SCIENCE FOR DEMOCRATIC ACTION

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IEER'S GOALS AND THE DEMOCRATIZATION OF SCIENCE

Arjun Makhijani

The aim of the Institute for Energy and Environmental Research is to bring scientific excellence to public policy issues in order to promote the democratization of science and a safer, healthier environment.

When scientists write for each other, they do so largely in ''peer-reviewed'' journals. When the process works well (it doesn't always) it means that a number of qualified people have looked over the research and commented on it before publication. The authors of the work have taken every comment into account in their revision, or if they have rejected a comment, they have provided a reason for it. An editor of a journal decides whether the revision has adequately taken the comments into account. The process fails when the common assumptions that scientists use are faulty, and that does happen. But it also helps expose faulty assumptions when enough evidence accumulates.

Unfortunately, the very term ''peer review'' means that people who are affected by those decisions are not only left out of the review, they are generally not

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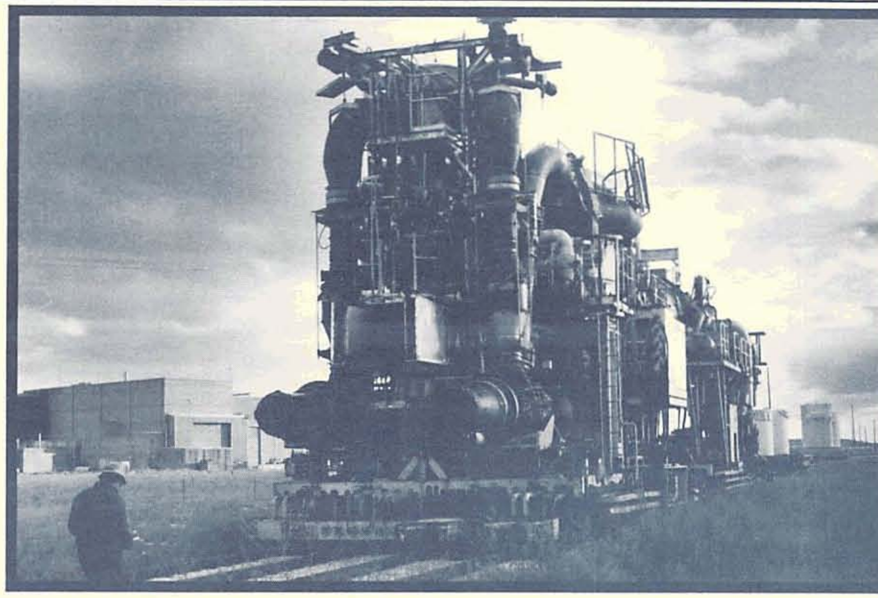

Science Without the Activist - Nuclear Jet Engine
photo by Robert Del Tredici

Options for Plutonium from Dismantled Nuclear Weapons

Arjun Makhijani

There are about 100 tons of nuclear weapons grade plutonium in the U.S. nuclear weapons stockpile and a roughly similar amount in the Soviet stockpile. The vast majority of this plutonium is in the nuclear weapons themselves. The problem of what to do with the plutonium when large numbers of weapons are dismantled is looming as a large strategic, security, and environmental issue.

The first major question is a conceptual one: Is the plutonium to be treated as a resource or a waste? If it is a resource, should it be kept for further nuclear weapons production or should it

The first major question: Is the plutonium to be treated as a resource or a waste?

be used for the production of nuclear energy? We should note that in some countries, notably France, the U.K., the Soviet Union, Japan, Germany, and the U.S., there are considerable stocks of non-weapons grade plutonium stockpiled for use in nuclear reactors -- at least, that is the official position. This plutonium,

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even a part of the audience, since scientists write for each other in very narrow disciplines. There are literally thousands of scientific journals which are published. The language is so esoteric that it is often very difficult for people from other scientific disciplines to understand it, let alone non-scientists. And the relevance for public policy is generally unstated or is part of those common assumptions which rarely come up for public scrutiny.

IEER's aim is to provide people with literature which has a quality equal to that in scientific journals, but which doesn't require you to go back to college to get a degree in science to understand it. Our audience is that of the determined activist concerned about their world, the concerned policy-makers, the knowledgeable journalist.

We also choose our subjects so that they are relevant to environmental protection and other aspects of human well-being. The goal is to put literature in your hands you can use confidently. We rely mainly on primary scientific literature and official documents. We have our materials reviewed. This includes review by people who may not agree with the policy conclusions or recommendations. We take each review comment seriously. As a result our work has held up well to intense scrutiny by DOE and its contractors, as well as others who have reason to dislike our conclusions.

Our project to provide technical support to grassroots activists is the result of a great many years of work with activists in the U.S. and other countries. We have a competent staff that cares about people and we are all glad of the confidence the grassroots activists continue to place in us. Let us hear from you. There will be a letters column in subsequent newsletters. Send your comments, suggestions and criticisms to the editor of this newsletter, Stacy Stubbs.

SCIENCE FOR DEMOCRATIC ACTION

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while not "weapons grade", can still be used to make nuclear weapons, though it takes more of it per weapon.

Short-term Considerations

In the United States, the conceptual issue is actually rather academic in the short-term. The U.S. does not possess the facilities for any large scale conversion of plutonium to forms suitable for use in nuclear reactors. There are also no substantial facilities to convert the plutonium in weapons into a waste form by mixing it with molten glass or ceramics for long-term disposal. Nor have we studied the environmental consequences of doing so.

Thus, in the short-term (the next few years), there are essentially two options which have somewhat different environmental and military implications. First, the plutonium can be left in its present form, as plutonium metal. Where this plutonium is stored is more a military security than an environmental question, since there are different risks of theft at different facilities. Today, this problem is much more serious in

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the former Soviet Union than in the U.S., due to the collapse of the Soviet economy and the disintegration of the Soviet Union.

The other option is to convert plutonium metal into oxide form. We have not studied the issue of converting metal back into oxide in any detail. This could conceivably be done at existing facilities (such as PUREX and PFP at Hanford, or similar facilities at Savannah River Site). This poses safety and environmental risks, since these are aging plants with many unresolved safety issues. However, converting plutonium to an oxide form does reduce some of the risks of accidental dispersal, notably by fire or accidental explosions in the non-nuclear parts of nuclear weapons. Further, plutonium is unsuitable for use in weapons when it is in oxide form. It must be converted back into metal and forged into the shapes suitable for triggers by processes used at Rocky Flats. At a minimum, it seems to me that an Environmental Impact Statement or Environmental Assessment would be required to initiate such a conversion. Finally, while conversion to oxide would probably be opposed by the military anyway, such opposition would be especially strong unless the former Soviet Union also embarked on a similar program.

Converting plutonium metal back to an oxide form reduces some of the risks of accidental dispersal

Long-term Options

The following is a list of the long-term options for plutonium. There is no good solution. All options will involve some quantities of long-lived radioactive products. Plutonium-239 is itself very long-lived (half-life over 24,000 years -- see the column "Arithmetic for Activists" in this newsletter), and therefore presents a problem of long-term disposal.

Use in nuclear reactors produces some long-lived fission products, and generally also requires reprocessing to extract unused portions for reinsertion into the reactor for complete burn-up. Thus, use in reactors also creates high-level liquid radioactive wastes, which are in many ways the number one environmental problem in the nuclear weapons complex, due to dangers of tank explosions or fires.

The five options for long-term disposition of plutonium which we have identified are:

1. Plutonium oxide could be mixed with uranium and used in nuclear reactors as fuel. It requires reprocessing to consume all the plutonium, so it increases high-level waste volume, creates liquid high-level wastes, and also security problems from further plutonium separation.

2. Transmutation of plutonium in fast reactors (reactors in which fast neutrons are the main agent of producing fission, as distinct from slower, thermal neutrons in light water reactors).

3. Transmutation in accelerators (proton or electron): the technologies are not yet well developed. There will be fission products and some neutron activation products to be disposed

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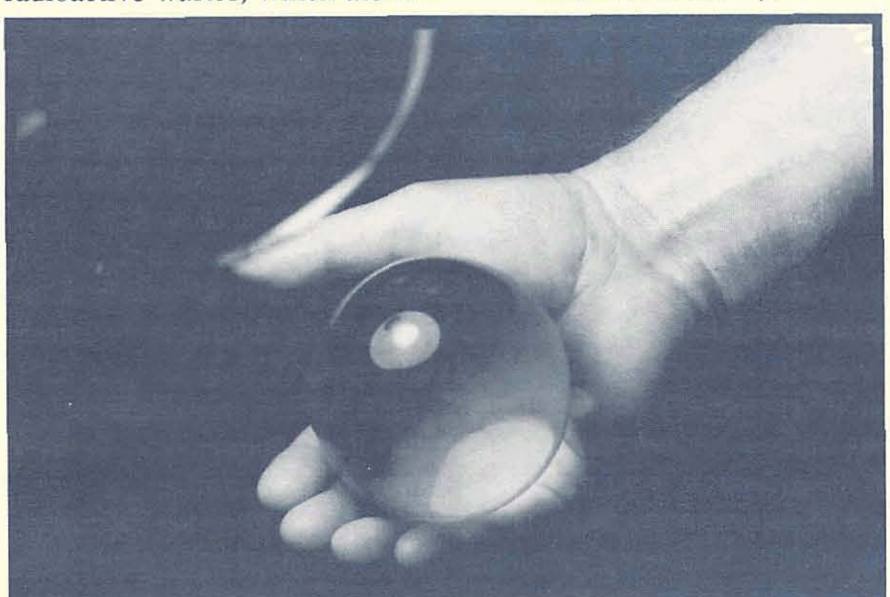


Amount of Plutonium Contained in Nagasaki Bomb
photo by Robert Del Tredici

Options for Plutonium, cont. from p. 3

of. Some of these nuclear wastes will be very long-lived.

4. Conversion to oxide and mixing with ceramics or other waste-forms in sufficient quantities so as to make the plutonium essentially irretrievable for use in weapons. This would convert the plutonium into a waste. Total civilian plutonium in U.S. spent fuel rods which is likely to need disposal will be on the order of 500 to 1,000 tons. Military plutonium is about 100 tons. In the long-term the plutonium waste would be disposed of with other high-level wastes (see IEER recommendations on this in this newsletter).

5. Packaging in canisters in metal form and sub-seabed disposal, as an urgent measure to prevent a world plutonium market from developing. This would probably require an explicit and limited exception for plutonium to current international law against dumping of nuclear wastes at sea. However, plutonium from under the sea may not be irretrievable over the long haul.

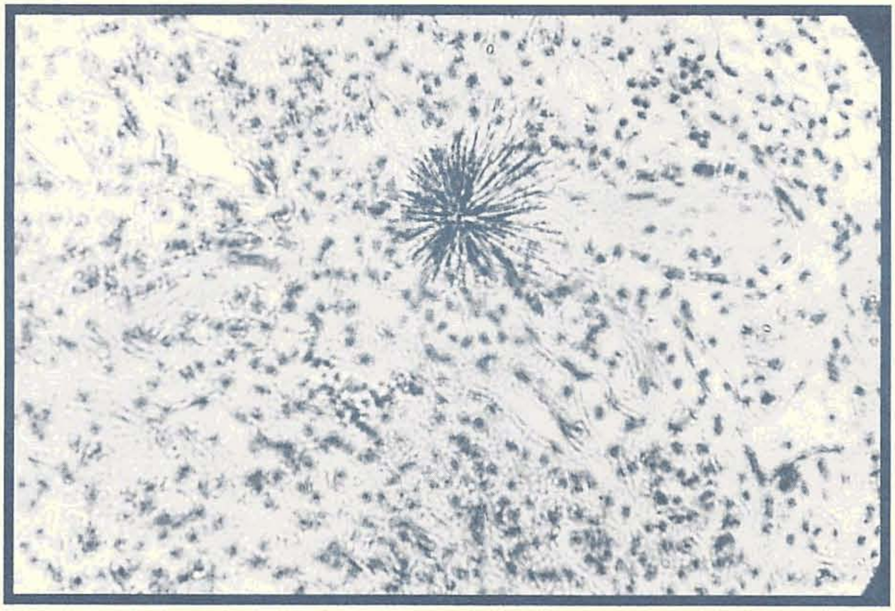
6. Explosion of the nuclear weapons underground, as has been proposed by some in the Soviet nuclear establishment. Besides the many problems of this suggestion, the fact to note in regard to plutonium is that exploding weapons does not get rid of most of it since only about a third of the plutonium is used up in the explosions. That is why there is so much plutonium contamination underground at the Nevada Test Site, Semipalatinsk in the Soviet Union and other underground test locations. Such explosions essentially wind up creating an unlicensed nuclear waste dump at each explosion location.

IEER will be issuing a report on plutonium in 1992, in collaboration with the International Physicians for Prevention of Nuclear War, which will include a more detailed examination of these and other issues.

This article is based on initial work done for a report on plutonium production and high-level liquid radioactive wastes around the world that IEER is producing for the International Physicians for the Prevention of Nuclear War.

In order to use plutonium in existing light water nuclear reactors, plutonium must first be converted into an oxide form, then mixed with uranium oxide and finally formed into pellets which can be put into fuel rods for the reactor. This is known as "mixed oxide" fuel (known as "MOx" fuel). There are some facilities for producing mixed oxide fuel outside the U.S.

This suggestion has been put forward for discussion by Peter Gray.



The black star in the center of this magnified photograph of the lung tissue of an ape shows the tracks made by alpha rays emitted from a particle of plutonium-239.

photo by Robert Del Tredici

Recommendations on Radioactive Waste Disposal

Scott Saleska

In December, IEER released a new study on U.S. radioactive waste management entitled *High-Level Dollars, Low-Level Sense.* The study and government documents released by IEER reveal problems with U.S. plans for management and disposal of radioactive waste, and the suppression of proposed environmental regulations to address some of those problems.

The study, the release of which was covered in the December 12, 1991 *Washington Post*, calls existing plans for long-lived radioactive waste management "irrational and inconsistent" because of the way the wastes are categorized. In addition to providing a thorough critique of the current U.S. waste management system, *High-Level Dollars, Low-Level Sense* proposes an alternative approach based on four components:

1) ***Reclassification of wastes by hazard and longevity***, which would result in the transference of the more dangerous low-level wastes to a long-lived category.

2) ***Abandonment and restructuring of the DOE's repository program for long-lived wastes.*** The study recommends cancellation of the repositories in New Mexico and Nevada, and says that work "should begin again with basic consideration of geology, rock types, as well as consideration of alternative approaches such as sub-seabed disposal."

Along these lines, the study also recommends the removal of the DOE from the waste management program and the establishment of a truly independent radioactive waste management authority which would focus on long-term health, environmental, and basic scientific issues.

3) ***"No siting, construction or operation of new low-level waste disposal facilities should be allowed to proceed in the absence of comprehensive EPA standards for low-level waste disposal."*** As a minimum first step the draft standards should be formally proposed to allow the public to be participants in a debate which has, until now, been going on behind closed doors.

4) ***Provisions for extended onsite storage as an interim step*** in order to accommodate the needs of a restructured program for long-term management and disposal. This includes "planning to allow for up to 100 years of at-reactor storage" of used radioactive fuel from nuclear power plants, and deferral of the dismantlement of old shut down nuclear plants.

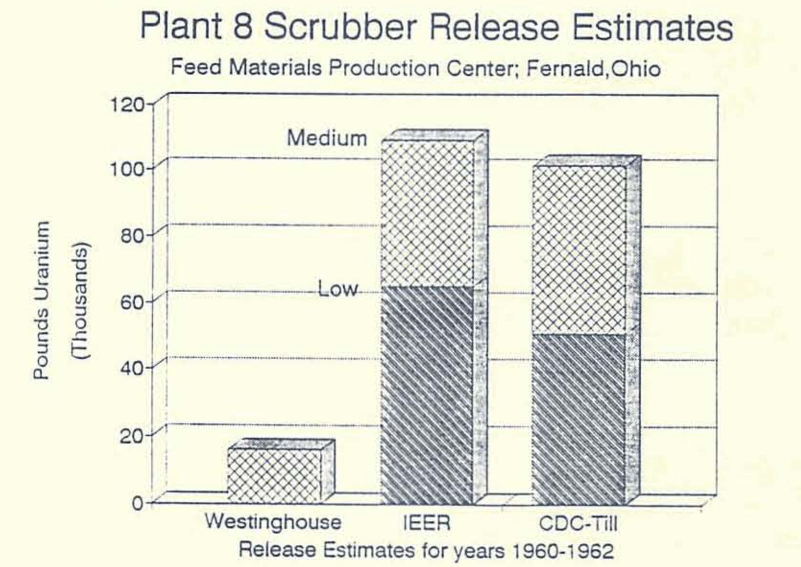
The study concludes that a restructured program "will allow science to be done in parallel with the politics, in contrast to the present program where politics ... have tended to dominate."

Current IEER Work

- Revision of *Saving Our Skins*, our book on ozone depletion.
- Report on global environmental impacts of plutonium production for IPPNW.
- Project to support grassroots group working on nuclear weapons production issues.
- Fernald Workers Lawsuit, for employees of this DOE plant and their families.
- Portsmouth Residents Lawsuit, for neighbors of this DOE uranium enrichment facility.
- Work for NACE's fight against Sequoyah Fuels in Gore, Oklahoma.
- Work for HEAL on the high level waste tanks at Hanford.
- Mound Residents Lawsuit for neighbors of the Mound Plant, near Dayton, Ohio.
- Publication of *High-Level Dollars, Low-Level Sense: A Critique of Present Policy for Management of Long-Lived Radioactive Wastes and Discussion of An Alternative Approach.*
- Publication of *The Nuclear Power Deception: Military and Civilian Nuclear Mythology from Electricity "Too Cheap to Meter" to "Inherently Safe" Reactors.*

IEER's Work on Fernald

Arjun Makhijani



Note: High estimates are not shown because IEER and CDC - Till estimates apply to different time periods and are thus not comparable.

In 1989, IEER published what was, to my knowledge, the first ever independent estimate of releases of radioactive materials from a nuclear weapons plant done by anyone. We analyzed the government's records and concluded that much of the data was fabricated and some of the analytical methods were deceptive and wrong. Our estimates of releases were far higher than those of the DOE and its contractors, National Lead of Ohio, later Westinghouse. Due to limitations of time and data, we restricted our analysis to releases of uranium to the air.

In 1990, the Centers for Disease Control commissioned Radiological Assessments Corporation (headed by John Till) to examine the question of releases and doses. On December 18, 1991, the John Till's team and the CDC released their first figures pertaining to releases of radioactive materials, including uranium, during 1960-1962, as a first portion of a $1.5 million study.

The CDC-Till draft assessment has vindicated IEER's analysis. (Till's team had access to our materials, via the CDC.) Their analysis agreed with ours both in the order of magnitude of the total release estimates for uranium during 1960-1962, and in all essential details as to why the official release estimates up to that time were serious underestimates. The bar chart above shows the Westinghouse-DOE estimates, the CDC-Till estimates and IEER's estimates for Plant 8 scrubbers, the area in which IEER found the largest problems.

This is more than just vindication for IEER. Every time we have done a detailed examination of DOE and contractor records of radiation release estimates and dose records we have found serious gaps in the records as well as grave problems with the quality of the data and analysis. That is why IEER filed a report at the CDC workshop on health studies in early December 1991, as part of our technical support to grassroots groups, asking that the CDC make it a policy that all studies of doses and health effects, whether to workers or offsite populations, be accompanied by an independent evaluation of the records of releases and doses, based on primary plant records and documents. IEER's work and the CDC-Till study demonstrate that any study that fails to make such an independent evaluation should not be accorded scientific credibility.

Arithmetic for Activists #1

Arithmetic For Activists

A half-life can be forever

by Arjun

Numbers can be your best friends (well, almost). This column is to help you become as familiar with DOE's arithmetical antics you are with its political ones. For those of you who are accomplished with numbers, enjoy.

Mathematics is like a language. Many people skip over a page of numbers in a text the way one blanks out a page of Latin, if one doesn't know it. Moreover, merely knowing the elements of arithmetical operations, as most people do, doesn't seem to help. I find that *if you really need it and want it, and there's a good way to learn it*, you can catch on fast. My wife's niece, who is French, had never imagined she would one day speak Norwegian. But she fell in love with a Norwegian fellow, and is now studying architecture in Oslo, in Norwegian. It was, evidently a necessity driven by Cupid.

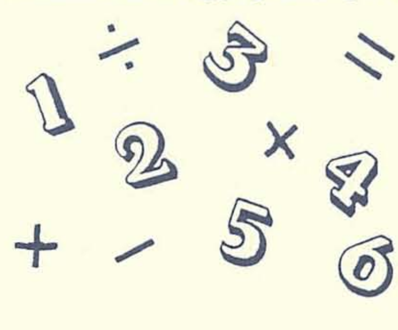
Well, I can't say that star-struck love might characterize what you all feel for the DOE, but the necessity is there. Moreover, there is the love we have for our children and our communities and the need we feel to leave future generations an Earth in somewhat better shape than the radioactive mess that exists today in the nuclear weapons complex.

So resist the tendency to tune out numbers and read on. This column has an explanation of a "half-life", which could lengthen yours, if you understand it.

Half-Life

Each atom has a tiny nucleus surrounded by electrons swirling around it, much in the way the planets swirl around the sun. The nucleus and the electrons around it form the element. An element is radioactive when its nucleus is unstable.

Radioactivity is the way an unstable nucleus releases energy on its way to a more stable form. The principle is similar to the way that a cone standing on its point releases its energy by falling over on its side. After it falls, the cone is in a more stable state. It often happens that the new state of a nucleus is also unstable, so that numerous transitions, and emissions of radioactivity may be required for a nucleus to achieve a stable, non-radioactive state. This is the process of "radioactive decay" of an unstable element.



Resist the tendency to tune out numbers and read on!

Nuclear transformations of lighter unstable elements like fission products or tritium typically happen by the emission of an electron (beta particle). Nuclear transformations of heavy elements like plutonium or thorium happen by emission of a beta particle or an alpha particle (which is the nucleus of a helium atom and about 7,350 times heavier than a beta particle). Gamma rays are emitted when the nucleus remaining after a nuclear transformation is in an excited state. Gamma rays accompany many but not all nuclear transformations.

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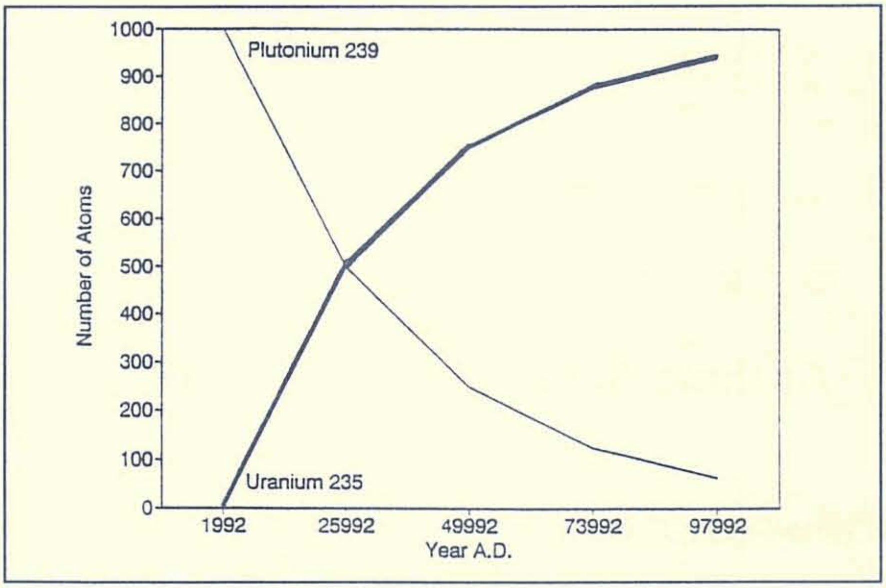

"**Half-life**" is a concept which describes how many particles a given amount of a radioactive element emits. At the end of a time equal to a half-life, only half of the number of atoms of the elements will be left, the other half having been transmuted into another element due to radioactive decay.

Plutonium-239

Plutonium-239 has a half-life of about 24,000 years. Suppose you had 1,000 atoms of plutonium-239 in your backyard on January 1, 1992. After 24,000 years, (that is by 25,992 A.D) 500 of them will have emitted an alpha particle. The 500 atoms of plutonium-239 which emitted alpha particles during that time are have changed from plutonium into another element -- in this case uranium-235. As it happens, uranium-235 is also radioactive (half-life 704 million years).

In the next 24,000 years, half of the remaining 500 atoms of plutonium-239 that are left will have emitted alpha particles. So at the end of 48,000 years (in the year 49,992, A.D.) there will be 250 atoms of plutonium left. The process is shown in the table.

If we take an average over 24,000 years, note that from 1,000 atoms of plutonium, there is one emission of an alpha particle about every 48 years. This isn't a whole lot, and the likelihood of anyone getting zapped from 1,000 atoms is very small. Unfortunately, the number of atoms of plutonium that we have made is very large, and so the amount of radiation

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The decay of plutonium-239 into uranium-235

Year, A.D.	Number of Atoms of plutonium-239	Number of atoms, uranium-235
1992	1,000	0
25,992	500	500
49,992	250	750
73,992	125	875*
97,992	62.5**	937.5**

Notes:

*Uranium-235 is also radioactive, with a very long half-life of 704 million years. Over 100,000 years or so, we would not expect any disintegrations from a few hundred atoms of uranium-235.

** We don't really get fractional amounts of plutonium and uranium atoms. The fraction "62.5" is a probabilistic statement: if we had lots of piles of plutonium of 1,000 atoms each in the year 1992, then the average number of plutonium atoms in the piles in the year 97,992 will be 62.5. For Las Vegas fans, we might make an analogy to throws of dice. We can only have outcomes which are integers 1 through 6. But of we average the outcomes (and if the dice are not loaded), the average after a large number of throws will be 3.5, which is not a number which can appear on any particular throw.

Units of Radioactivity -- Bequerels and curies

The amounts of a radioactive substance that you might have in your backyard are not in standard units or multiples of Avogadro's number. So you need to know how much radioactivity there is without necessarily knowing how much radioactive material there is. To measure this we count the number of particles emitted by whatever amount of radioactive substance is present in a unit of time. Nuclear transformations that emit radioactivity are called ''disintegrations'' (of the nucleus). The standard international unit (''S.I.'' unit) of radioactivity is one disintegration per second, called a becquerel (abbreviation Bq), after Henri Becquerel who discovered radioactivity.

That's not the only way to do it, of course. Just as we can measure weight in pounds or grams, the radioactivity of a substance can be measured in many different units. The historical unit is a ''curie'' (abbreviation Ci), named after Marie Curie, the discoverer of radium-226 (half-life 1,600 years). One gram of radium-226 equals one curie. It so happens that one gram of radium-226 emits 37 billion alpha particles per second (that is, it undergoes 37 billion disintegrations per second). Thus one curie equals 37 billion disintegration per second, or, what is the same thing, 37 billion bequerels. It took about 25 to 30 micrograms of radium-226 (25 to 30 microcuries of alpha-emitting radioactivity) in the jaw to kill the radium dial painters of the 1920s.

Arithmetic for Activists, cont. from p. 8

being emitted is likewise large.

Nuclear weapons typically contain about 3 to 5 kilograms of plutonium-239 each. Let us calculate the number of atoms in 5 kilograms of plutonium-239. The atomic weight of plutonium is given by the isotope number. In this case it is 239. In the nineteenth century a very remarkable number was discovered. The atomic weight in grams *of any element contains about 600 billion trillion atoms* -- that is 6 with 23 zeroes after it, also written in arithmetical shorthand as $6x10^{23}$, pronounced as ''6 times ten raised to twenty three''. This is called Avogadro's number, in honor of the Italian fellow who figured it out. The arithmetic could be done in pounds: the atomic weight in pounds of any element would contain 454 times as many atoms, since there are 454 grams per pound. So Avogadro's number in British units would be about 270 trillion trillion or $2.7x10^{26}$ atoms.

In sum, it takes about 600 billion trillion atoms to make up 239 grams of plutonium (just over half a pound). Therefore five kilograms (or about 11 pounds) have about 12,500 billion trillion atoms of plutonium-239 (or $1.25x10^{25}$ atoms). So even with a long half-life of 24,000 years, the plutonium in a single nuclear weapon emits a lot of alpha particles -- in fact almost 16 trillion every second!

Editor's Corner

Editor's Corner will be a regular feature of Science for Democratic Action. However, for the first issue, Arjun has introduced the publication with an introductory editorial, *IEER's Goals and the Democratization of Science.*

I would like to take this opportunity to say welcome to our newsletter, and to thank the IEER staff for all their assistance with the production. Thanks also to our wonderful consultants, Sally James for Pagemaker and Robert Del Tredici for photos. Finally, thanks to Jack Stubbs for his design advice, Linda Bohlke for her groovy graphics, and to Dave Anderson for his infinite patience.

Stacy Stubbs

"Dear Arjun"

I have been asked these question by various activists around the country, but not in the form presented, which is for your amusement.

Dear Arjun,
What is gross alpha and gross beta?
Frightened in Florida

Dear Frightened,

In the tourist industry, the terms gross alpha and gross beta are equivalent and describe what happens if you pig out on alphabet soup in Greece. In the nuclear world, the meaning is quite different.

Gross alpha denotes the total number of alpha disintegrations per minute (or other unit of time) in a given quantity of air, water, or soil. It is used to describe the total alpha radioactivity in the medium, when the individual elements contributing to that alpha activity have not been analyzed. Similarly, gross beta describes the total beta activity in disintegrations per unit of time (usually a minute or a second) when the individual elements emitting beta radiation have not been analyzed. Limits for discharges from DOE facilities are set both in terms of individual elements and gross alpha and gross beta discharges. One disintegration per second equals one becquerel or about 28 picocuries of radioactivity.

The measurements of gross alpha and gross beta can be easily converted into curies of radioactivity. To satisfy your curie-osity, I have written a column on half-life and curies from which you can figure out how to do this. However, it is not possible to convert such measurements into estimates of radiation dose, since different elements behave differently in the body, and have different energies of radiation associated with their disintegration.

Dear Arjun,
What is depleted uranium?
Mystified in Massachusetts

Dear Mystified,

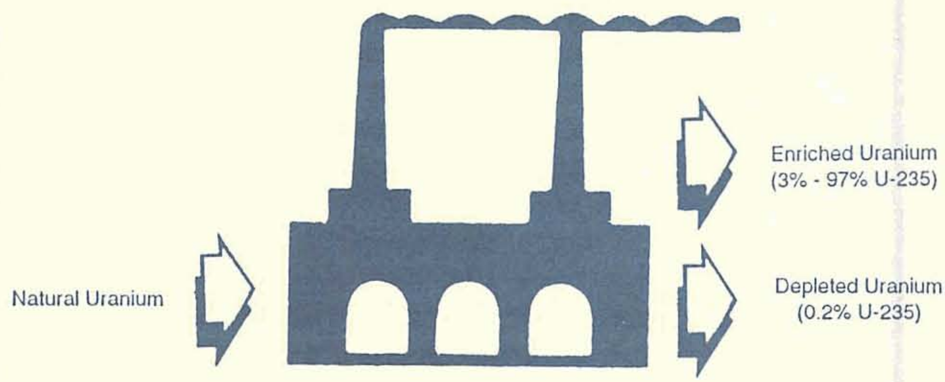
Depleted uranium is a medical condition which afflicts the cranium of activists who have gone to too many DOE hearings. In the nuclear establishment, it means something quite different.

Uranium has a number of isotopes. The three isotopes of uranium in natural uranium are: uranium-238 (half-life: 4.47 billion years), uranium-235 (half life: 704 million years), and uranium-234 (half-life, 245,000 years). The isotopes occur in a ratio in natural uranium which changes only over hundreds of millions of years, controlled by the decay rate of uranium-235. The proportions are as follows: uranium-238: 99.284%; uranium-235: 0.711%; and uranium-234: 0.005%. All three isotopes are alpha-emitters. The isotope of interest for nuclear fission is uranium-235, since this is the fissile isotope -- that is it can sustain a chain reaction under certain circumstances, once nuclear fission is initiated. Uranium-238 can be fissioned, but cannot sustain a chain reaction

-- that is, a fission of uranium-238 does not produce enough neutrons to initiate another fission so as to keep the reaction going without any further external source of neutrons. Therefore, uranium-235 is the main isotope of interest for nuclear power plants. It can also be used to make nuclear weapons. Natural uranium is too dilute in uranium-235 to sustain a *sudden, explosive* chain reaction. Therefore, natural uranium cannot be used to make nuclear weapons. In order for uranium to be used for nuclear weapons, the proportion of uranium-235 must be increased. This is done in uranium enrichment plants.

Uranium "enrichment" plants take natural uranium, which has 0.71 percent uranium-235, and yields a product which contains anywhere from 3 percent to 97 percent uranium-235. Nuclear weapons can only be made with uranium containing more than 20 percent uranium-235. Most often, the weapons contain uranium enriched to more than 90 percent uranium-235, since lesser enrichments make for bulky weapons which are more difficult to "deliver". Ninety-seven percent enriched uranium-235 is used as fuel for naval reactors.

The residue from the enrichment process is called "depleted uranium." Since most of the uranium-235 is now in the enriched uranium, the residue contains far less. Since it would take an infinite amount of energy to separate all the uranium-235 from the uranium-238, it is the practice to stop using uranium with less than 0.2 percent uranium-235 as feed materials for the enrichment process. Thus, depleted uranium contains 99.8% uranium-238 and 0.2 percent uranium-235. Essentially all the uranium-234 goes along with the



enriched uranium stream. Uranium-234 is the isotope which is the source of most concern for radiation doses in enriched uranium.

Since uranium is a hard and heavy metal, and since large quantities of depleted uranium are available, depleted uranium has come to be used for a variety of purposes such as tank armor plating and "cop-killer" bullets which can penetrate "bullet-proof" vests.

All three isotopes of natural uranium are alpha emitters. They are dangerous mainly when incorporated into the body. Depleted uranium in metal form is a source of external beta radiation. Uranium in the form of an aerosol or powder can be dangerous when inhaled. If one inhales about 33 micrograms (about one-millionth of an ounce) of insoluble uranium in the form of fine particles, it gives a dose of 25 millirem to the lung, the annual limit for civilian, non-worker populations. Soluble forms of uranium would take larger quantities to produce the same dose since they are expelled from the body more easily.

The Science Challenge will be a regular Science for Democratic Action feature. There is no way to learn arithmetic except to do it. We want to make it more immediately rewarding by offering prizes for correct solutions to the Science Challenge. Work the problem below and submit the answer to Stacy Stubbs, c/o IEER, 6935 Laurel Avenue, Takoma Park, MD 20912. If more than 5 correct entries are received, the winners will be chosen from the correct entries at random. The deadline for submission of entries is March 15th. The prizes will be $25 each. People with science, math, or engineering degrees are not eligible.

Science Challenge

How Much Gross Alpha?

This problem is to illustrate how the quantity of radioactivity changes with time in a mixture of radionuclides. The information needed to answer these questions is contained in the Arithmetic for Activists column in this newsletter.

Suppose you have 100 curies of radium-226 (half life 1,600 years) and 10 curies of plutonium-239 (half-life 24,000 years) today.

1. How much gross alpha activity does the mixture contain today, in becquerels (disintegrations per second)?

2. How much gross alpha would the mixture contain in 24,000 years, in becquerels? In curies?

Ignore any radioactivity from the decay products of plutonium-239 and radium-226.

We gratefully acknowledge the generous support of the W. Alton Jones Foundation, the Winston Foundation for World Peace, and the North Shore Unitarian Universalist Veatch Program, whose funding has made possible our project to provide technical support to grassroots groups working on DOE issues.