SCIENCE FOR DEMOCRATIC ACTION

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Fernald metals worker sitting on top of a one-ton depleted uranium metal ingot as he adds a serial number

Photo by Robert Del Tredici

Mirror, Mirror on the Wall, Which Site is the Cleanest of Them All?

Arjun Makhijani

The problem of clean-up of sites contaminated by nuclear weapons production and testing has two long-term components affecting health and the environment:

1. The standards for individual site clean-up, which determine how clean the site will be, and which may restrict the kinds of uses to which the land and underlying water may be put in the future.
2. The way in which long-lived radioactive and hazardous wastes (some of which may be produced by clean-up activities) are managed, which limits land and water use in disposal areas, if shallow and deep land disposal are the ways chosen for waste management.

The term, "clean-up" addresses only the first of these two: the digging and scraping of dirt, the dismantling and removal of contaminated equipment and buildings, or the extraction of contaminants from groundwater (when possible). But these activities do not address the question of waste management and disposal: what to do with the enormous amounts of

See "How Clean" - p. 5

New Evidence on Low-Dose Radiation Exposure

Scott Saleska

Public health policy regarding radiation health standards is generally based on recommendations of advisory scientific bodies, such as the International Commission on Radiological Protection (ICRP) and the National Academy of Sciences' Committee on the Biological Effects of Ionizing Radiation (BEIR). These bodies have, until now, recommended the use of the assumption that radiation doses delivered at slow rates are less dangerous for producing solid cancer tumors than the same total dose delivered suddenly.

This assumption expresses itself by the use of "risk reduction" factors, by which the estimates of total cancer fatalities are lowered if the dose is delivered at a slow rate.

Low dose rates may be more harmful than official bodies assume

If this assumption is wrong, as new evidence indicates, then most radiation exposures to the public and workers would be more harmful than assumed by standard-setting

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Radiation
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bodies.

So, for example, the ICRP recommends that a risk of four fatal cancers per 10,000 person-rem of exposure be assumed when estimating the consequences of low-dose rate radiation exposure. This is consistent with the range suggested by the most recent National Academy of Sciences' report. Because it results from the use of a risk reduction factor, this risk estimate is a factor of two lower than the estimate derived for relatively high dose rate from the Japanese atom-bomb survivors (8 cancer deaths per 10,000 person-rems, according to the National Academy of Sciences). However, with the exception of leukemia cancers, there is scant human evidence to support this practice; rather, it is based principally on animal studies.

The New British Study

A recent nuclear-industry funded study on British radiation workers adds new scientific support to the theory that radiation exposure causes cancer risk even at low doses and dose-rates.

The new British study, published by members of Britain's National Radiological Protection Board (NRPB) is of external radiation doses at low dose rates, and it does *not* support the above-mentioned assumption that such radiation is less dangerous than the same total dose delivered in a short time.

Based on average worker exposures of 3.4 rem delivered over many years, the study indicates that the risk of fatal cancer per unit of radiation received gradually is about 10 cancer deaths per 10,000 person-rems -- roughly the same as for risks at relatively high dose-rates (10 to hundreds of rems delivered all at once) derived from the Japanese atom-bomb survivors (8 cancer deaths per 10,000 person-rems, according to the National Academy of Sciences).

Even though the British worker study ostensibly applies to doses in the range of a few rem (with an average of 3.4 rem), its logical consequences are that doses at far lower levels still (on the order of a few thousandths of a rem) are sufficient to cause health risks. This is because the dose values given in the British worker study are *cumulative* doses resulting, in many cases, from years or decades of exposure. The actual average individual doses received by most workers are typically no more than a few thousandths of a rem per day. (A thousandth of a rem is called a millirem.)

Since most known cell repair mechanisms generally require only a few hours, it is reasonable to assume that such cell repair that does take place in response to damage that might have been caused by a given day's radiation exposure will be completed before the next work-day begins. This means that doses from one day to the next are independent of each other in terms of their cancer-causing effect. Thus, cancer risks incurred by a cumulative dose over time would be the result of the accumulation of the *separate* risks of each of the daily doses. (In other words, according to this assumption, if the daily dose were too small by itself to increase the risk of cancer, then there would be no excess cancers observed at all -- even after many years and total dose accumulations which were quite large.)

See "Radiation" - p. 4

SCIENCE FOR DEMOCRATIC ACTION

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Editor's Corner

Nuclear Testing: Toys for the Boys, Dumps for the People

The Cold War is over. Threatened by the prospect of large reductions in nuclear arsenals and even nuclear disarmament, nuclear scientists are circling the wagons around a vision of "nukes forever." Their ideas include earth-burrowing nuclear weapons which could penetrate hardened bunkers, small "battlefield nukes," and, according to Lawrence Livermore Lab scientist Robert Budwine, a nuclear bomb hundreds of times more powerful than any bomb previously made. Envisioned by Edward Teller, the "father" of the H-bomb, this weapon would decimate the Earth if it was ever used. Budwine thinks it could be used to blow up enemy decoy missiles during a nuclear war. Who the enemy is remains unclear.

Another proposal is to use nuclear explosions to produce power. The heat from the explosion of one-kiloton weapons would produce steam to drive turbines. The Lawrence Livermore National Laboratory scientists who proposed this scheme ignored the environmental impact of producing the huge quantities of explosives that will be needed, nor did they consider the effects of accidents such as containment failures.

The latest proposal is to prepare nuclear weapons to be used in the event that a large asteroid is discovered to be on a collision course with Earth. Before they try to deal with destructive acts of God, we suggest the weapons designers deal with destructive acts of man, starting with their own. They should devote their efforts to cleaning up the mess from almost five decades of weapons production and testing.

In spite of the lack of justification for continued testing, U.S. nuclear test explosions continue. These tests threaten to stir global tensions at a time when an unparalleled relaxation of tensions is possible. The Russians are discussing breaking their unilateral moratorium on testing in response to continued U.S. testing; France may not continue its recently announced moratorium beyond the end of 1992. Continued U.S. testing also makes achieving nuclear non-proliferation far more difficult. It is ironic that countries that do not have nuclear arsenals want a comprehensive test ban, but the U.S., which has a huge and proven arsenal, wants to continue testing, even at the risk of increasing weapons proliferation.

Each nuclear test creates an uncharacterized, unlicensed, nuclear waste dump. In fact, after each test the DOE notifies the EPA under the Superfund law that it has just released hazardous radioactive materials into the environment and created future clean-up liabilities. This is especially ironic when one considers the rigorous characterization activities that are being required of the DOE before they are allowed to emplace the same type of waste at the proposed high-level waste disposal site at Yucca Mountain, Nevada, only a few miles away from the Nevada Test Site.

This irresponsible behavior should not continue. All nuclear testing should be halted immediately. A thorough environmental impact statement evaluating the long-term environmental impacts of past and any proposed future testing should be conducted so that the issues can receive a full and democratic debate.

Stacy Stubbs

Radiation, cont. from p. 2

It thus appears from the British study and from what is known about cell repair mechanisms that even millirem doses are likely to be as effective at causing cancer per unit dose received as larger doses received in a short period.

Uncertainties

Although it provides telling evidence, the British study does not settle the issue definitively since, even with such a large number of workers, the absolute number of cancers is still relatively low. Consequently, the uncertainties are large: the 90% confidence interval (the "error bar") ranges from less than zero risk to 24 cancers per 10,000 rem. This is wide enough to include the ICRP estimate. Based on this, the authors of the British study feel the evidence does not justify a revision of "risk estimates for radiological protection purposes." However, the most likely estimate of risk in the study lends specific scientific support to the reasonable practice of rejecting an assumption of risk-reduction at low dose rates. It also provides support for using the same risk factors for low dose rates as for high ones. It should be noted that in the absence of good solid *human* -- as opposed to animal -- evidence *for* such reductions, this would be sound, conservative public health practice in any case, even without the new results of the British study.

Another uncertainty is that this study, like most studies of radiation workers, is complicated by the uncertainties associated with internal radiation doses, especially from alpha emitters, such as plutonium-239, which are difficult to detect in small quantities. The doses and risks from internal alpha radiation relative to external gamma radiation are still the subject of considerable research, and risk factors may well have to be revised in light of new work.

Implications for Standards

The ICRP (which is an international advisory body) recommends a worker exposure standard of two rem per year, but this is based on a risk coefficient which the British worker study indicates may be low by a factor of two (due to inappropriate application of a risk-reduction factor). Correspondingly, the ICRP should reduce its recommended maximum dose for worker exposure by a factor of two, to one rem per year.

The British standard, at 1.5 rem, is already somewhat more strict than the ICRP recommendation. However, Friends of the Earth in the UK has called for a further reduction to 1 rem, in part due to the findings of the British worker study. By comparison, standards in the U.S. lag far behind even the current ICRP recomendation, with the NRC and DOE still using a 5 rem per year standard for workers that has prevailed in the U.S. for the last 35 years.

References

G.M. Kendall, C.R. Muirhead, et. al., "Mortality and occupational exposure to radiation: first analysis of the National Registry for Radiation Workers," *British Medical Journal*, Vol. 304, 25 January 1992.

National Research Council of the National Academy of Sciences, Committee on the Biological Effects of Ionizing Radiation, *Health Effects of Exposure to Low Levels of Ionizing Radiation, BEIR V*, National Academy Press, January 1990. This is popularly called the BEIR V Report, after the name of the committee.

Dear ieer,

. . .I was given a copy of your booklet, "Science for Democratic Action." Since I am overwhelmed with newsletters and other reading matter, I almost threw your booklet away. Fortunately, I did not! It is exactly what I am looking for.

I am a 20/20 VISION core chairman and national board member. I also work with a coalition on environmental groups in the Southeast in an attempt to educate the public about the long-term effect of hazardous waste, radioactive pollution, and contamination from industrial by-products such as organochlorines . . . .

. . . May I further suggest that you be as brief and simple as possible. While humor is appreciated, most of us have very little time or file space for pleasantries . . . .

Sincerely,
Joan O. King

Letters to the editor are welcome. Please include your name and address. Letters may be printed in excerpted form.

How Clean, cont. from p. 1

radioactive, hazardous, non-radioactive, and mixed wastes that have been created by weapons production and that will be generated by clean-up activities? Seen from the perspective of radioactive wastes, there is really no such thing as clean-up of the complex as a whole (in the sense that the waste is ultimately gotten

If the wastes are not managed properly in the short-term, they will be the clean-up problems of the future

rid of); rather, waste management is the problem of containment that is left over after the Cold War.

A principal connection between these two aspects of clean-up is that if the wastes are not managed properly in the short-term, they will wind up as the clean-up problems of the future. This is not a theoretical proposition. Some of the most serious clean-up and waste management issues of today -- such as the Hanford, Washington high-level radioactive waste tanks, the West Valley, New York dumps, the Maxey Flats, Kentucky low-level waste dump, and uranium mill tailing sites -- are the result of past irresponsible waste management and disposal practices dominated by short-term expediency.

The Present DOE Approach

There is some inevitable tension between clean-up and waste management: the more thorough the local clean-up, the larger the volume of contaminated materials that will have to be managed as waste. However, the DOE seems intent on aggravating this tension by repeating many of the mistakes of the past, exemplified by its current primary reliance on land disposal of poorly characterized and classified wastes at hurriedly and inappropriately selected sites.

Radioactive and Toxic Waste Disposal Ditch at Hanford
photo by Robert Del Tredici

It is clear that much of the land at DOE weapons sites is heavily contaminated and cannot be put to any general, unrestricted use today. Further, in most cases contaminated water and soil contain both short-lived and long-lived radionuclides. Wastes in tanks and barrels and buried wastes also contain large amounts of long-lived, highly hazardous radionuclides. The half-lives of such materials range from around 30 years (as in the case of strontium-90 and cesium-137) to tens of thousands of years (as with plutonium-239 and thorium-230).

For some long-lived wastes, the DOE's proposal is to put them in repositories at the Waste Isolation Pilot Project (WIPP) in New Mexico and Yucca Mountain in Nevada. IEER's analysis, presented in our new book, *High-Level Dollars, Low-Level Sense*, points out some basic flaws of these sites, of the standards that govern waste disposal in them, and of the process that led up to their selection. Thus, even for the portion of wastes for which the DOE claims to have a plan, isolation of waste (or even compliance with inadequate standards) for the relevant periods is far from assured.

Most of the rest of the long-lived wastes are destined for "low-level" radioactive disposal sites, or for mixing with cement to form grout for on-site disposal. This disposal is governed by "low-level" waste disposal criteria which require institutional control for 100 years and isolation for 500 years.

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How Clean, cont. from p. 5

Yet, there is little history of institutional control over any site to the degree required for periods like 100 years. Moreover, in some cases, such as some decommissioned reactor parts or buried transuranic wastes, the wastes remain dangerous for tens of thousands of years.

Standards

One of the principal difficulties is that there are no general standards for land use to govern the process of site restoration. Two narrow and inadequate standards do exist -- one for radium-226 and one for plutonium. According to the Environmental Protection Agency's (EPA) regulations, actions regarding clean-up of radium in areas near uranium processing sites should be taken when contamination exceeds 5 picocuries per gram in the top 15 centimeters (six inches) of soil. The suggested action level for plutonium is 0.2 microcuries per square meter of surface contamination, with resuspension in air constituting the main assumed threat. This is very important for sites such as Hanford, the Idaho National Engineering Laboratory, the Nevada Test Site, and Rongelap, in the Marshall Islands.

Yet it is not at all clear that the clean-up that the DOE is undertaking would meet even these standards for land throughout the complex; nor is it clear that the EPA standard of limiting doses from groundwater to 4 millirems per year would be met after there is no more institutional control of the sites. Indeed, clean-up is being planned without systematic consideration of long-term compliance with these standards, and without the promulgation of more comprehensive and adequate standards. Rather, the DOE and the Nuclear Regulatory Commission (NRC) continue to do things like block the EPA from even publishing for public comment draft standards governing low-level waste disposal that would be more comprehensive than those in force at present.

DOE clean-up plans may not meet even current inadequate standards

Unremediated Uranium Mill-Tailings Pile In Canada
photo by Robert Del Tredici

Evolving Land Use

The objectives of clean-up and short-term waste management can be expressed as follows:

- Eliminating waste due to new production and testing by stopping these activities.
- Minimizing or eliminating the risk of short-term catastrophes and irreversible spread of contamination in ways that do not compromise sound long-term management or unrestricted land use.
- Reducing the contamination of the sites themselves so that the uses of land and water may become progressively less restrictive than they are today over larger and larger areas, to a degree agreed upon by the adversely affected parties.
- Restoration of groundwater sources, and the development of technologies to do so where they do not now exist.
- Minimizing exposure of workers and off-site residents during clean-up.

The question "how clean is

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clean?'' does not need a one-time, permanent answer. So long as new production activities are stopped, immediate threats are being alleviated, adequate standards are set, land-use is becoming less restricted and clean-up is proceeding in conformity with environmental laws and regulations, there is no need to accept land-use categories that will condemn some portion of the land to essentially permanent second class status, or worse. Solutions that compromise long-term land-use, such as vitrification of soil and grouting, should be avoided to the extent possible, unless the long-lived radionuclides can be extracted first. The following principles need to be incorporated into the technologies for long-term waste management:

- Separation of long-lived radionuclides from wastes where possible, and the development of technologies to do this where they do not exist.
- Concentration and processing into solid form of long-lived radionuclides.
- Monitored, above-ground and retrievable storage of short-lived wastes until they decay to very low levels.
- Interim, on-site storage of long-lived wastes and a fresh start to the process of considering the least dangerous means of long-term management and disposal.

The Nuclear Production Complex

Arjun Makhijani

In the past two years, the nuclear weapons complex has been revealing itself to be as descriptive of a fixated mental condition of many nuclear scientists, engineers and bureaucrats in the Department of Energy (DOE) and its contractors as of a set of physical facilities for producing and testing weapons. Consider the following facts:

- The Cold War is over -- Russia has asked to join NATO.
- The U.S. nuclear arsenal in 1990 was about 20,000 weapons and the largest arsenal that has been proposed (by President Bush) is about 6,300 weapons; the lowest numbers range from zero to 100 weapons.
- Even with an arsenal of 6,300weapons, the largest under any current proposal, there is a surplus stock of about 90 tons of unwanted plutonium.
- There is such a large supply of highly enriched uranium (500 to 600 tons) that the DOE recently shut down the only production line in the country for this material (Portsmouth, Ohio).
- The tritium from the nuclear weapons already proposed to be dismantled will last until at least the year 2005 to 2010, even according to Secretary of Energy, Admiral James Watkins. Smaller arsenals would mean longer periods for which existing tritium supplies could meet governmental weapons requirements.

In the face of this plethora of materials and weapons, consider the following facts about the determination of the Departments of Defense and Energy to continue production and testing:

1. The DOE continues to test nuclear weapons, knowing full well that it is creating substantial radioactive contamination with each test. In fact, under the Superfund law, the DOE notifies the National Response Center after each test that it has released substantial quantities of hazardous radioactive materials into the underground environment and thereby created future clean-up liabilities.

2. The DOE is ready to restart the aged K-reactor. This reactor could not meet civilian licensing standards. The DOE wants to restart it without safety equipment that even it says is needed. There is apparently some urgency to demonstrate that the U.S. has a tritium production capacity, though who the demonstration is for or why it is needed with such urgency has not been explained.

3. The DOE is throwing away as waste tritium that it has at various sites. An October 1991 report on tritium noted that ''DOE line managers and

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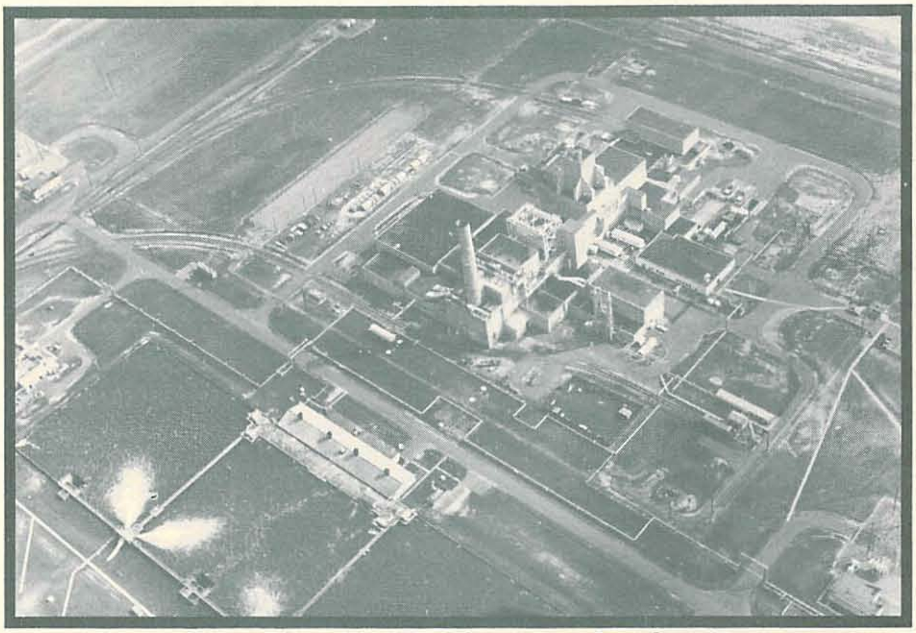
contractor personnel...were generally unaware of the increasing value of tritium. Among those who use it, tritium is most often viewed as a no-cost, government-provided material....[T]he accepted norm for handling contained releases of tritium within process areas is to intentionally convert tritium to tritium oxide and treat it as waste, thereby forfeiting significant quantities of tritium-bearing materials."[1]

4. At Rocky Flats, where the plutonium triggers for nuclear weapons are made, the operational readiness review for the first building to be restarted did not review plutonium materials accounts (critical for security, and environmental issues), long term waste management, or facility security.



One of the Five SRS Tritium Production Reactors
photo by Robert Del Tredici

The schemes of the weapons designers are getting wilder and wilder. They range from making world-busting weapons of "tens of thousands of megatons" to using nuclear explosions to generate electricity. In the nuclear weapons establishment, the careful reasoning and attention to facts that characterizes good science seems not to extend beyond the very narrow confines of designing and testing nuclear explosives. Social, economic, health and environmental issues have suffered from sloppy practice and some of the worst science, including fabrications of data, an "inherently deceptive" formula (according to an official document), and cover-ups. But then, the self-image of the most prominent among the nuclear scientists in the social realm has often been that of members of a priesthood rather than that of scientists. Consider the sentiments of Alvin Weinberg, former director of Oak Ridge National Laboratory, delivered in 1972:

> [N]uclear weapons have stabilized at least the relations between the superpowers. The prospects of an all out third world war seem to recede. In exchange for this atomic sense, we have established a military priesthood which guards against inadvertent use of nuclear weapons, which maintains what a priori seems to be a precarious balance between readiness to go to war and vigilance against human errors that would precipitate war....The discovery of the bomb has....called forth this military priesthood upon which in a way we all depend for our survival.[2]

He essentially calls upon people to give up their democratic freedoms to a nuclear priesthood. Reflecting on his enthusiasms for things nuclear a few years later, Weinberg compared his zeal for plutonium and nuclear energy to that of an ayatollah (for religion).[3]

But the issues of production and testing of nuclear weapons cannot be resolved by handing them over to a priesthood that wants to perpetuate itself and its fancy jobs. Indeed, the problems of clean-up cannot be satisfactorily addressed unless we subject the nuclear weapons establishment to the fresh winds of truth and democratic debate on the issues of production and testing.

Footnotes:

[1]Report of the Task Group on Operation of Department of Energy Tritium Facilities, DOE/EH-0918P, Washington, D.C.: U.S. Department of Energy, October 1991, p. 27.

[2]Alvin Weinberg, "The Safety of Nuclear Power," lecture presented to the Council for the Advancement of Science Writing Briefing on New Horizons in Science, Boulder, Colorado; November 14, 1972.

[3]Alvin Weinberg, 1981 interview, quoted by Daniel Ford, *The Cult of the Atom*, New York: Simon and Schuster, 1982, p. 25

Arithmetic for Activists #2

Arithmetic for Activists

Nothing Ventured, Nothing Gained

by Arjun

We received no responses to the Science Challenge in the first issue of *Science for Democratic Action*. That's right, no responses, right or wrong!

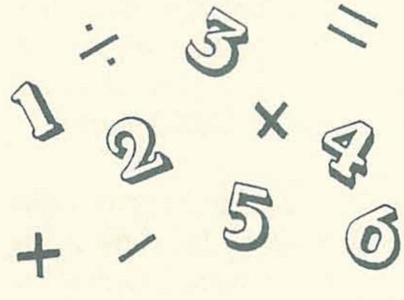
Numbers can't be your best friends unless you introduce yourself to them, and, after a decent interval, expose yourself to them in a sufficiently intimate manner. This means that you must take a risk. The **worst** that could happen is that you could be wrong. This is the kind of risk that should be easy to take, since the cost of failure is small and even negligible, and the benefits of success are great. That's very different from the sort of proposition that the DOE makes to folks, when it proposes dumps and weapons plants in their neighborhoods.

We cannot learn anything without making mistakes. That is part of human nature, whether it is learning to walk and talk as children or learning math or music as grown-ups. In fact, I might add that one of my greatest problems with nuclear technology is that it is contrary to human nature because it does not allow for learning from mistakes, since some mistakes invite the risk of catastrophe. This was illustrated by the 1986 Chernobyl accident.

Contrary to the impression you get when you look at text books of mathematics and science, the things that are worked out and that seem so orderly were actually discovered after many mistakes and many false starts. So, follow in the tradition of truly **great** science. Don't be afraid of mistakes, and make an attempt to answer the questions! We have restructured the prizes to correspond to this philosophy. So go on, take a risk, and try this time's Science Challenge.

Solution to Science Challenge Number 1.

The problem was entitled: How much Gross Alpha? It was:



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.

Solution:

Gross alpha activity is the total amount of alpha activity from all radioactive substances present. In this case there are two -- radium-226 and plutonium-239. The amounts of these substances are 100 and 10 curies, for a total of 110 curies (one can add up curies from different radioactive materials together to find out how much total radioactivity is present). As this solution shows, this radioactivity changes with time because of radioactive decay, and the proportion that each substance

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Calculating Specific Activities

It is a relatively straightforward matter to calculate the approximate specific activities of radioactive elements. Specific activity is defined as the number of radioactive disintegrations per unit time per unit weight of a substance. One common unit is curies per gram. One curie is equal to 37 billion disintegrations per second.

To calculate specific activity, we need to know the half-life of the element, its atomic weight, and the properties of a standard (or "reference") radioactive element. The usual reference element is radium-226. The number that follows an element is its atomic weight. In this case, the atomic weight of radium-226 is equal to 226 grams. The half-life of radium-226 is 1,600 years, and we know that 1 gram of radium has a specific activity of 1 curie per gram.

We want to find the specific activity of some element "x." This is done by comparing its half-life and atomic weight to that of radium-226. Specific activity is inversely proportional to atomic weight and half-life. In view of this, we take the product of three quantities - the atomic weight of radium-226, the half-life of radium-226 and the specific activity of radium-226 - and put them in the numerator. Then we divide by the product of the atomic weight and the half-life of the element "x." We take care to ensure that all half-lives and atomic weights are expressed in the same units (grams and years in each case, for instance).

So we have specific activity of "x"=

$$\frac{\text{(226 grams * 1,600 years * 1 curie per gram)}}{\text{(Atomic wt. of ``x'' in grams * half-life of ``x'' in years)}}$$

$$= \frac{(361{,}600)}{\text{(atomic wt of ``x''* half-life of ``x'')}}$$

The answer is in units of curies per gram. For example, the specific activity of tritium (atomic weight 3 grams, half-life 12.3 years) is 361,600/(3*12.3)=9,799 curies per gram. This is not an exact figure, since we have used approximate figures for half-life and atomic weight. Note that you can figure the weight of something that it will take to make up one curie of radioactivity by taking the inverse of the specific activity. The answer is then in units of grams per curie.

Try it out on a few of your favorite radioactive elements - such as plutonium-239 (half-life: 24,000 years), uranium-235 (half-life: 704 million years), strontium-90 (half-life: 29.1 years).

Arithmetic,
cont. from p. 9

contributes to the total changes with time, because the half-lives of the substances are different.

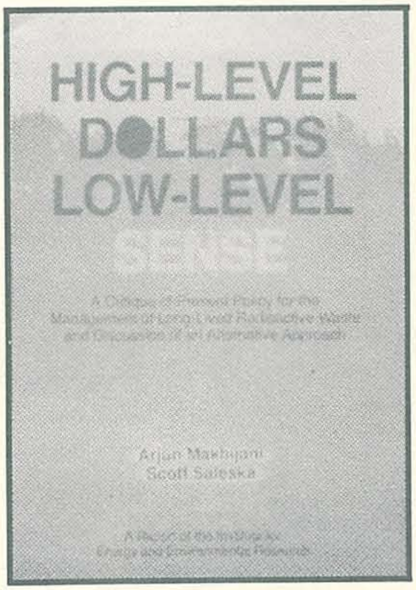
The initial amount of curies can be converted to becquerels by multiplying by the conversion factor of 37 billion becquerels per curie. Since both radium-226 and plutonium-239 are alpha emitters, the gross alpha initially is 4.07 trillion becquerels.

After 24,000 years, both radium-226 and plutonium-239 have decayed, but to different extents. The amount of plutonium-239 is reduced by half to 5 curies. However, the amount of radium-226 is reduced to a far greater amount, since 24,000 years amounts to fifteen half-lives of radium-226. This means that radium-226 has been reduced by a factor of 32,768, which is two multiplied by itself fifteen times. There are about .003 curies of radium-226 remaining. Thus, in terms of alpha radioactivity, it is plutonium that dominates after 24,000 years.

After 24,000 years the gross alpha activity is about the same as the activity of plutonium-239, or about 5 curies. This amounts to 185 billion becquerels. (There is some additional radioactivity from decay products, but after 24,000 years, this is small relative to five curies.)

Note that, although the number of curies of radium-226 remaining after 24,000 years is small compared to the number of curies of plutonium-239, there is still a significant amount of radium. .003 curies is 3 milligrams, and it took only 25 to 30 *micro*grams (.025-.03 milligrams) in the jaw to kill the radium dial painters of the 1920s.

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.*

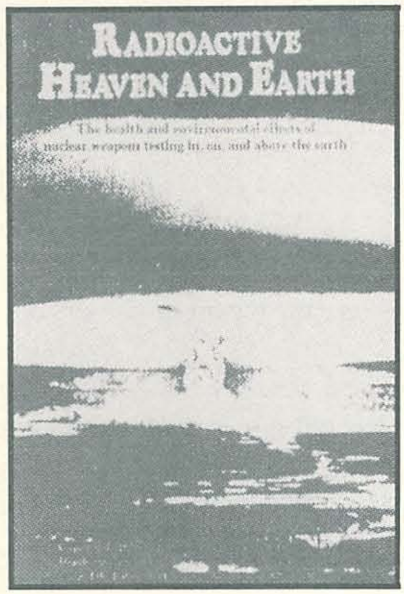
-- Barry Commoner, Center for Biology of Natural Systems, Queens College

PRICE: $15.00 including postage and handling

Radioactive Heaven and Earth

The Health and Environmental Effects of Nuclear Weapons Testing in, on, and above the Earth

by International Physicians for the Prevention of Nuclear War and IEER

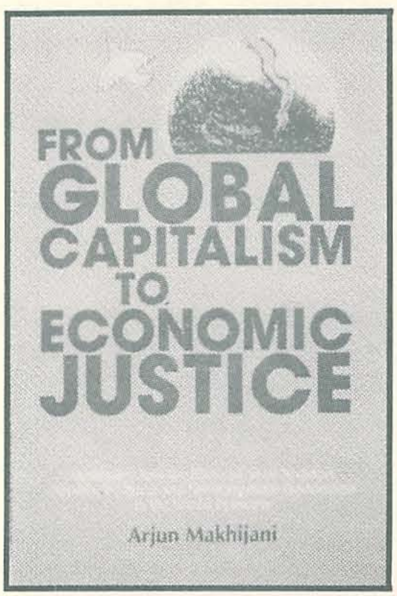


Radioactive Heaven and Earth is the first global analysis of the health and environmental effects of nuclear weapons testing, both atmospheric and underground, since testing began at Alamogordo, New Mexico in 1945.

Radioactive Heaven and Earth *is in the great tradition of physicists and scientists as they continue to document the dangers of nuclear testing. This authoritative book exposes the human costs and environmental damage wreaked on the earth as the United States and other nuclear powers continue to develop new, more destructive nuclear weapons.*

- Rear Admiral Eugene Carroll (Ret. US Navy),
Deputy Director, Center for Defense Information

PRICE: $17.00 including postage and handling



From Global Capitalism To Economic Justice

An Inquiry into the Elimination of Systemic Poverty, Violence and Environmental Destruction in the World Economy

by Arjun Makhijani

In capitalism, not only workers and communities everywhere, but also the well-off pay a heavy price. Everyone is dispossessed by militarized borders and global environmental destruction. This book presents a vision that unites local and private initiative with distributive justice.

This is a book of hope--that working people everywhere, by joining hands at the grassroots, can yet achieve real economic democracy. Everyone committed to building a more just and sustainable future should read this book--and then act on its message.

-- Anthony Mazzocchi, Assistant to the President and former Secretary-Treasurer, Oil, Chemical and Atomic Workers International Union

PRICE: $17.00 including postage and handling

"Dear Arjun"

Dear Arjun,
What are units, and why are there so many?
Baffled in Buffalo

Dear Baffled,

In ancient times, units used to be the people who guarded harems. At that time, few men could afford harems, so there weren't many units around. Since the Age of Enlightenment, harems have become less common, and the scientific establishment has given units a new meaning altogether.

A unit is simply a standard quantity of something we want to measure. For instance, we measure weight in terms of ounces, pounds and so on; we measure length in terms of inches, feet, miles, etc.; volume in terms of quarts, gallons, etc.; time in terms of seconds, hours, days, and so on. Each one of these units refers to a standard amount of something physical.

If a unit of measure is too large or too small to measure something, it is customary to create another, more convenient unit of measure which corresponds more to the dimension of the thing being measured. Thus we measure the time to cook something in minutes or hours, and the seasons in weeks or months, when we could, in principle, measure everything in days or seconds. So, the volume of irrigation water is often measured in acre-feet (which is the volume it would take to cover an acre of land one foot deep), but since this is alot of liquid (about 325,000 gallons) gasoline in an automobile tank is usually measured in gallons.

When things get too small (or too large), it is usual to create new units by having them be thousandths, millionths, billionths, etc., of a fraction of an existing unit (or thousands, millions, billions, etc., multiples of an existing unit). We give these new units names by attaching Greek prefixes to existing units -- *milli-*, a one-thousandth part (as in millisecond), *micro-* for a millionth part (as in microsecond), *nano-* for a billionth part (as in nanosecond), *pico-* for a trillionth part (as in picosecond) and *femto-* for a one-thousandth of a trillionth part (as in femtosecond). *Kilo-* means one-thousand times greater, *mega-*, a million times greater, *giga-*, a billion times greater, and *tera-*, a trillion times greater.

From a basic set of units for length, weight, time, and electrical charge, we can create a whole host of compound units that are designed to measure diverse physical properties of things. Thus, to measure the flow of water in a river, we use a unit of cubic feet per second. We can give this compound unit a new name if we wish, and it is common practice to do so. In this case, the name is *cusec*, which is equal to a flow of water of one cubic foot per second.

In environmental and health matters concerning radioactivity, we are concerned with units designed to measure the properties in which we are interested, such as how radioactive something is, how much of a radiation dose it gives the body, how long it sticks around, how much of it is there in a given amount of water or soil or air, and so on.

The units I have mentioned above are all British units. The French invented metric units -- they measure weight in grams, kilograms, and metric tons; length in millimeters, centimeters, meters, and kilometers; volume in cubic centimeters, liters, cubic meters, and so on, which are units which progress by factors of ten, one hundred, etc. (Notice the common use of the some of the prefixes, such as kilo- and milli-, described above.) This is very practical and easy, once you get a feel for it. (The world of units is, perhaps, an area where the British are more romantic and the French more pragmatic.) In revenge for Waterloo, the French successfully dedicated their efforts to making their system generally accepted in the world of science and (apart from the U.S.), in industry as well.

In the radiation field, too, there are different units to describe the same thing. For example, in the U.S., radiation exposure is often measured in rems, while most of the rest of the world uses sieverts (1 sievert equals 100 rems, and a one-sievert dose is a lot of radiation exposure!). Radioactivity is measured in either curies or becquerels.

It is often confusing to people to convert from one unit of measure to another one. That is natural. Just remember that the larger the unit of measure, the smaller the number it takes to express a given amount of something. If you measure your weight in ounces, a small unit of measure, it will be a much larger number than if you measure in pounds. Happiness is a scale that measures one's weight in tons!

Dear Arjun,
What is the specific activity of tritium?
Without Seafood in Savannah

Dear Without Seafood,

Tritium was a famous gladiator in ancient Rome. The specific activity for which he was well known was that he would finish off his opponents in three jabs and then write graffiti consisting of the Roman numeral III all over the entrance to the Colosseum - hence his name, Tritium.

In the nuclear industry, the specific activity of a substance (whether it be tritium or any other radioactive substance) refers to its radioactivity (measured in terms of the number of nuclear disintegrations per second) per gram of the substance. It is a convention that the unit of weight is always a gram, though it could be some other unit such as an ounce or a pound. (One pound equals about 454 grams.) The unit for the number of disintegrations per second can be becquerels (one disintegration per second, abbreviation: Bq) or curies (37 billion disintegrations per second, abbreviation: Ci), defined as the number of disintegrations per second that occurs in one gram of radium-226 (thus, one curie of radium-226 equals one gram of radium-226).

The specific activity of any radioactive substance is related to its half-life (half-lives were discussed in the last "Arithmetic for Activists" column). The shorter the half-life, the higher the specific activity, and vice-versa. This makes sense because if something has a very short half-life, it must lose its radioactivity very fast (otherwise it would be around for a long time!). The only way it can do this is by having many atoms decay at a time, which means many disintegrations in each bit of the substance -- which is the same thing as a high specific activity.

Radium, with a half-life of 1,600 years and a specific activity of 1 curie per gram, provides a good reference point. (See the box in the Arithmetic for Activists column to learn how to calculate the specific activity of any element.)

Thus, the specific activity of tritium (which has a half-life of only 12.3 years) is much more than radium: about 9,700 curies per gram, or about 360,000 billion becquerels per gram (written in scientific notation as $3.6*10^{14}$ Bq/gm). Since the DOE hardly ever knows discharges to the environment accurately, it is easy, convenient and correct to use an approximate figure of 10,000 curies per gram in most situations.

This is a very high specific activity. A typical nuclear weapon, which uses tritium to boost its explosive power, uses about 4 grams of tritium, which has almost 40,000 curies of radioactivity. The leak of tritium-containing heavy water from the K-reactor at the Savannah River Site last December was about 0.5 to 0.6 grams or 5,000 to 6,000 curies.

IEER's Sister Institute in Germany

Bernd Franke

IEER has a sister institute, located in Heidelberg, Germany, founded in 1978. Its name, the Institut fur Energie- und Umweltforschung (**ifeu**), is the German version of IEER's name. It currently has a staff of 23 people working in the following areas:

Municipal solid waste management: ifeu has developed solid waste management plans for German cities and states that emphasize source reduction and recycling. It is assisting the German Environmental Protection Agency in developing regulatory policies for solid waste management.

Risk analysis: ifeu has studied the impacts of radioactivity releases from nuclear power plants due to accidents as well as the impacts of the whole nuclear fuel cycle. This work has included analysis of the Chernobyl accident.

Environmental impact assessments: ifeu does environmental impact assessments of transportation systems, products and waste disposal practices. It has a number of contracts to assess the lifecycle impacts of products and packaging, as well as of airborne emissions due to transportation.

Energy and Environment: ifeu has a major project to design a program for the city of Heidelberg to reduce carbon dioxide emissions from fossil fuel use by 30 percent.

ifeu and IEER do collaborative projects and call upon each other's technical expertise as needed. This provides both institutes with a far larger range of scientific experience, and also allows us to benefit from the best in environmental practices and assessments in Europe and the United States, when we offer recommendations for public policy. They are independent institutes.

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Stacy Stubbs

Selected IEER Work

- Report for IPPNW entitled *Plutonium - Deadly Gold of the Nuclear Age.*
- Outreach on protection of the ozone layer.
- Project to support grass-roots groups working on nuclear weapons production, testing and clean-up issues.
- Portsmouth Residents lawsuit, for neighbors of this DOE uranium enrichment facility.
- Work with Native Americans for a Clean Environment on Sequoyah Fuels in Gore, Oklahoma.
- Mound Residents lawsuit for neighbors of the Mound Plant, near Dayton, Ohio.
- Publication of *The Nuclear Power Deception: Military and Civilian Nuclear Mythology from Electricity "Too Cheap to Meter" to "Inherently Safe" Reactors.*
- Production of source-book on global environmental effects of nuclear weapons production for IPPNW.

Science Challenge

How Many of Which Unit?

These are problems to get used to the idea of dealing with units, and for converting between them. Background on units (including possibly useful information) is provided in one of the answers in the "Dear Arjun" column.

1. A standard for tritium in water is 20,000 picocuries per liter (written pCi/l). Suppose the DOE reports a tritium release from one of its plants of 0.028 microcuries per liter. What is this concentration in picocuries per liter?

2. Suppose your car runs out of gas in a society which has not converted to the metric (French) system, and the few units which are used are mostly obscure ones from the cumbersome English system. The society has primarily an agriculture-based economy, and all volume measurements are done in acre-feet (since lots of irrigation water is used in growing crops). You walk to the nearest service station and would like to ask for 5 gallons of gas, but the attendant has never heard of such a unit and will only sell you a certain number of acre-feet of gasoline. How much do you ask for?

3. Suppose you are told, after your cat walks through the particle beam at your neighborhood nuclear physics lab, that it received a dose of 400 centisieverts. How many sieverts is this? How many rems?

The Science Challenge is a regular Science for Democratic Action feature. There is no way to learn arithmetic except to do it! We offer ten prizes of $10 each 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 Stacy Stubbs, IEER, 6935 Laurel Avenue, Takoma Park, MD 20912. If more than 10 people enter and there is more than one correct entry, the winners will be chosen at random. The deadline for submission of entries is June 30th. 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.

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