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Disposing of Fissile Materials

The Challenge Ahead

By Noah Sachs

Disposing of the fissile materials from dismantled nuclear weapons is one of the most vexing problems the United States faces today. The Department of Energy is dismantling about 1,400 warheads per year at its Pantex facility and is currently evaluating disposition methods for the tens of tons of plutonium and highly enriched uranium (HEU) that will become surplus. These materials were produced during the Cold War, but no contingency plan was developed for a time when the U.S. would no longer want or need them. Now we face the challenge of preventing their re-use in nuclear weapons and isolating them from the environment.

Catherine Huber demonstrates an early use of borosilicate glass, circa 1921.

IEER recently released a report on fissile materials disposition, entitled *Fissile Materials in a Glass, Darkly*. It is the first study of this issue to detail a concrete plan that could put all excess plutonium into non-weapons-usable form in about ten years.

The report recognizes that all disposition methods have drawbacks. No existing technology can completely eliminate fissile materials, and the U.S. must choose from a menu of difficult disposition options. After a careful assessment, the report concludes that the most promising method for plutonium disposition is vitrification, that is, mixing plutonium with molten glass to form glass logs. Vitrification accords with U.S. non-proliferation goals (see below) and is technically feasible. The report suggests that the Department of Energy (DOE) build three or four pilot vitrification plants within the next two years to test various vitrification methods.

Fissile Materials in a Glass, Darkly considers the problems posed by both commercial and military plutonium because both can be used to make nuclear weapons. Commercial plutonium is made in commercial nuclear power plants and can be separated from spent fuel for use as a reactor fuel. This chemical-separation process is known as "reprocessing." Five countries (Britain, France, India, Japan, and Russia) continue to reprocess. The amount of separated plutonium in the commercial sector may surpass the amount from dismantled weapons over the next one or two decades. It thus makes little sense for the U.S. to focus only on disposing of weapons plutonium without addressing the growing global problem of commercial plutonium production in these five countries.

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Moreover, the United States is well positioned to persuade others to stop reprocessing because it has itself stopped both military and civilian reprocessing. The recommendations of the report are designed to achieve the goal of a universal, interim halt to reprocessing.

There is no guarantee of completely safe storage of plutonium in any country, but fissile materials in Russia pose especially large security risks at present. Russia is not only reprocessing spent fuel (about 30 metric tons of plutonium are stockpiled at one reprocessing site), but it is also dismantling over 1,000 warheads per year. Russia is unlikely to put its plutonium into a non-weapons-usable form until the U.S. does. Indeed, there is every sign that Russia is determined to press ahead with separating even more plutonium. Given the political and economic instability there, it is important for the U.S. to select and implement a disposition method quickly and persuade Russia to do the same.

Fissile Materials in a Glass, Darkly has five principal recommendations:

1. The U.S. Should Declare Excess Plutonium a Liability.

This step is essential for the U.S. government to strengthen its hand in dissuading other countries from separating plutonium. The liabilities of plutonium are widely acknowledged (see *Science for Democratic Action* Vol. 3, No. 3, and *Plutonium: Deadly Gold of the Nuclear Age*). The U.S. has stopped production of plutonium for weapons and wisely abandoned the commercial use of plutonium over a decade ago. Recently, Secretary of Energy Hazel O'Leary stated that plutonium is a global security risk and an economic liability. Formalizing these practices and statements into a strong policy declaration on the security, economic, and environmental liabilities of plutonium, preferably by President Clinton himself, will give the U.S. the solid footing it needs to convince other countries to cease reprocessing. In October of 1994, IEER was joined by thirty-eight U.S. organizations and seven individuals in sending a letter to President Clinton urging him to make such a declaration.

2. Vitrify Excess Plutonium: No Reactor Technologies Should be Used.

In January of 1994, the National Academy of Sciences released a report on fissile material disposition. The report stated that the two most promising methods for disposing of plutonium are either vitrification or conversion into mixed-oxide fuel (MOX) for use as fuel in existing nuclear reactors.

Fissile Materials in a Glass, Darkly recommends vitrification over the MOX option for several reasons. First, vitrification accords with U.S. non-proliferation goals. It would send a signal to the five countries that reprocess that the U.S. considers plutonium a waste and will not use plutonium for energy purposes even when the plutonium is "free." The MOX option, in contrast, would legitimize the use of plutonium as a

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Science for Democratic Action Managing Editor: Ellen Kennedy

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nuclear fuel and would undermine U.S. efforts to dissuade Britain, France, India, Japan, and Russia from continuing to separate more plutonium.

Second, the MOX option could also lead the U.S. down the dangerous path toward a plutonium energy economy by creating vested interests in plutonium use. Once the money is invested to build a plant to convert weapons plutonium into MOX fuel, and once nuclear reactors are re-licensed to burn MOX fuel, there will be a strong institutional momentum to continue to use plutonium as a nuclear fuel even after all the weapons plutonium has been run through reactors.

Vitrification marries two well-known technologies—glass-making and plutonium metallurgy—and has few technical hurdles to overcome.

Although the electricity generated from using the plutonium in reactors does offset some of the costs of the MOX option, fabricating the MOX fuel would be so expensive (because of worker protection and safeguards needs), that the National Academy of Sciences estimated that the overall costs of the MOX option and vitrification would be about the same.

While vitrification offers several advantages, it also has some drawbacks. Although there is extensive knowledge and experience in other countries regarding MOX fabrication and use, large-scale vitrification of plutonium has not been tried before. Nevertheless, vitrification marries two well-known technologies—glass-making and plutonium metallurgy—and the report concludes that there are only a few technical hurdles that need to be overcome. Further, France has been vitrifying its high-level wastes for over two decades, and the U.S. could draw on the French experience when designing plutonium vitrification plants.

3. Build Three or Four Pilot Vitrification Plants.

After examining the troubled history of U.S. high-level waste vitrification efforts, the report concludes that the problem is not that vitrification is too difficult, but that it was not properly carried out. The Department of Energy built a multi-billion dollar full-scale vitrification plant (the Defense Waste Processing Plant at Savannah River Site) without ever having cast a full-size glass log with real radioactive waste. IEER thus recommends building three or four pilot vitrification plants so that the technical, environmental, and safety issues surrounding vitrification of plutonium can be studied and worked out.

More than one pilot plant is needed because several different methods for vitrifying plutonium are promising. Most studies recommend that the plutonium be vitrified along with high-level radioactive waste so that the resulting glass logs would be highly radioactive, creating a strong barrier to attempts to re-extract the plutonium. The glass logs would meet the "spent-fuel standard" recommended by the National Academy of Sciences. That is, it would be about as hard to extract plutonium from the glass logs as it would be to produce new plutonium by reprocessing spent fuel.

This method of vitrification has some disadvantages, however. It takes a long time to complete because expensive shielding and safety measures would be needed to handle the high-level waste. Moreover, the radioactive wastes will largely decay after 500 years while the plutonium will remain a threat to security, health, and the environment for over 100,000 years. Finally, with such a high barrier to re-extraction, it would be difficult to convince countries to stop reprocessing and to vitrify their plutonium with the potential for re-extraction (see recommendation number 4 below).

The IEER report argues that it may be better to use a slightly lower barrier to re-extraction of the plutonium to complete the vitrification process sooner and to aid the goal of achieving a universal, interim halt to reprocessing. For example, depleted uranium or a rare-earth metal such as europium could be added to the plutonium before vitrification. It would still be very difficult to chemically separate the plutonium from these materials, but expensive radiation shielding would not be needed.

One method of vitrification that holds particular promise is to vitrify the plutonium without high-level radioactive wastes, and

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then to add a gamma-emitting fission product such as cesium-137 to the canister that will hold the glass log. This would provide a high barrier to theft and re-extraction of plutonium by making the container highly radioactive, but fewer fission products would be needed than if they were added to the glass itself. As a result, worker exposures to radiation and environmental risks may be reduced.

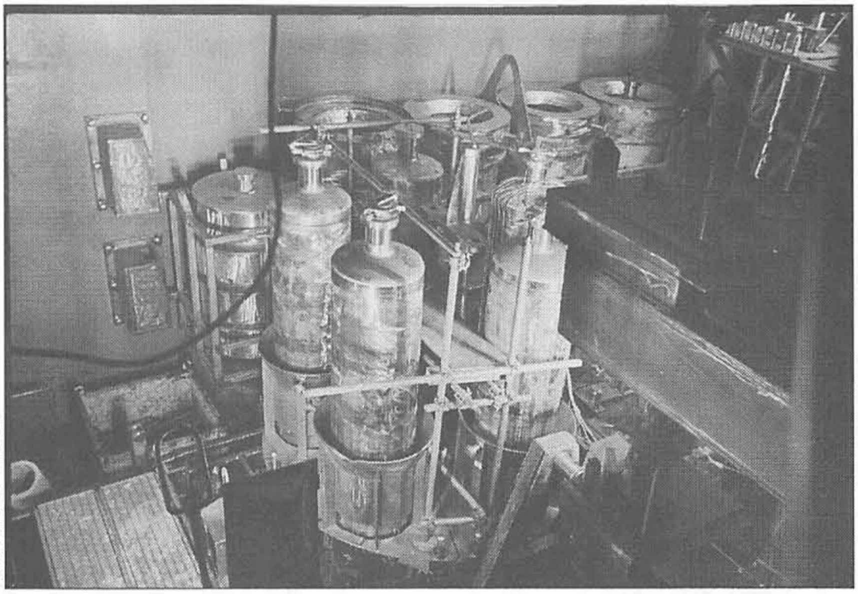
Clearly, further study will be needed to evaluate and compare the various vitrification methods outlined above. Constructing pilot vitrification plants would give the Department of Energy the real-world experience it needs in order to build sound facilities for plutonium vitrification.

4. Create an international financial guarantee for the re-extraction of plutonium from glass.

This recommendation is the key to achieving a global, interim halt to commercial plutonium pro-duction. The countries that are currently reprocessing generally recognize that plutonium is an uneconomical fuel in the near term, even if they do not often say so publicly.

Their rationale for reprocessing, then, is that plutonium and the technology to produce it may be needed in the long term if uranium, which is the most common nuclear fuel, becomes scarce. This would be like producing oil from oil shale rock today at $70 a barrel—more than three times the current market price—on the assumption that the price of oil will increase to at least $70 a barrel in the coming decades.

In the meantime, commercial plutonium is piling up in large quantities, posing a large proliferation risk, especially in Russia. Britain, France, India, Japan, and Russia may be more easily convinced to stop reprocessing and to vitrify their current stocks of plutonium (thus making it non-weapons-usable) if an international financial guarantee were given for re-extraction of the plutonium from the glass if plutonium ever became an economical fuel. The vitrified plutonium would in effect become a plutonium reserve, which would alleviate countries' fears about uranium scarcity and energy self-sufficiency. Of course, the details of such a financial guarantee still need to be worked out. For example, international monitoring would be required to ensure that the plutonium is not used for nuclear weapons and is removed from the reserve only with international consensus that plutonium has actually become economical.


ROBERT DEL TREDICI

Canisters for vitrified high-level waste, Savnnah River Site, South Carolina.

5. Create a reserve of uranium reactor fuel.

As another incentive to halt reprocessing, a reserve of low-enriched uranium fuel (LEU) suitable for nuclear reactors should be created. This would provide an alternative to plutonium-based fuels for decades, and like the financial guarantee discussed above, it would alleviate countries' concerns about uranium scarcity and energy self-sufficiency. The uranium reserve could be formed by diluting weapons grade uranium to make LEU, which is suitable for use in reactors but cannot be used to make weapons. Any LEU that remains after the reserve is created could be released to the uranium market.

The report urges a full programmatic environmental impact statement (PEIS) of this issue be done as part of a PEIS on weapons usable fissile materials.

Implementing the five principal recommendations of the report would reduce to a large extent the dangers posed by fissile materials

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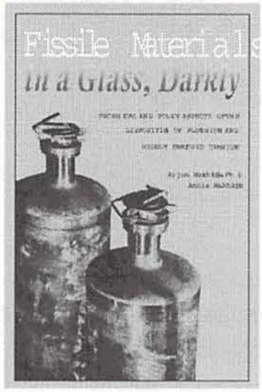
around the globe, but the long-term future of this problem is inextricably tied to the future of nuclear energy, since essentially all nuclear reactors produce plutonium in their spent fuel.

The report is skeptical that DOE can carry out the needed program without institutional change and openness. While there have been some very positive changes within the Department of Energy, especially in its openness initiatives and its opposition to funding the Advanced Liquid Metal Reactor (ALMR), it is not clear that these changes have permeated the entire nuclear-weapons complex, nor is it clear that the positive changes will continue. It is not even clear that the agency whose main mission it was to build bombs is well-suited for dismantling them and disposing of their materials. Continued public interest in the disposition issue, combined with the DOE's willingness to address public concerns, are vital to ensure that vitrification is chosen as the disposition option and that it is carried out with the necessary diligence to protect the environment and the health and safety of workers and surrounding communities.

For details on how to order a copy of *Fissile Materials in a Glass, Darkly*, please see p. 5.

To send comments on fissile materials disposition to the DOE, call the Office of Fissile Materials Disposition at 202-586-7550.

SELECTED PUBLICATIONS



Fissile Materials In a Glass, Darkly

IEER Press, 1995

by Arjun Makhijani and Annie Makhijani

IEER's most recent report analyzes the options for disposition of plutonium and highly enriched uranium. It recommends policies designed to put these materials into non-weapons-usable forms as rapidly as possible. It urges that the U.S. adopt vitrification of plutonium as its disposition option (rather than using it in reactors) in order that the U.S. may persuade countries still separating plutonium from civilian spent fuel to stop doing so.

Fissile Materials In a Glass, Darkly *makes a compelling, highly readable case for disposing of plutonium as a waste and rejecting the dangerous notion that it is a valuable asset. The risks and options for disposing of nuclear-weapon material are explored thoroughly, and in a lucid style for the non-technical reader. This report should be required reading for those who insist that plutonium from warheads can only be disposed of by turning it into fuel for nuclear reactors. But the report's greatest value is as a primer for the public at large.*

—Paul Leventhal, Nuclear Control Institute

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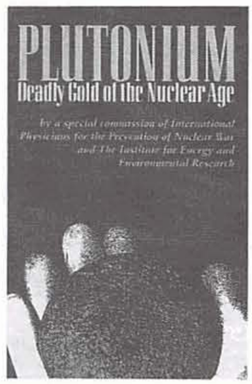
Plutonium

Deadly Gold of the Nuclear Age

by International Physicians for the Prevention of Nuclear War and IEER



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

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

—Daniel Ellsberg

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Uranium: Its Uses and Hazards

Incineration of Radioactive and Mixed Waste

"Dear Arjun"

Dear Arjun,

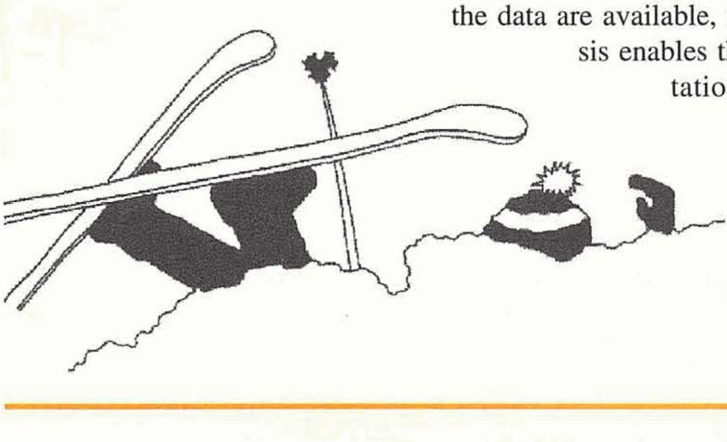
What is "risk analysis" and how is it used?

—Perplexed in Peoria

Dear Perplexed

Risk analysis was originally a technique used by French match makers to predict the extent of marital harmony. Hence a risqué person was one prone to discord due to an adventurous temperament.

In modern times risk analysis has been reformulated as 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 relies on probability; it seeks to quantify both the probability and the magnitude of adverse consequences that individuals, populations, or ecosystems might suffer from specific hazards.



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

Determining the Nature of Hazard

First, one must decide whether and how a particular substance, process, or event could be harmful. For substances, it is necessary to determine the doses at which harm occurs and factors that could influence how harm occurs. For instance, a substance may be acutely toxic or poisonous only upon prolonged exposure. When hazards involve an event (an accidental release), one must also calculate the probability of the accident occurring. A series of failures may be needed for an 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 sub-systems that could lead to an overall system failure. When the data are available, this analysis enables the computation of an overall probability of failure.

Determining Exposure

To estimate a person's or population's exposure as a result of environmental contamination (called "dose reconstruction"), it is crucial to know the amount of the pollutant (called a "source term") released to a particular medium, such as air or water. Alternatively, an accurate history of concentrations of pollutants in air, water, and soil is necessary.

Discharges to one medium can affect another medium. If particles of a radioactive material are released to the air, they will also be deposited in soil as "fallout." 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, tritium, and carbon-14 and many organic toxic compounds can be incorporated from air, water, and soil into food.

"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

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A SPECIAL CENTERFOLD FOR TECHNO-WEENIES

A Tool Kit on Natural and Man-made Radiation

This Centerfold gives figures for radioactivity commonly found around us due to natural sources and man-made sources (such as atmospheric nuclear weapons testing).

Natural radiation is ubiquitous; it is found in soil, water, and air. Yet levels of natural radiation are not uniform. In soils, for instance, the concentration of natural uranium varies from one place to another. And the radiation dose due to cosmic rays increases with altitude, since the rays filter through a smaller amount of atmosphere at higher altitudes. It is also important to note that human activity like uranium mining and milling may concentrate natural radioactive materials and/or make them a more mobile and accessible part of the environment.

Types of Natural Radiation

Cosmic rays originate from the sun and outer space. They vary with altitude and latitude.

Cosmogenic radionuclides are produced from the interaction of cosmic rays with atoms in the atmosphere. The principal cosmogenic radionuclide is carbon-14.

Primordial radionuclides are found in the earth's crust Examples are potassium-40 and the nuclides in the uranium and thorium decay chains.

The table entitled "Radionuclide Disposition Due to Fallout from Atmospheric Testing" shows the increase in radionuclides due to nuclear weapons testing. It includes radionuclides that occur naturally (tritium, for example), and radionuclides that do not occur naturally (strontium-90, for example).

How to Use the Centerfold

The Centerfold can be used as a general reference, as a tool for understanding contamination at a given nuclear facility, or to help the reader determine whether unnatural radioactivity is present at a particular location.

In addition to concentrations and doses for natural radiation, the Centerfold includes typical ranges to give some idea of variations. These values are more useful for determining if there might be artificial radioactivity and/or very high levels of radioactivity at a given location. For example, a typical value for uranium-238 is about 1 picocurie per gram (pCi/g) of soil, and a typical upper value for the range is 3.8 pCi/g.[1] While uranium-238 radioactivity levels of 10 picocuries per gram or more can occur in certain areas, values over three or four picocuries per gram are often indicative of man-made contamination. Sometimes even values as low as 2 picocuries per gram may be partly caused by human activity. On the other hand, uranium ore with a uranium concentration of 0.2 percent has a specific activity of 1,300 picocuries per gram and such ores are sometimes found close to the earth's surface. (See Dr. Egghead for definition of specific activity.)

[1] A "picocurie" is a measurement of radioactivity. The prefix "pico" means "one trillionth." U-238 contributes about half of the activity to natural uranium.

Natural Radionuclide Concentrations in Sea Water

RADIONUCLIDES	CONCENTRATION (picocuries/liter)
Potassium-40	300
Rubidium-87	2.8
Natural Uranium	2.2
Radium-226	0.03
Radon-222	0.1
Tritium	2.7

Sources: Eisenbud 1987; NCRP 1988; Benedict et al. 1981.

Natural Radionuclide Concentration in Soils

RADIONUCLIDE	AVERAGE (pCi/g)	RANGE (pCi/g)	COMMENTS
Natural Uranium*	about 2	0.2 – 7.6	Uranium ore at 0.2% concentration is 1300 pCi/g. About one half of the radioactivity is from uranium-238, about one half is uranium-234, and only a small amount is due to uranium-235.
Natural Thorium-232*	about 1.0	0.1 – 3.5	
Natural Radium-226	about 1.0	0.2 – 4.3	
Carbon-14 in plants and animals	6 pCi of carbon-14 per gram of total carbon**		
Potassium-40	about 10		
Rubidium-87	about 1.4		

Sources: Myrick et al. 1983; Eisenbud 1987; NCRP 1987.

* The Nuclear Regulatory Commission (NRC) has published draft radiological criteria for the decommissioning of licensed facilities. Under present clean-up guidelines, written in 1981, the NRC uses a maximum allowed concentration of natural uranium and natural thorium for surface contamination of soil of 10 pCi/g.

** Most carbon is carbon-12, the non-radioactive isotope of carbon that forms the foundation of living matter.

Natural Radionuclide Concentrations in Continental Waters

RADIONUCLIDE	SURFACE WATER (pCi/liter)	GROUND WATER (pCi/liter)	NOTES
Uranium	about 1	about 3	
Radium-226*	0.1 – 0.5	0.5 – 100**	EPA standard for radium-226 in drinking water is 5 pCi/liter***
Radon-222◊	> 1.0	100 – 1,000	The EPA proposed standard for radon in drinking water is 300 picocuries/liter. Some areas of Maine have very high concentrations, where the mean concentration 24,000 pCi/l
Tritium (H_3)	5.4 – 24.3	–	

Sources: UNSCEAR 1982; NCRP 1988; NCRP 1984; Eisenbud 1987.

* The radium content of surface waters is low. In the U.S., three-fourths of the population uses surface water as its drinking water supply. Measurements for average natural radium-226 activity in groundwater, however, have been sparse because water with a gross alpha activity of less than 5 pCi/l is not normally investigated for radium activity. Daily consumption of 2 liters of water containing 25 pCi/l of radium-226 would give an annual dose to the bone of 1 rem. The EPA organ dose limit for bones and all other organs except the thyroid is 0.025 rem (25 millirem) per year.

** Some drinking water supplies in many areas exceed the limit of 5 picocuries per liter of radium-226; some have concentrations as high as 25 picocuries per liter.

*** Under the Safe Drinking Water Act (Public Law 93-523), water whose total alpha activity is more than 5 picocuries per liter has to be analyzed for radium-226 activity. If this activity is more than 3 picocuries per liter, the water has then to be tested for radium-228 as well.

◊ Radon concentrations in groundwater, including some used for potable water supplies, can be very high, up to several thousand and even several tens of thousands of picocuries per liter. However, the ranges vary a great deal. Measurements of radon in drinking water have tended to be taken in areas with high levels. There is no comprehensive survey that has determined a reliable average concentration figure for radon in groundwater used for domestic water supply.

Radionuclide Deposition Due to Fallout from Atmospheric Testing

RADIONUCLIDE	CONCENTRATION (picocuries/gram)	COMMENTS
Tritium in water during peak fallout period	several thousand picocuries/liter	mostly decayed away by the 1990s
Krypton-85 in air from fallout and plutonium production in 1970	0.01 picocuries/liter	
Plutonium-239 in soil		
Northern hemisphere	0.04	
Northern hemisphere 40-50°	0.06	
Plutonium-241 in soil		
Northern hemisphere	0.80	
Northern hemisphere 40-50°	1.23	
Plutonium-240 in soil		
Northern hemisphere	0.02	
Northern hemisphere 40-50°	0.04	
Cesium-137 in soil		
Northern hemisphere	5.7	Figures are for original deposition
Northern hemisphere 40-50°	8.8	Over half has decayed away.
Strontium-90 in soil		
Northern hemisphere	3.6	Figures are for original deposition
Northern hemisphere 40-50°	5.5	Over half has decayed away.

Sources: UNSCEAR 1993; Eisenbud 1987.

Typical Estimated Annual Effective Dose Equivalent* From Natural Sources

SOURCE	EFFECTIVE DOSE EQUIVALENT (millirem/year)		
	EXTERNAL	INTERNAL	TOTAL
Cosmic rays (including neutrons)	30	–	30
Cosmogenic nuclides (Mainly carbon-14)	–	1.5	1.5
Primordial nuclides			
potassium-40	12	18	30
rubidium-87	–	0.6	0.6
Uranium-238 series			
uranium-238 through uranium-234	9	1.0	10
thorium-230	–	0.7	0.7
radium-226	–	0.7	0.7
Thorium-232 series through radium-224	14	1.6	15.6
Total (rounded)	**65**	**24**	**89**

Source: Eisenbud 1987. Doses exclude radon and its decay products.

*"Effective Dose Equivalent" refers to the equivalent dose to the whole body received by a person. It is calculated by assigning factors to convert radiation dose to specific organs, such as bone or lung, to equivalent whole body dose. The "totals" section of the table shows that each person typically receives about 89 millirem per year from natural sources of radiation at sea level.

Natural Radiation from Outdoor and Indoor Radon-222

SOURCE	AVERAGE CONCENTRATION (picocuries/liter)	TYPICAL RANGE (picocuries/liter)
Outdoor concentration	0.27	0.1 – 0.4
Indoor concentration	1.10	0.3 – 8*
Unventilated uranium mines	—	1,000 – 100,000
Caves	—	10 - 300

Source: NCRP 1988; UNSCEAR 1993.

*In some areas and homes the concentration of radon-222 can be much higher, as high as 100 pCi/l or more. It is estimated that 10,000 pCi/l of radon in domestic water supply will add about 1 pCi/l to the average indoor air concentration.

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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. An "absolute risk" specifies the actual number of bad outcomes (like cancers) that would occur as a result of the exposure. To say that an individual's risk of getting a cancer as a result of a given level of

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exposure is 1 in 100,000 means that one "excess cancer" in a population of 100,000 would be expected if each person were exposed to the same degree.

A "relative risk" shows the risk in the exposed population compared to the risk in the unexposed population. For instance, the relative individual risk 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.

Limitations of Risk Analysis

Uncertainties are inherent in risk analysis, since risk estimates are 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.

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. It should *not* be used to impose risk without informed consent and full democratic debate. Its inherent uncertainties mean that complementary techniques are generally desirable or necessary to determine environmental hazards and evaluate effectiveness of policies.

For a fuller discussion of the uncertainties and limitations of risk analysis, see *Science for Democratic Action* Vol. 2, No. 2: Spring 1993.

An Example of Risk Assessment and Dose Reconstruction: A Uranium Processing Plant

The following example is an invented scenario of accidents at an industrial plant and how to calculate exposure to the surrounding population.

Suppose the chance of an accidental release from the plant is roughly 1 in 10 per week (10 percent), and the plant operates for 50 weeks per year. One would expect 5 accidents per year. Suppose each of these accidents releases 400 kilograms (almost 900 pounds) of uranium for a total source term for air releases for that year of 2,000 kilograms. (An uncertainty range for probable emissions can be calculated if the range of releases in accidents and the variability in accident frequency is known).

The next step in the analysis would be to assume various prevailing weather conditions and calculate uranium concentrations in air at various locations. Once these concentrations are estimated, we can calculate the amount of uranium inhaled by someone living a certain distance from the plant. We do this calculation based on the breathing rate of the average person (about 20 cubic meters of air per day), and the size of the uranium particles that were inhaled. With this information, we can then estimate the total dose to the body. A certain fraction of the inhaled uranium is retained in the lung, irradiating the lung and migrating from there to other organs, like bones, also irradiating them. The total dose from uranium depends on how long it stays in the body, which in turn depends on the solubility of the chemical form of inhaled uranium. Inhaled uranium is excreted via urine.

The uncertainties in such calculations are typically very large, especially if the weather, chemical form, location of the exposed person, and particle size are uncertain. This is often the case. Estimated offsite doses in such cases can range from a fraction of a millirem to many rem (a rem is one thousand times bigger than a millirem), even when the source term is known.

COMMUNITY CORNER

New National Network on Dioxin

To learn about the Stop DIOXIN Exposure Camapign, contact CCHW for a free 8 page Campaign start-up kit.

Write to: CCHW, PO Box 6806, Falls Church, VA, 22040, call 703-237-2249. E-mail address: "listproc@essential.org".

Until 1994, *SDA* had three issues per year. 1995 will have four.

It Pays to Increase Your Jargon Power

by Dr. Egghead

At long last, IEER's expert on jargon has returned from his extended journey to the Galapagos Islands. Since he had some sort of accident on the way home involving a magnifying glass (he won't tell us what happened), he has given us questions on words that are commonly used in the field of risk analysis.

1. **relative risk**
a. the risk that one's relatives will drop by for an extended stay
b. the likelihood that a storyteller will talk on and on and on
c. the ratio of disease incidence (or mortality) in an exposed population to that in an unexposed population.

2. **control population**
a. the fraction of the population who are control freaks
b. the upper echelons of the power elite
c. a group of people not exposed to the toxic agent under study but otherwise as close in all characteristics to the exposed group as possible.

3. **pathway analysis**
a. a Freudian therapy that involves going back to the familiar paths of childhood
b. the little-known study of ant messages in which the twisting paths of ant farms are decoded for hidden messages (S.O.S. seems to be the most common one)
c. 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.

Relative Risk?

4. **specific activity**
a. the term Miss Manners uses to refer to distasteful or unsavory habits, as in "stop that specific activity!"
b. the snoring of nuclear bomb-makers when they sleep on a special bed (really) at the Nevada Test Site after a successful test
c. As radionuclides undergo radioactive decay, their nuclei "disintegrate" ("transmute") into other nuclei by emitting particles or radiation. Specific activity refers to the number of disintegrations over a given period of time (referred to as "activity") per unit mass of a pure radioisotope; or the activity of a radioisotope in a material per unit mass of that material. Specific activity is expressed in becquerels per gram (Bq/g), curies per gram (Ci/g), or various decimal fractions of curies per gram (like microcuries per gram).

5. **source term**
a. the mother of all terms
b. a code word for an undercover informant
c. 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 emission from the Hanford Chemical Separation Plant."

Dr. Polly C. Wonk's Federal Forum

Dr. Wonk is IEER's esteemed consultant who regularly writes a column of advice to Washington officialdom. Dr. Wonk welcomes short letters from those in the government concerned with nuclear-weapons related issues. Letters should discuss good, bad, or ugly aspects of current policy and what ought to be done to improve the latter two. Dr. Wonk may publish some of these letters. She reserves the right to abbreviate them.

Two government agencies recently teamed up to develop guidelines for decommissioning radioactively contaminated sites. In late 1994 the Nuclear Regulatory Commission (NRC) issued draft regulations for decommissioning the facilities at which its licensees use radioactive materials. The Environmental Protection Agency (EPA) will also issue its own draft standards in early 1995 that will apply to Department of Energy nuclear weapons plants and all other radioactively contaminated sites not licensed by the NRC. Since the NRC and EPA are working together to develop these rules, the NRC standards are likely to heavily influence the EPA rules.

There are a number of serious problems with the NRC draft regulations. These deficiencies are so fundamental that I urge that the NRC to go back to the drawing board and publish draft regulations. If the NRC fails to do that, then the EPA should reject the NRC draft proposals as fundamentally flawed and override them.

What's so bad about the draft regulations? Read on for some of the highlights.

Risk Minimization: The draft regulations do not integrate risks from non-radioactive and radioactive hazardous materials. Moreover, they inappropriately ignore non-cancer risks, especially from non-radioactive hazardous materials.

Grandfather Clause: The grandfather clause exempting sites that fall under the Site decommissioning Management Plan (SDMP) does not meet minimal requirements for the protection of populations living nearby. Even worse, many sites where there are not yet approved decommissioning plans would also be exempted.

ALARA Requirements: The requirement that doses be kept as low as reasonably achievable (ALARA) has no numerical guideline incorporated within the regulation itself. This is a step backwards from the previous draft circulated to participants in the NRC's workshops on decommissioning regulations.

Exposure Limits: The proposed exposure limits are too high. The limit of 15 millirem per year with a suggested ALARA dose of 3 millirem per year are, for instance, fifty percent above the corresponding British limits of 10 millirem and 2 millirem.

Release of Documents: The proposed regulations do not require that the licensee make public all relevant documents about environmental releases and contamination that occurred during the period of facility operation and the period of decommissioning. This is a serious omission since cancer and other adverse health risks from future exposure add to risks from past exposure.

Fund for Environmental Monitoring: The draft regulations do not require licensees to establish a fund for environmental monitoring and public education whenever there is residual radioactivity at the time of license termination. So long as doses are in addition to natural background, there must be a fund for monitoring and public education.

See **Polly C.**, *page 14*

Polly C., *from page 13*

Compliance with Drinking Water Standards: The proposed rule does not require strict compliance with EPA standards for groundwater supplies.

Unlike most Washington pundits, I prefer to give concrete suggestions to remedy deficient policies like the draft regulations. I recommend that, at a minimum, the following changes be made to the decommissioning standards:

Explicit analyses of the cost, risk, and technical feasibility of clean-up to background should be required as part of the rule.

- A guideline of a cancer risk of one part in one million per year should be set under the rule of keeping exposures as low as reasonably achievable (ALARA). This limit should include all cancer risks from residual radioactivity, residual carcinogenic non-radioactive materials, and on-site waste disposal. If contamination is due to radionuclides alone, then the annual radiation dose corresponding to this risk would be about 2 millirem per year (using current EPA and NRC risk coefficients). This is the ALARA level in British standards. Chemicals known to pose non-cancer risk, such as risk of damage to the reproductive system, should be explicitly listed in the regulations.

- All plant documents relating to health and environmental issues from the licensees' operations as well as from decommissioning activities should be required to be made public prior to license termination.

- A fund for environmental monitoring and community education controlled by the community (for example by the local government) should be required in all cases where there is demonstrable residual contamination above background, even if such contamination corresponds to levels that are below maximum limits set for unrestricted use of the site after license termination.

- Sites for which no decommissioning plan has been approved as of the January 1, 1995 should not be exempted from the rule. Licensees that have approved decommissioning plans as of December 31, 1994 should be required to show that conforming to the new rules would not cause irreparable harm to them financially. If not, additional clean-up activities to meet the new rules should be undertaken. In any case they should be required to set up an environmental monitoring and public education fund.

- Strict compliance with EPA groundwater standards (40 CFR Part 141) should be required.

IEER has filed more detailed comments with the NRC. If you wish to receive a copy, please call IEER. To get a copy of the NRC's draft regulations, write to: RPHEB Secretary, Office of Nuclear Regulatory Research, US Nuclear Regulatory Commission, Washington, DC 20555, and ask for the regulatory analysis referred to in the Federal Register, Vol. 59, No. 161, August 22, 1994, p. 43200. For related documents (NUREG-1496; NUREG-1501; and NUREG-1500) write to: Distribution Services, Printing and Mail Services Branch, Office of Administration, US Nuclear Regulatory Commission, Washington, DC 20555.

Answers to the Last Atomic Puzzler

Last issue's Puzzler introduced readers to "fuel burn-up," showing how fuel used in a nuclear reactor changes after it has been "spent." The answers were as follows: 1) After three years, 3% of the spent fuel is fission products and 1% is uranium-235. 2) In the spent fuel, there will be 0.4 tons of uranium-235, 1.2 tons of fission products, 37.6 tons of uranium-238, and 0.8 tons of plutonium isotopes.

For a detailed explaination of the answers, please write to IEER.

Credits for this Issue

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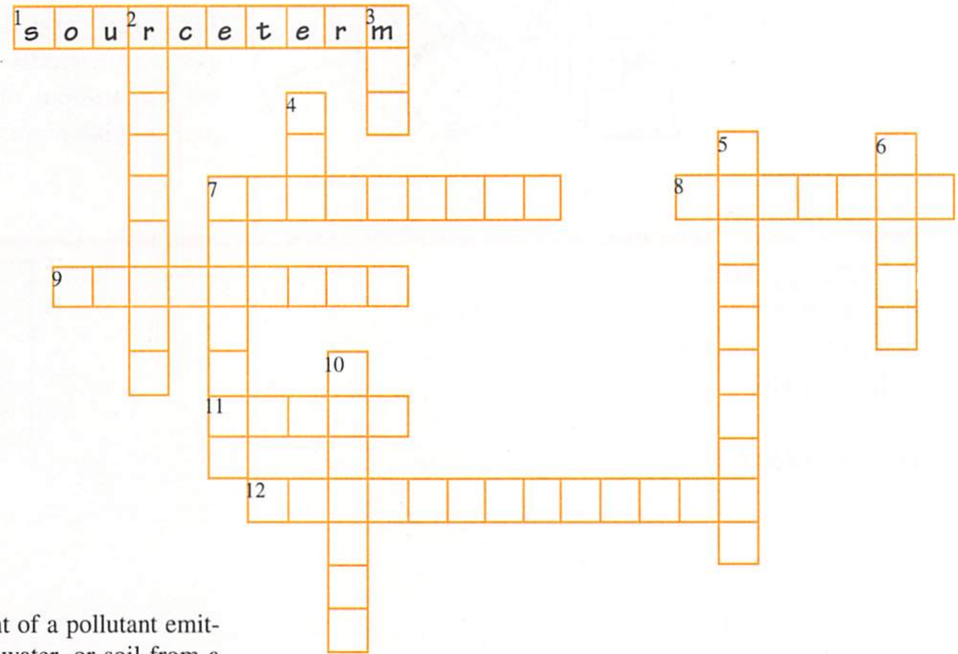
Atomic Puzzler

Everyone needs a break from numbers every now and then, even technoweenies. So this Atomic Puzzler will challenge your word power rather than your arithmetic ability.

Look at the clues and fill in the blocks with the appropriate words. *All words are described somewhere in this issue of the newsletter.* The first clue has been filled in for you. And remember, **you could win $25!!**



ACROSS

1. The amount of a pollutant emitted to the air, water, or soil from a specific source, like a uranium machining plant.

7. A fissile material common in nuclear warheads that is primarily an emitter of alpha radiation.

8. Radiation released to the environment after a nuclear explosion. It may look like snowflakes in some cases.

9. The _______ standard means that weapons plutonium would be stored so that it would be as difficult to extract as plutonium from civilian spent fuel.

11. A regulatory requirement that a dose be kept as low as reasonably achievable.

12. The technology that mixes a material with glass.

DOWN

2. To separate plutonium and uranium out of spent fuel from reactors.

3. The common abbreviation for mixed-oxide fuel, in which the oxide form of uranium and plutonium are combined.

4. The abbreviation for one of two fissile materials that may readily be used in a simple bomb.

5. Radiation that is found "naturally" in the environment.

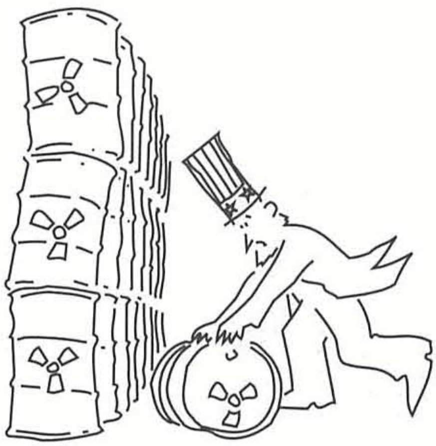
6. The unit of radioactivity named after the husband-wife science team that discovered radium.

7. The route by which a person or several people are exposed by a substance.

10. One of the five countries that continues to reprocess spent nuclear fuel.

The **Atomic Puzzler** is a regular *Science for Democratic Action* feature. We offer 25 prizes of $10 to people who send in solutions to all parts of the puzzle, right or wrong. There is one $25 prize for a correct entry. Fill in the puzzle and submit the answer (either a photocopy of the solved puzzle or the answers written out) to Ellen Kennedy, IEER, 6935 Laurel Avenue, Takoma Park, MD 20912. If more than 25 people enter and there is more than one correct entry, the winners will be chosen at random. The deadline for submission of entries is **March 31, 1995**.

The Institute for Energy and Environmental Research (IEER) provides the public 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 healthier environment.



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