SCIENCE FOR DEMOCRATIC ACTION

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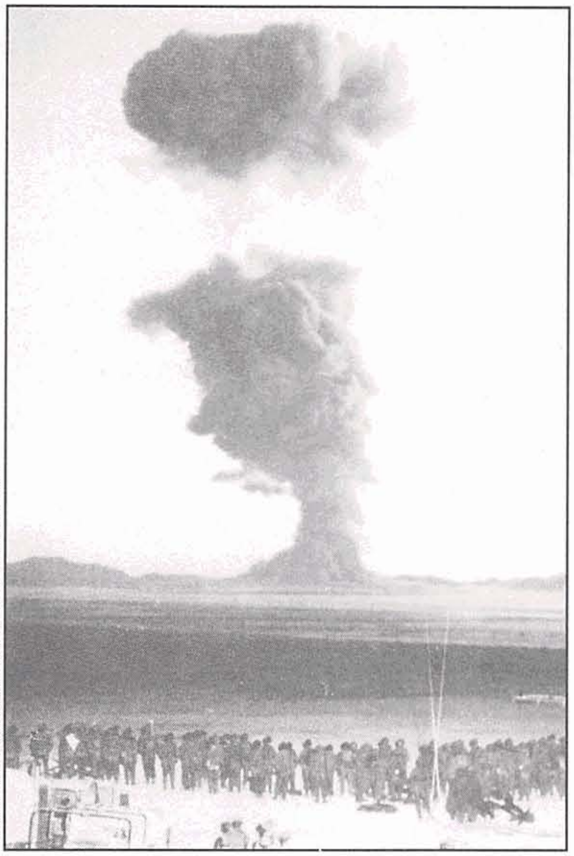
Risk Analysis: Only One Tool

Arjun Makhijani

Risk analysis is a relatively new discipline that has come to be a crucial part of public debate and decision-making on a wide variety of environmental issues. It attempts to quantify the hazards posed by dangerous substances and/or processes. At its core, risk analysis is probabilistic: it seeks to quantify both the probability and the magnitude of adverse consequences that individuals, populations, or ecosystems might suffer from specific hazards.[1]

There are several steps in assessing risk that range from determining the nature of the hazard to estimating exposure and actual effects.



PHOTOGRAPH COURTESY OF DEFENSE NUCLEAR AGENCY

Soldiers at risk: watching an atmospheric weapons test.

Determining the Nature of Hazard

First, one must decide whether and how a particular process or substance could be harmful. For instance, a substance may be acutely toxic, poisonous only upon prolonged exposure, carcinogenic, mutagenic, etc. It is also necessary to determine the doses at which these and other effects occur. When hazards involve accidental releases, one must also calculate the probabilities of accidents. A series of failures may be needed for an

See "Risk Analysis"—p. 2

[1] A useful (though rather uncritical) overview of risk analysis that includes many of the relevant regulations and background documents is John J. Cohrssen and Vincent T. Covello, *Risk Analysis: A Guide to Principles and Methods for Analyzing Health and Environmental Risks*, Council on Environmental Quality, Executive Office of the President, Washington, D.C. 1989. (Available from the National Technical Information Service, Springfield, Virginia). I would like to thank Jim Werner of the Natural Resources Defense Council for extensive comments on a draft of this article.

Editorial

Combatting Involuntary Risk:

Sound Science and Freedom of Information

Those who impose risks upon the public often seem to be more concerned about public relations than about the actual nature of the risk. Under the guise of "risk communication," it is common practice for risk imposers to try to minimize the magnitude of their particular risk by comparing it to risks from natural phenomena (see the "Dear Arjun" column in this issue for an example) or to risks from voluntary actions like skiing or driving. Many in the scientific community complain that despite their efforts to communicate risk probabilities, public perceptions of risk remain illogical because people are often more tolerant of some statistically high risk activities than they are of other comparatively low risk activities.

These comparisons and objections miss a host of crucial issues. First, as noted in the accompanying article, the fact that risks are often imposed without

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accident to occur. In such cases, risk analysis typically involves the construction of "fault trees," which are diagrams that show the sequence(s) of failures in subsystems that could lead to an overall system failure. This ideally enables the computation of an overall probability of failure.

Determining Exposure

In estimating exposure due to environmental contamination (called "dose reconstruction"), it is crucial to know the amount of a pollutant released to a particular medium, such as air or water, from a source of pollution (called a "source term"). Alternatively, an accurate history of concentrations of pollutants in air, water, and soil is necessary.

Discharges to one medium can affect another medium. Thus, emissions of particulate radioactive materials to the air will result in their deposition in soil as they "fall out." Pollutants on the soil surface may percolate into the groundwater or be washed into surface waters by rain and melting snow. Radionuclides like cesium-137, strontium-90, and carbon-14 and many organic toxic compounds can be incorporated from air, water and soil into vegetation and crops.

In estimating exposure, it is crucial to know the amount of a pollutant released to the environment.

"Pathway analysis" clarifies the often complex ways in which pollutants reach people via the environment. This analysis enables release estimates to be converted to dose estimates. Worker exposures, in principle, can be ascertained more directly. For instance, workers in nuclear plants wear film badges that record levels of exposure to gamma and beta radiation. Internal exposure to radioactive materials can be determined from urine samples and whole body counting.

Harmful substances may also be contained in consumer products, in which case sampling of the products and patterns of use and consumption are needed to estimate exposure.

Assessing the Damage

Once levels of exposure to off-site populations and to workers have been determined, adverse health consequences can be estimated, if the effects of exposure to the substance are known. Another way to assess damage to health in many circumstances is to conduct an epidemiological study—if suitable exposed and control groups can be established.

Risks can be expressed in absolute or relative terms and on an individual or population basis. To say that an individual's risk of getting a cancer as a result of a given level of exposure is 1 in 100,000 is generally equivalent to saying that one would expect one "excess cancer" in a population of 100,000 if each person were exposed to the same degree. This is a statement of "absolute risk" because it specifies the actual number of cancers that would occur as a result of the exposure.

One can also define a "relative risk," for instance by saying

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that an individual risk (within an exposed population) of a particular cancer has doubled as a result of an exposure. This means that one would expect to find twice the number of cancers in the exposed population as in a comparable but unexposed "control" population.

Uncertainties in the Nature of the Hazard

In identifying hazard, the acute (short-term) effects from high levels of exposure to toxic substances are often well-known; in such cases it is relatively easy to show that an effect was probably caused by a certain hazard. For instance, the acute effects of exposure to high levels of radiation, which include vomiting and loss of hair, are well-known.

Extrapolations from high to low doses give rise to numerous uncertainties.

In contrast, the chronic effects of exposure to lower levels of toxic materials and radiation are manifest over the long-term and may be subject to many confounding factors, such as diet, genetic predisposition, and exposure to other harmful substances. For example, the long latency period and uncertainties about the causes of cancer make it difficult to connect an exposure with an adverse outcome.

See "Risk Analysis"—p. 4

The Explosion at the Tomsk-7 Nuclear Weapons Plant

The explosion on April 6, 1993 at the Tomsk-7 plutonium reprocessing (extraction) center, is another reminder of the danger posed by Russia's nuclear complex and continued plutonium production. The explosion was reportedly in a tank containing uranium, nitric acid, and probably some other radioactive materials and chemicals. It sent a fallout cloud over the surrounding area.

More than 100,000 people live in Seversk, the closed city at the Tomsk-7 site. While the reported external radiation levels are far lower than those produced by the Chernobyl accident, they are thousands of times higher than natural background in several places. Moreover, official reassurances that there are no victims are misleading and premature because the radioactivity doses being reported are only for external exposure. However, the worst doses from uranium exposure may come from inhalation of the radioactive particles.

The Tomsk-7 facility, which includes plutonium production reactors and a uranium enrichment plant in addition to the reprocessing plant, has also created enormous pollution from its routine operations, having discharged more than a billion curies of highly radioactive liquid wastes deep underground and released other radioactive wastes into the soil, air, rivers and reservoirs.

Over the past year there have been many fires and other accidents (though without major radioactivity releases) at Chernobyl type reactors in the former Soviet Union. In 1957 there was a huge accidental explosion that blew up a nuclear waste tank at the Chelyabinsk nuclear weapons plant. At that time, the evacuation of people was stretched over two years, leading to unnecessary exposure. Now the explosion at Tomsk has once more revealed the vulnerability of the Russian nuclear complex. Official reassurances are not reassuring.

The inherently dangerous business of plutonium production continues in Russia, though it has been stopped in the U.S. Moreover, it is becoming more dangerous everyday due to Russia's deteriorating infrastructure and economy. Russia seems to be a powderkeg of nuclear accidents waiting to happen.

Other countries, such as France, Britain, and Japan, also continue to produce plutonium, even the in the face of evidence that it is an economic failure, an environmental liability, and a security threat: a testament to the power of an irrational faith in plutonium.

Arjun Makhijani

PHOTOGRAPH COURTESY OF DEPARTMENT OF ENERGY

A tank at Hanford containing highly radioactive wastes and explosive chemicals.

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Additional problems arise from the fact that estimates of long-term effects are often based on extrapolations rather than on direct data: from relatively high doses to relatively low doses, from animal studies to human studies, from men to women, and from adults to children or fetuses. A number of problems arise from such extrapolations. For instance, some substances may have thresholds below which they do not cause a specific harm, thus rendering extrapolations from relatively high to low doses invalid. In other cases, standards set for adults may do more harm (proportionally) to children and fetuses.

Another serious problem with identifying hazards is a lack of data. A very large number of chemicals have been introduced into common use without analysis of their long-term toxicity at low-doses. Synergistic effects of toxic chemicals acting together or in combination with radiation have all too often not been studied at all. Finally, the focus of hazard identification research has been on cancer, often to the exclusion of other important deleterious health effects, such as birth defects in children or immune system damage.

Uncertainties in Estimating Exposure

To calculate exposures from accidents, one must estimate both the accident's probability and its consequences. These estimates are relatively straightforward for well-understood systems. For example, the number of automobile accidents in the U.S. and their consequences can be estimated fairly accurately from year to year.

But there are numerous problems estimating probabilities for new, complex systems that have components with failure frequencies that are expected to be low. Interdependence between failure of components or subsystems may not be well-understood. In such cases, limited data provide the basis for predicting the frequency of catastrophic events such as core meltdowns of nuclear reactors. Simulations can help reduce these uncertainties, but not eliminate them. Sometimes, it is even difficult to foresee the types of catastrophic accidents that might occur, let alone specify their probabilities.

Exposure estimates also depend on a sound knowledge of source terms or concentrations of pollutants released into the environment. Sometimes there are no data because no measurements have been made. For instance, there were no measurements of radium-226 releases to the air during the first three decades of operation of Department of Energy's uranium processing plant near Fernald, Ohio. In other cases, official estimates may be poor, because of inadequate monitoring, poor maintenance of instruments, and a host of other problems. Re-estimating source terms for releases of harmful substances is a large part of the work of estimating doses and adverse health effects to off-site populations near DOE weapons plants. In contrast, estimating exposure to chemicals put in food is often relatively easy.

Events of catastrophic consequence but low probability are treated on par with events of minor consequence but high probability.

Similarly, in the case of workers, appropriate data are often not available or are too unreliable to make accurate assessments of worker exposure. For example, exposure of workers to non-radioactive hazardous materials, like hydrofluoric acid, from operations of many nuclear weapons plants cannot be directly ascertained

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because no measurements of these materials were made. Yet these exposures may be far more important than has been realized.

Limitations of Risk Analysis

Uncertainties are inherent in risk analysis, since risk estimates are generally probabilistic statements. It is good practice to estimate uncertainties and state them explicitly. When data are reasonably good, uncertainty calculations are quite straightforward. However, when data are poor or non-existent, such calculations are far more problematic and controversial, since they involve personal judgments of "experts" in place of real data and analysis. The range of uncertainty in such cases can be quite enormous.

However, even if all the necessary data needed to calculate risk are available, risk analysis should not be the sole basis for decision-making for a number of reasons. First, it does not distinguish between voluntary and involuntary risks. There are a fundamental human, political, and ethical differences between these risks. One might lose a hundred dollars voluntarily on a long-shot in a horse race, but justifiably resent losing a single dollar in a hold-up.

A second fundamental problem with risk analysis is that events of catastrophic consequence but low probability are treated on par with events of minor consequence but high probability. This happens because simple risk is calculated as the product of the probability of an event multiplied by the estimated consequence. Thus, rare, large-scale accidents like Chernobyl or Bhopal are treated on a par with a far more probable routine leak of a much smaller quantity of radionuclide or chemical. This problem is especially serious when the consequences of accidents, such as loss of life or limb, or widespread contamination of groundwater, are irremediable.

Risk analysis generally equates risks that extend out far into the future with risks that are borne by the generation that benefits from the activities. Similarly, risks borne by one section of society are equated with benefits accruing to another section, even when the imposition of risks is discriminatory in effect. For instance, rural people and ethnic minorities are often burdened with a disproportionate share of the risk from activities that benefit urban middle-class and wealthy people.

In sum, risk analysis can be a useful quantitative guide to decision-making *if* sound science underlies it, and *if* it is complemented by social and political decision-making processes that take into account its inherent limitations. (See accompanying editorial.)

LETTERS

Thanks for the $10.00 for entering the "Science Challenge" contest . . . . Thanks for a fun contest. Looking forward to the next one. I donated the $10.00 to the Franciscan Missions, so I'm sure the children they help in Third World countries thank you too.

Helen Stanbro
Los Alamos, NM

. . . *Science for Democratic Action* appeared in my mail spontaneously . . . . It is the first publication I've received in may years that actually had something for me to learn. Within that first hour, I had "worked" out *Arithmetic for Activists* and *Science Challenge.*

Edward Coffin
Poughkeepsie, NY

I just *loved* the techno-weenie centerfold pin-up. The newsletter is just great. I'm still not able to do the math problems, but I read them religiously anyway. I appreciate your work.

Roxanne Turnage
Freestone, CA

With all due deference to the Creator, Roxanne, I suggest you stop reading the problems religiously and start doing them arithmetically.

Arjun Makhijani

"Dear Arjun"

Dear Arjun,

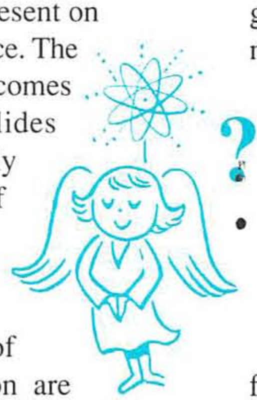
What is natural background radiation and why are various numbers so different?

Curious in California

Dear Curious,

Natural radiation is the radiation that God (or Nature) put on Earth or sends to Earth from the Heavens. The nuclear establishment seems to think that if it attributes more radiation to God, then it will seem less awful when it irradiates people from various military and civilian nuclear plants or by creating dumps in their neighborhoods. Sometimes, the nuclear establishment just plain confuses itself with God. Here are the facts:

Natural background radiation consists of external radiation and internal radiation. The external portion is due to cosmic rays and to natural radioactive materials, like uranium, present on the Earth's surface. The internal portion comes from radionuclides present naturally in our bodies, of which the principal one is potassium-40. Other sources of internal radiation are lead-210 and polonium-210 which are decay products of naturally occurring uranium-238.



Radiation dose is measured in millirems. The approximate break down of annual natural radiation dose to an individual at sea level is as follows:[1]

SOURCE	QUANTITY MILLIREM/YR
1. Cosmic rays (sea-level)	20 to 30
2. External radiation (terrestrial sources)	30
3. Potassium-40 (natural), internal	20
4. Other radionuclides, internal	10
TOTAL	80 to 90

Natural background radiation can vary a great deal from one location on Earth to another, since the amounts of uranium and thorium present in the soil vary a great deal. Radiation from cosmic rays increases with altitude so that places at higher elevations tend to have higher levels of natural background radiation. For instance, in mile-high Denver radiation from cosmic rays is about 50 millirem per year.

The nuclear establishment has found it convenient to include other items in natural background radiation from time to time. The largest item that is often slipped in is indoor exposure from radon-222, a radioactive gas which is a decay product of radium-226. This inflates the figure for annual average "natural background" exposure to about 300 millirem per year.

It is wrong to attribute doses due to indoor radon to "natural background" radiation because the dose not only depends on how much radon is seeping out of the soil, but also on house design, construction, and ventilation. When indoor radon levels are high, the amount of exposure can usually be reduced greatly by relatively simple engineering measures.

The nuclear establishment also often slips in fallout from atmospheric nuclear weapons testing into the discussion. One often hears about "background" cesium-137 or plutonium-239. While documents may not actually say "*natural* background" plutonium-239 or cesium-137, but they nonetheless tend to leave that impression, since the word "background" is generally used in

See "Dear Arjun"—p. 7

[1] The source for these figures and a good reference work on this subject is David Sumner et al, *Radiation Risks*, Third Edition, Tarragon Press, Glasgow, 1991. Another reference is Merril Eisenbud, *Environmental Radioactivity*, Academic Press, San Diego, 1987.

Dear Arjun

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association with "natural" as a matter of common practice. There is nothing natural about plutonium-239, cesium-137, or other radionuclides from nuclear weapons testing.

Some figures for exposures from other sources are as follows:

Radon: A general range for the U.S. might be 100 to 300 millirem per year (whole body equivalent), though it can be far higher in certain areas. Indeed, it can vary a great deal from one house to the next.

Medical X-rays: A chest X-ray with modern devices might expose a person to an equivalent of 5 or 10 millirem of whole body radiation.

Consumer products: The public gets approximately 5 to 13 millirem per year from consumer products. For instance, some fluorescent lamps contain various radioactive materials in their starter bottles, and most smoke detectors contain americium-241.

Worker exposures: The average exposure for radiation workers is officially estimated at 230 millirem per year. How good the worker dose estimates are is at present an open question, especially regarding DOE facilities.

The DOE often justifies increased exposures to the public by saying they are only a few millirem per year (as, for instance, is the case for average, worldwide exposures for nuclear weapons testing fallout). However, these are involuntarily imposed exposures, as distinct from exposures due to deliberately made choices and exposures due to the natural order of things. The fact that the natural order of things means that we must all die one day doesn't allow someone to punch you in the nose just because it is a smaller "dose" than dying.

Finally, many groups of people have been disproportionately affected by radiation related to nuclear weapons. They include people living just downwind from atmospheric nuclear weapons test sites, many nuclear weapons plant workers, and many military personnel who participated in atmospheric nuclear weapons testing.

NEWSFLASH

The Nuclear Regulatory Commission is conducting a workshop on site cleanup and decommissioning in Washington, DC, May 6-7. The workshop is open to the public and will allow questions from the floor. Your presence could be important to setting standards at cleanup sites, even sites under DOE control. You can all the Keystone Center (303-468-5822) for information on the workshop. The workshop will be held in Arlington, VA, at the Doubletree Hotel, 300 Army Navy Drive. The hotel's telephone number is (703) 892-4100.

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: Military and Civilian Nuclear Mythology from Electricity "Too Cheap to Meter" to "Inherently Safe" Reactors.*
- 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

Selected Derived Air Concentration Limits[1]

Radionuclide	Solubililty[2]	Existing Air Concentration Limits (picocuries per liter)	Limits Effective January 1994 (picocuries per liter)
Hydrogen-3	Insoluble	200	100
(Tritium)	Soluble	200	100
Strontium-90	Insoluble	0.2	0.006
	Soluble	0.03	0.03
Technetium-99	Insoluble	2	-
	Somewhat soluble	-	0.9
	Soluble	70	8
Ruthenium-106	Insoluble	0.2	0.02
	Somewhat soluble	-	0.08
	Soluble	3	0.1
Iodine-131	Insoluble	10	0.2
	Soluble	0.1	0.2
Cesium-137	Insoluble	0.5	0.2
	Soluble	2	0.2
Barium-140	Insoluble	1	2
	Soluble	4	2
Lanthanum-140	Insoluble	4	-
	Somewhat soluble	-	2
	Soluble	5	2

The techno-weenie centerfold table in this issue lists the legally allowable air concentrations of many radioactive materials commonly found in nuclear weapons, nuclear power plants, and/or radioactive waste.[3] These radionuclide-specific air concentrations called Derived Air Concentrations (DACs), represent a limit on what a "reference man" could be exposed to "at the boundary" of an emitting facility in compliance with federal regulations. These standards apply to facilities licensed by the Nuclear Regulatory Commission and are applied to members of the public. Occupational exposure limits for nuclear facility workers are higher.

The legally allowable air concentration is dependent upon the particular radionuclide chosen and is calculated such that a dose limit of 50 millirems is not exceeded (see Arithmetic for Activists). The air concentration calculation for a particular radionuclide depends upon the half-life of the radioactive material, the solubility of that material and the type of radiation emitted (alpha, beta

IEER TECHNO-WEENIE CENTERFOLD

Radionuclide	Solubililty[2]	Existing Air Concentration Limits (picocuries per liter)	Limits Effective January 1994 (picocuries per liter)
Polonium-210	Insoluble	0.007	-
	Somewhat soluble	-	0.0009
	Soluble	0.02	0.0009
Radium-226	Insoluble	0.002	0.0009
	Soluble	0.003	0.0009
Radium-228	Insoluble	0.001	0.002
	Soluble	0.002	0.002
Thorium-230	Insoluble	0.0003	0.00003
	Somewhat soluble	-	0.00002
	Soluble	0.00008	-
Thorium-232	Insoluble	0.001	0.000006
	Somewhat soluble	-	0.000004
	Soluble	0.001	-
Nat Uranium	Insoluble	0.005	0.00009
	Somewhat soluble	-	0.0009
	Soluble	0.005	0.003
Plutonium-239	Insoluble	0.001	0.00002
	Somewhat soluble	-	0.00002
	Soluble	0.00006	-
Plutonium-241	Insoluble	1	0.001
	Somewhat soluble	-	0.0008
	Soluble	0.003	-
Americium-241	Insoluble	0.004	0.00002
	Soluble	0.0002	0.00002

or gamma). The concentration limit set for each radionuclide also assumes that it is the *only* one inhaled and that the average diameter of the inhaled particles measure one-millionth of a meter. Allowable concentrations are proportionately reduced if more than one radionuclide is present.

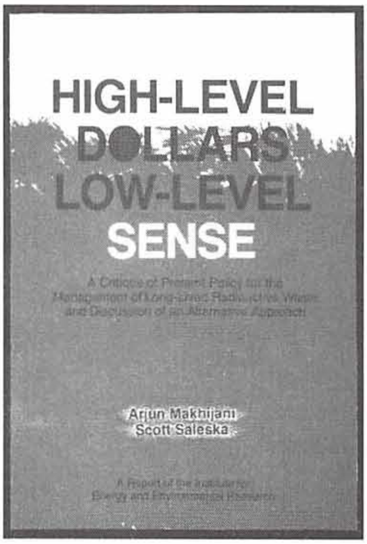
The solubility of the radioactive material is a reflection of how likely it is to dissolve in water. The less soluble a given amount of inhaled material, the more difficult it is for your lungs to remove it. Therefore, all else being equal, most insoluble material spends more time in your lungs and has more time to do damage. For this reason, insoluble forms of most radionuclides have lower air concentration limits.

1 Concentration limits can be found in U.S. Nuclear Regulatory Commission, *Code of Federal Regulations*. 10 CFR 20, January, 1988 (Washington DC: Government Printing Office).

2 In the 1991 regulations, solubility is listed as "class Y" ("Y" stands for "years"), "class W" ("W" stands for "weeks") and "class D" ("D" stands for "days"). These correspond to "insoluble", "somewhat insoluble" and "soluble" in the table.

3 IEER staff thanks Pame Kingfisher of Native Americans for a Clean Environment for introducing us to the term "techno-weenie."

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

Plutonium

Deadly Gold of the Nuclear Age

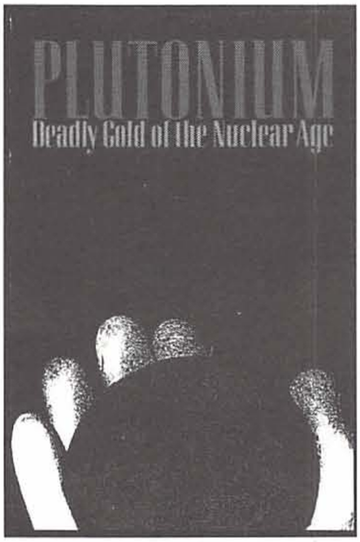
by International Physicians for the Prevention of Nuclear War and IEER

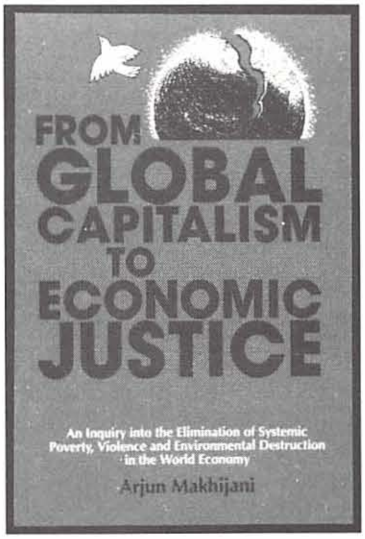
The Cold War is over, yet production of plutonium continues in many countries, including Russia. While much of it is allegedly for nuclear power, all plutonium can be used for nuclear weapons. This book examines the huge security, health and environmental risks posed by plutonium globally and spells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

PRICE: $17 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, Chemical and Atomic Workers International Union

PRICE: $ 17.00 including postage and handling

Arithmetic for Activists #5

Solution to the Problem in *SDA* volume 2, number 1

Last issue's Science Challenge was as follows:

1. Suppose a soil sample contains 2 milligrams of uranium-238 per gram of soil. Express this in microcuries per gram of soil. Also find the answer in bequerels per gram of soil. Bequerels (Bq) are another way of measuring radioactivity. One curie = 37 billion bequerels.

Answer: a glance at last issue's techno-weenie centerfold will show that the specific activity of uranium-238 is 0.34 microCi/gram. Given that there are 2 grams of soil, there must be .00068 microCi/gram of our example, or 25.16 bequerels/gram. Watch those decimal places!

2. If the tritium content of water is 4 picograms per liter, how much is it in picocuries per liter? (pico = one trillionth)

Answer: The specific activity of tritium is 9,800 curies/gram. So there is a total of 39,200 picocuries/liter.

3. If the plutonium-239 content of a soil sample is 5 nanograms, and the plutonium-240 content is 0.3 nanograms, calculate the total radioactivity of plutonium in the sample. (nano = one-billionth)

Answer: The specific activity of plutonium-239 is 0.063 curies/gram, and 0.23 for plutonium-240. Thus there is a total of .315 nanocuries of plutonium-239, and .069 nanocuries of plutonium-240. The total radioactivity of plutonium in the sample is .384 nanocuries.

Ten people sent in replies to the *Science Challenge* in the last issue. There were 2 correct answers. Congratulations! We drew lots for the $25 prize from among the correct answers, and the winner is Bill Wekselman, of Pittsburgh, PA. Everyone who entered the contest will get a $10.00 prize.

We couldn't give away all our prizes last time, since there were not enough entries. **Don't let these prizes go unclaimed!** If you are one of 25 to respond to this issue's *Science Challenge,* you are **guaranteed a $10.00 prize.** Even if your answers are not correct, you get a prize for trying. So rise to the challenge!

DACs

The derived air concentrations (DACs) in the centerfold table are constructed such that the dose from a single radionuclide present in air and inhaled for an entire year at the allowable concentrations would not exceed 50 millirem. The overall limit for doses to members of the general public is 100 millirem. The DACs calculations are all based on an assumption that up to half this dose could come from drinking contaminated water. DACs for water are therefore calculated the same way.

It is important to remember that the standards are constructed assuming that exposure to only *one* radionuclide occurs. Should you be exposed to more than one of the radionuclides listed in the centerfold table, the *combined*, inhaled dose must not exceed 50 millirems per year. For the mathematically inclined, here is the formula used to calculate doses when more than one radionuclide is present:

$$C1/L1 + C2/L2 + C3/L3 <= 1$$

This works as follows: if the concentrations of three radionuclides are C1, C2 and C3, whose respective limits are L1, L2 and L3, then the sum of their ratios

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Arithmetic

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must be less than or equal to one. (The symbol "<=" means "less than or equal to".)

The DACs given here also assume that the average diameter of the inhaled particles is one-millionth of a meter. The diameter of an inhaled particle will affect whether it gets into the lung. Typically, the smaller the particle, more easily it will get into the lung. While particle size varies greatly depending on specific conditions at the radionuclide-emitting facility, the diameter used to derive the limits in the centerfold table is considered the most common.

Should you be exposed to radioactive material in the air, it is useful to know whether limits have been exceeded and by how much. Try the *Science Challenge* to practice using the air concentration standards.

CREDITS FOR THIS ISSUE

1. Photographs: Defense Nuclear Agency and the Department of Energy
2. Stats of books: Metrophoto of Washington, D.C.
3. Production: Sally James of Cutting Edge Graphics, Washington, D.C.

Involuntary Risk

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full and democratic debate, and hence informed consent, is at the heart of much of the public's distrust and unwillingness to accept involuntary risks. Many of the institutions imposing involuntary risks are also distrusted because their *primary* goals are focused on profit or activities such as nuclear weapons production, rather than on protection of health and the environment.

Corporations and bureaucracies doing secret work have eroded public confidence by hiding essential facts and misleading the public.

Typically, large corporations and government bureaucracies engaged in secret work have hidden many aspects of their business practices from the public, preventing independent evaluations of their health, safety, and environmental claims. With respect to the public, they have seemingly operated on the principle that "what they don't know can't hurt us."

These same institutions have financed much of the science that is quoted in "risk communication" to reassure the public. There is very little independent scientific analysis, for example, on thousands of the chemicals introduced into commerce, about which even manufacturers usually do not know enough to assess the long-term risk to workers and the public.

Finally, the record indicates that conflicts of interest have perverted and distorted science in the areas of health and environmental protection. For instance, in the pursuit of nuclear weapons production, the Department of Energy has violated laws so routinely that the Bush administration's Justice Department refused to indict contractor employees at the Rocky Flats Plant in Colorado for alleged criminal violations because it claimed the "culture" of the Department abetted these violations. By breaking laws, circumventing regulations, misleading the public, and hiding essential facts, institutions have eroded public confidence in their assurances of safety.

Corporations and secretive bureaucracies should stop treating the public as incompetent illiterates and look more closely at their own unenviable record. Since these institutions make risk a public issue by polluting air, soil, and water for generations to come, they must yield all necessary information to the public. Independent analyses will enable debate and decision-making on risk to proceed, if not on an equal footing in terms of money, then at least with equal opportunity in terms of information.

We recognize that living in society creates risks that arise from common needs (such as having transportation, energy, and health care systems). Such risks

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It Pays To Increase Your Jargon Power

by Dr. Egghead

Dr. Egghead is IEER's leading authority on jargon. He has kindly consented to make his column, *It Pays to Increase Your Jargon Power*, a regular feature of *Science for Democratic Action*. This column will not only cure your jargon blues, but produce a positive exhilaration. This is one of IEER's many continuing contributions to reducing health care costs in these United States.

Choose the correct definition. Answers are given below.

1. **source term**

a. a code word for a CIA informant
b. the mother of all terms
c. Adam and Eve
d. the amount of a specific pollutant emitted or discharged to a particular medium, such as air or water, from a particular source, as for instance in the phrase: "the iodine-131 source term for air emissions from the Hanford chemical separation plant."

2. **quality factor**

a. the amount of quality time that parents spend with their children
b. a measure of economic competitiveness
c. the number of wrinkles in a no-iron shirt
d. a factor used to compare the biological effectiveness of a particular type of radiation in producing adverse health effects with that of gamma radiation. As a reference point, quality factor for gamma radiation is fixed at 1. The quality factor of beta radiation is also 1. Alpha radiation and neutrons are more effective in causing diseases. The quality factor (also called Q factor) currently recommended for alpha radiation by the International Commission on Radiological Protection is 20. For neutrons, it is between six and 20.

3. **POOS**

a. French way of saying pussy cat in English
b. Russian way of saying pussy cat in English
c. "**P**acific **O**cean **O**glers **S**ociety"
d. "plutonium-out-of-specification"—used to describe the recycled uranium recovered from uranium-plutonium chemical separation plants that contains plutonium in concentrations in excess of allowable limits. At the plant near Fernald, Ohio, the limit was 10 parts per billion. POOS materials may be important contributors to dose estimates at some uranium processing plants.

4. **multi-media model**

a. a person who models male and female clothes
b. a model who poses for TV and newspaper advertisements
c. a light and sound show designed to advertise a product
d. a model for estimating exposure of people to pollutants that takes into account exposures via various environmental media, such as air, water and soil, and the transfer of pollutants between these media.

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5. **one-hit model**

a. drive-by shootings in the days when guns only fired one shot at a time
b. a model who is a hit for only one show
c. a DOE plan for building a nuclear waste repository in Nevada alone
d. a biological model for the carcinogenic effects of a substance based on the theory that one "hit" of the substance to a cell above a certain threshold quantity could initiate irreversible biological damage leading to a tumor

6. **pathway analysis**

a. an analysis of the ways in which the road to hell can be paved with good intentions
b. a way of figuring out how all roads lead to Rome
c. a metaphysical concept which states that you can go to heaven even if you stray from the straight and narrow
d. an analysis of the ways in which toxic or radioactive substances can reach human beings from the plant, place, or process in which they are made, stored, used, or dumped—via air, water, soil, the food chain, or some combination of these pathways

Answers: 1 d; 2 d; 3 d; 4 d; 5 d; 6d

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should be evaluated through full and complete disclosure, independent science, public examination of common ends and the means to achieve them, and decided upon democratically.

In contrast to most other countries, people in the United States have rather extensive information rights with respect to the federal government through the Freedom of Information Act (FOIA). Britain, for instance, has a kind of anti-FOIA law called the "Official Secrets Act." Yet all too often in the U.S., federally collected information is unjustifiably denied under cover of national security. Furthermore, U.S. corporations are required to release even less information to the public, though they have introduced thousands of substances into commerce without adequate testing.

We need freedom of information in all areas that affect public health and the environment, including internal corporate documents. There is some evidence that at least a portion of the corporate sector has decided that the time has come to stop living in the shadows of secrecy with profit as the only principal driving goal.

At a 1989 conference on the sustainable use of energy sponsored by the West German government at which most western governments (including the United States) as well the International Chambers of Commerce were represented, the following resolution was adopted by consensus:

"Companies are invited...

"■ to prepare generic environmental impact assessments for public information of their products, manufacturing processes, and activities which should include assessments of impacts under anticipated conditions of use.

"■ to consider significant environmental protection actions in areas where there is potential for serious ecological harm based on risk prevention even if conclusive physical evidence of that damage is not yet available.

"■ to provide voluntarily to governments and NGO's [non-government organizations] sufficient information to enable independent analyses of environmental impacts of their activities."[1]

Few corporations have adopted these principles, much less implemented them. It is time to consider enactment into law of a broad measure along these lines ensuring freedom of information. Only then can the public can make fully informed, democratic decisions about health and environmental protection based on sound and independent science.

Arjun Makhijani

[1] Recommendations of the "Energy and Environment - Sustainable Energy Use", Federal Republic of Germany Workshop, 11-14 December 1989, Westphalia, Germany.

Science Challenge

You live about one mile downwind of a uranium mill. You have just used your trusty air monitoring equipment and measured the amount of radioactivity in the air. You read 0.00037 becquerels per liter of air.

(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.

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

(b) What if the material was insoluble natural uranium?

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 Arjun Makhijani, 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 August 15, 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.

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