutonium continues in many countries, including Russia. While much of it is allegedly for nuclear power, all plutonium can be used for nuclear weapons. This book examines the huge security, health and environmental risks posed by plutonium globally and spells out policies to end the plutonium era.

Plutonium, with its dangers, is, in human terms, forever. Deadly Gold is the first truly comprehensive account of the legacy of threats that production of plutonium—still continuing —bequeaths to the next one hundred thousand years. Its specific short- and long-term policy recommendations provide an immediate agenda for the incoming Clinton administration.

—Daniel Ellsberg

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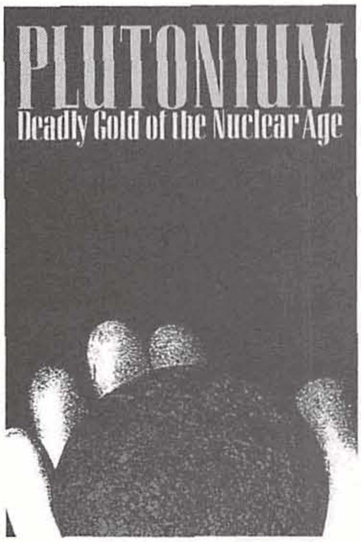

Radioactive and Mixed Waste Incineration

by David Kershner, Scott Saleska, and Arjun Makhijani

Many wastes generated by the Department of Energy, nuclear power plants, and medical and research institutions are both radioactive and chemically hazardous, known as "mixed waste." Land disposal regulations for radioactive and mixed wastes have increased the economic incentives for incineration. This report, the second in a series of IEER *Science for Democratic Action Papers*, helps inform citizens and policy-makers about the complex environmental and health issues surrounding incineration of radioactive materials.

An important new paper from the Institute...it covers virtually all issues involved in incineration of radioactive materials—focusing primarily on DOE existing and planned facilities—and should be highly useful if any incinerators are planned in your backyard.

—The Nuclear Monitor

PRICE: $ 10.00 including postage and handling

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For a free copy of IEER's **Fact Sheet on Incineration of Radioactive and Mixed Waste,** please send a self-addressed stamped envelope to IEER, ATTN: FACT SHEET.

"Dear Arjun"

Dear Arjun,

What is a uranium curie and why is it double?

I.M. Curie-ous in
Yellowcake, Utah

In ancient Rome, "uranium" was short for "your annual salary." Uranium was measured in curies, which was short for curriency, which was the money of the day. The slaves of Rome went on strike and the Roman Senators were so drunk and full of good cheer that they doubled the slaves wages (and their own), leading to a double uranium curie for everyone.

The double uranium curie was reincarnated on January 1, 1961. The Atomic Energy Commission (AEC) reintroduced this double curie as a special unit of radioactivity for measuring the radioactivity due to all uranium isotopes in natural uranium. This equally fictitious unit remained part of Nuclear Regulatory Commission regulations (10 CFR Part 20) until December 31, 1974.

The entire record of radioactivity measurements reported in curies for the period 1961-1974 (inclusive) needs translation so far as natural uranium is concerned.

There are three isotopes of uranium in natural uranium: uranium-238, which is 99.284% by weight; uranium-235, which is 0.711% by weight; and uranium-234, which is 0.005% by weight. Despite being only a trace isotope, uranium-234 contributes almost half the radioactivity in natural uranium because it has a high radioactivity per unit weight (a high "specific activity"), with about an equal amount coming from uranium-238. Uranium-235 makes only a small contribution to the total radioactivity.

Since these three isotopes always occur in about the same ratios in natural uranium, it was the practice of early radiobiologists and health physicists to lump them all together while doing dose estimates and use a figure slightly greater than double the radioactivity of uranium-238 for the total radioactivity of natural uranium.

In 1960, for reasons not clear to me, the AEC adopted this convention as a formal regulatory practice, and defined a new curie consisting of 37 billion disintegrations per second arising from uranium-238, plus 37 billion disintegrations per second arising from uranium-234, and 900 million disintegrations per second from uranium-235. This new unit, representing more than twice the activity (as measured in disintegrations per second) of a standard curie was introduced to measure the radioactivity of natural uranium. This was called the "uranium-curie."[1] The regular curie is 37 billion disintegrations per second.

No new symbol was introduced for the uranium curie. This would be akin to defining a 24-inch foot for measuring desks, but continuing to measure all other furniture by a 12-inch foot. The double curie definition was abolished in 1974 (effective January 1, 1975), as a result of a petition from General Electric, which wrote the AEC in 1972 saying that the dual system was

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[1] Total number of disintegrations in double uranium curie was defined as 74.9 disintegrations per second. As it turned out the AEC's calculation for the contribution of uranium-235 was too low by about a factor of two. It should have been 1.7 billion disintegrations per second. The error has essentially no significance for the actual computations of environmental radioactivity because uranium-235 still makes only a small contribution to the total radioactivity from natural uranium.

It Pays To Increase Your Jargon Power

by Dr. Egghead

Dr. Egghead is IEER's leading authority on jargon. He left hurredly for a vacation in the Galapagos. Find correct answers, if there are any!

1. **fertile isotopes**

a. radioactive materials useful for increasing reproduction among cockroaches

b. isotopes like uranium-238 which cannot sustain a nuclear chain reaction, but which can be converted into other elements, like plutonium-239, which can sustain a chain reaction.

2. **breeding ratio**

a. the manners of old money divided by the manners of new money

b. enthusiasm divided by age

c. the ratio of the amount of new fissile material, such as plutonium-239, that is produced from fertile materials in a nuclear reactor to the amount of fissile atoms—such as uranium-235—that is consumed. This gives rise to the possibility of a "breeder reactor" which can produce more fissile material that it uses up.

3. **IFR**

a. cockney way of saying heifer

b. **I**ntegral **F**ast **R**eactor, a design concept for a nuclear reactor, which uses liquid sodium as a coolant. This type of reactor was originally meant to produce more plutonium than it used ("a breeder reactor" with a breeding ratio greater than 1). It is now being advertised as a way to use up surplus plutonium from dismantled nuclear weapons. An ALMR, or **A**dvanced **L**iquid **M**etal **R**eactor, using this concept, is being proposed.

4. **pyroprocessing**

a. the title of the song that Nero was fiddling as he watched Rome burn

b. cooking in the twenty-first century

c. an electrochemical technology using molten salt for separating plutonium (and other heavy elements called actinides) from fission products necessary for the operation of the Integral Fast Reactor (see above).

Workshops

continued from p. 7

Military Production Network (MPN) over the next year. We will also train activists in two separate workshops at the local groups' locations.

Workshop participants received a new IEER publication, *The Yellow Pages*, a technical reference guide to nuclear waste and clean-up issues. To order *The Yellow Pages*, please send a check or money order for $3.00 to IEER at the address on the back of the newsletter.

Arithmetic for Activists #6

Solution to the Problem in SDA volume 2, number 2

Last issue's Science Challenge was as follows:

You live one mile downwind of a uranium mill. Your trusty air monitoring equipment measured the amount of radioactivity in the air. You read 0.00037 becquerels per liter of air.

Remember that 1 curie = 37 billion becquerels and that the prefix "pico" means one-trillionth.

A) Laboratory analysis indicates that this is all due to insoluble Radium-228. Are you above or below the regulated standard? By how much? Use the "existing limits" column in the centerfold.

ANSWER: Last issue's Technoweenie Centerfold gives the "existing limit" of insoluble Radium-228 listed as 0.001 picocuries per liter.

Remember that becquerels and picocuries are different ways of expressing the same information, much as we use the metric system to measure centimeters and the British system to measure inches, for example. Just as inches are bigger than centimeters, becquerels are bigger than pico-curies.

We will need to express the information in the same unit in order to compare the measurement with the standard. "Pico" means "trillionth," so:

- 1 curie = 1 trillion picocuries
- 1 curie = 37 billion becquerels

so 1 trillion picocuries = 37 billion becquerels.

We can solve the equation for picocuries, as follows:

- divide each side of the equation by 1 trillion
- 1 picocurie = 0.037 becquerels

(or, 1 becquerel = about 27 picocuries)

We measured 0.00037 becquerels of Radium-228 in our sample, which we should now express in picocuries per liter.

$$\frac{\text{1 picocurie}}{\text{0.037 becquerels}} = \frac{\text{x picocuries}}{\text{0.00037 becquerels}}$$

- 0.00037 x 1 divided by 0.037 = 0.01 picocuries per liter.
- (or, you can multiply .00037 becquerels by 27 = .00999= .01)

Since the limit listed in the table is 0.001 picocuries per liter, we are exactly 10 times over the existing air concentration limits.

B) What if the material was insoluble natural uranium?

ANSWER: Again, look in the centerfold to find the limit; in this case it is 0.005 picocuries per liter for insoluble natural uranium. From our calculations above, we learned that our reading of 0.00037 becquerels per liter of radioactivity is the same thing as saying 0.01 picocuries per liter. Compare 0.01 and 0.005 and you will see that we are two times over the existing limits for insoluble natural uranium (divide 0.01 by 0.005 to get 2).

Errata

In last issue's *Arithmetic for Activists*, the answer to question 1 should read "given that there are 2 milligrams of uranium-238 per gram of soil," rather than "given that there are 2 grams of soil." Bob Schaeffer brought this to our attention and will receive a $25.00 prize. If you find errors in this or a future *Arithmetic for Activists* section, and you are the first person to let us know about it, you too can win a $25.00 prize!

Calculating Dose

There is no way to know exactly how much radiation a person may have received by

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Arithmetic

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drinking contaminated water or breathing contaminated air, for example. But scientists (and *SDA* readers) can estimate the dose by doing a few calculations.

The first step in calculating a dose, either from a single or continuous intake, is to know how much radioactivity has entered the body and by what path. Inhalation of ambient air with radioactive particles, or the ingestion of contaminated food or water are typical intake pathways.

In order to estimate the amount of radioactivity entering an individual's body from a single or continuous intake, you need to know two things: (1) the concentration of radioactive material in air, water or food and (2) how much of the air, water or food was inhaled or ingested. In the case of contaminated air inhalation, the amount of air entering the average adult male body during a typical day is almost 1 cubic meter per hour. So, if you know the number of hours over which the intake occurred, you can estimate the number of cubic meters of contaminated air entering an individual's body. Then, if the concentration of radioactive material in that inhaled air is known (typically in units of picocuries per cubic meter), the total amount of radioactivity entering the body during that exposure period can be estimated.

For example, suppose an individual was exposed to air contaminated with insoluble thorium-232 for 2 hours. Since the average breathing rate is about 1 cubic meter per hour, we estimate that this individual inhaled a total of 2 cubic meters of contaminated air (2 hours x 1 cubic meter/hour). Suppose the concentration of thorium-232 in the air was 3 picocuries per cubic meter; then the amount of radioactivity that entered his body would have been 6 picocuries in all (3 picocurie/cubic meter x 2 cubic meters).

By turning to the centerfold table in this issue of *SDA* we can calculate the dose this individual received. The dose conversion factor ("DCF") in the centerfold table for insoluble thorium-232 is 18.5 millirem per picocurie (1000 millirem equals 1 rem). Note that the organ from which this DCF was derived is the bone surface. So, if our individual inhaled 6 picocuries of thorium-232, the resulting dose to the bone surface (the standard setting organ) would have been 111 millirem (18.5 millirem/picocurie x 6 picocuries).

The same procedure can be followed if radioactive contamination occurs by ingestion. In this case the average rate at which water and food is ingested must be known or given in the instance of a single intake.

Test your understanding of dose calculations further with this issue's *Science Challenge*.

◆

Ask Arjun

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creating unnecessary confusion.

The entire record of radioactivity measurements reported in curies for the period 1961-1974 (inclusive) needs translation so far as natural uranium is concerned. Plant records probably have not been corrected to indicate that the amount of radioactivity from natural uranium as measured in air, water or soil and reported in curies is about twice as large as it would appear, since the unit in which they were being reported as about twice as large. (This works in the same as way as the example of inches and feet mentioned above. We would have to increase our estimate of the size of a desk to twice the value if we learned that this original figure was based on a 24-inch foot.)

IEER's inquiries revealed that there is very little institutional memory in the NRC or EPA about the history of the uranium curie, nor of the possibility that the historical record of measurements might be misleading for the 1961-1974 period. The amnesia with respect to the double uranium curie begs an important question; if the U.S. government cannot remember how it classified uranium 20 years ago, what is the prognosis for waste classification and disposal programs slated to last 10,000 years?

◆

SCIENCE CHALLENGE

Suppose you spent 8 hours walking in the vicinity of a uranium mill where the concentration of insoluble natural uranium in the air was known to be 3 picocuries per cubic meter. While you were out walking, you realized that you forgot your water-bottle at home. You stumbled across a lush, inviting well, where you drank 2 liters of water. As luck would have it, the well was contaminated with insoluble natural uranium (uptake fraction of 0.002) at a concentration of 1,000,000 picocuries per liter. What would be the dose due to inhalation? Due to ingestion?

Twelve people sent in replies to the *Science Challenge* in the last issue. There were 7 correct answers, a real improvement from the last issue. Congratulations! We drew lots for the $25 prize from among the correct answers, and the winner is Daniel Eisenbud, of Newton, MA. Everyone who entered the contest will receive a $10.00 prize. Be sure to enter in the next issue of *Science for Democratic Action.*

The Science Challenge is a regular Science for Democratic Action feature. There is no way to learn arithmetic except to do it! We offer 25 prizes of $10 to people who send in solutions to all parts of the problem, right or wrong. There is one $25 prize for a correct entry. Work the problem and submit the answer to Ellen Kennedy, IEER, 6935 Laurel Avenue, Takoma Park, MD 20912. If more than 25 people enter and there is more than one correct entry, the winners will be chosen at random. The deadline for submission of entries is December 1, 1993. People with science, math, or engineering degrees are not eligible.

The Institute for Energy and Environmental Research (IEER) provides citizens and policy-makers with thoughtful, clear, and sound scientific and technical studies on a wide range of issues. IEER's aim is to bring scientific excellence to public policy issues to promote the democratization of science and a safer and healthier environment.

We gratefully acknowledge the generous support of the W. Alton Jones Foundation, the Winston Foundation for World Peace, Ploughshares Fund, the North Shore Unitarian Universalist Veatch Program, the John D. and Catherine T. MacArthur Foundation, Public Welfare Foundation, and the Rockefeller Family Associates, whose funding has made possible our project to provide technical support to grassroots groups working on DOE issues.

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