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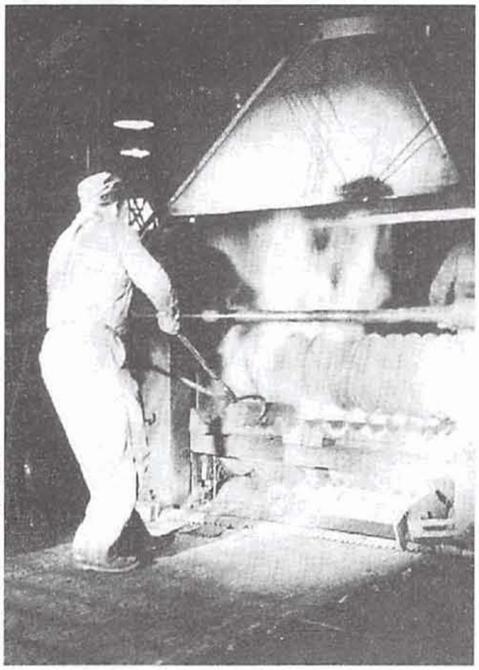
Science for Democratic Action

AN IEER PUBLICATION

Forgotten Exposures: Worker Doses at Three Nuclear Materials Processing Plants in the 1940s and 1950s



AMERICAN MEDICAL ASSOCIATION

Manual rolling mill, showing ventilation hood, circa 1959.

BY ARJUN MAKHIJANI, BERND FRANKE, AND HISHAM ZERRIFFI[1]

Editor's Note: This article is based on a report produced by IEER under a contract to the newspaper USA Today. The report calculated estimates for radiation exposure of workers at three privately-owned and -operated factories in the United States that processed uranium, including one that also processed thorium, in the 1940s and 1950s for use in the production of nuclear weapons.

The report concludes that working conditions at the three plants were very poor, that doses to many of the workers far exceeded then-prevailing standards, and that some workers had a high probability of getting cancer as a result of their exposure. The government appears to have deliberately misled workers about the dangers to which they were being exposed.

In a series of articles published September 6 through 8, 2000, USA Today identified approximately 150 privately owned facilities that were used for various stages of nuclear weapons production in the US in the 1940s ad 1950s. Subsequently, the US Department of Energy (DOE) released an "internal working list" of more than 570 facilities, both privately and government owned/operated, that were possibly involved in nuclear weapons related work. Some of these facilities carried out work

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Nuclear Plant Risk Studies: Dismal Quality

BY DAVID LOCHBAUM[1]

An accident at a US nuclear power plant could kill more people than were killed by the atomic bomb dropped on Nagasaki.[2] The financial repercussions could also be catastrophic. The 1986 accident at the Chernobyl nuclear plant cost the former Soviet Union more than three times the economical benefits accrued from the operation of every other Soviet nuclear power plant operated between 1954 and 1990.[3]

But consequences alone do not define risk. The probability of an accident is equally important. When consequences are very high, as they are from nuclear plant accidents, prudent risk management dictates that probabilities be kept very low. The Nuclear Regulatory Commission (NRC) attempts to limit the risk to the public from nuclear plant operation to less than one percent of the risk the public faces from other accidents.

The Union of Concerned Scientists (UCS) examined how nuclear plant risk assessments are performed and how their results are used. We concluded that the risk assessments are seriously flawed and their results are being used inappropriately to increase—not reduce—the threat to the American public.

Nuclear plant risk assessments are really not risk assessments because potential

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similar to that of the three plants analyzed here; others had different functions.

In April 2000, after decades of denial, the DOE acknowledged that nuclear weapons production harmed its workers due to exposure to radioactivity and toxic chemicals. The lion's share of attention generated by this announcement has been given to workers at the major, government-owned and -operated DOE sites. While this official concern is certainly warranted, and long overdue, the IEER report underscores the responsibility of the US government to also acknowledge those who worked at private facilities involved in nuclear weapons production. Furthermore, plant neighbors and the family members of nuclear weapons workers also may have been exposed to radioactive and toxic materials as a result of work at these sites.

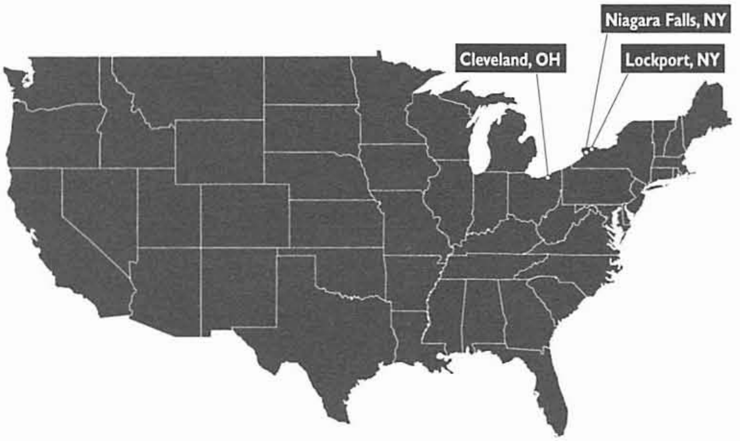
A full length version of the IEER report can be obtained by visiting USA Today*'s Web site at* http://www.usatoday.com/news/poison/docdex.htm *or by contacting IEER.*

In the IEER report produced for USA Today newspaper, titled *Preliminary Partial Dose Estimates from the Processing of Nuclear Materials at Three Plants during the 1940s and 1950s*, we analyzed some data in regard to working conditions and radiation exposures of workers at three nuclear materials processing facilities:

- Simonds Saw & Steel Co., Lockport, New York
- Harshaw Chemical Co., Cleveland, Ohio
- Electro-Metallurgical Co., Niagara Falls, New York

All three plants processed uranium during portions of the 1940s and 1950s. Simonds also processed thorium metal. These facilities

SITES OF NUCLEAR MATERIALS PROCESSING FACILITIES ANALIZED IN IEER'S STUDY



conducted industrial operations such as metal rolling that would later be conducted at government-owned facilities.

The study, on which this article is based, was a preliminary and

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Science for Democratic Action

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Editor: Lisa Ledwidge

partial evaluation of worker exposure in some job categories or locations. Its purpose was to perform screening-type of calculations to ascertain whether the doses to workers in at least some locations or job categories were high enough to cause serious health concerns.

We did not assess external radiation doses. There are clear indications that in some cases, at least, these exposures were substantial. We also have not attempted to assess exposures to non-radioactive toxic materials, which may also have been substantial in many cases. The study is necessarily limited in scope and partial. A thorough effort would require far more documentation, data, time, and resources than were available in this project.

We estimated doses due to inhalation of uranium by calculating the amount of uranium breathed in by a worker in a typical work day at a specific location or in a specific job category. The time-weighted air concentrations to which workers were exposed over a day were estimated by plant personnel taking into account the time spent by the workers in different plant locations. All dose calculations shown here are "committed doses," reflecting the fact that exposures resulting from a single intake are considered over the entire time that inhaled uranium remains in the body.[2]

Simonds Saw & Steel Co., Lockport, New York

Between 25 and 30 million pounds of uranium metal was rolled into rods at Simonds between March or April 1948 and 1956. Simonds also rolled 30,000 to 40,000 pounds of thorium metal. The work with uranium and thorium was done part-time, and the same machines were used to roll steel for commercial applications the rest of the time.

There is ample evidence that the plant premises became seriously contaminated during processing of radioactive materials. For instance, even air in the lunch areas was far above allowable limits of contamination. As a result, workers were exposed to radiation even when steel processing was going on, for instance through re-suspended particles. We did not attempt to assess the doses to workers during steel processing. We also did not attempt to estimate the consequences of food becoming contaminated as a result of poor industrial hygiene. Including all of these factors would increase the dose estimates.

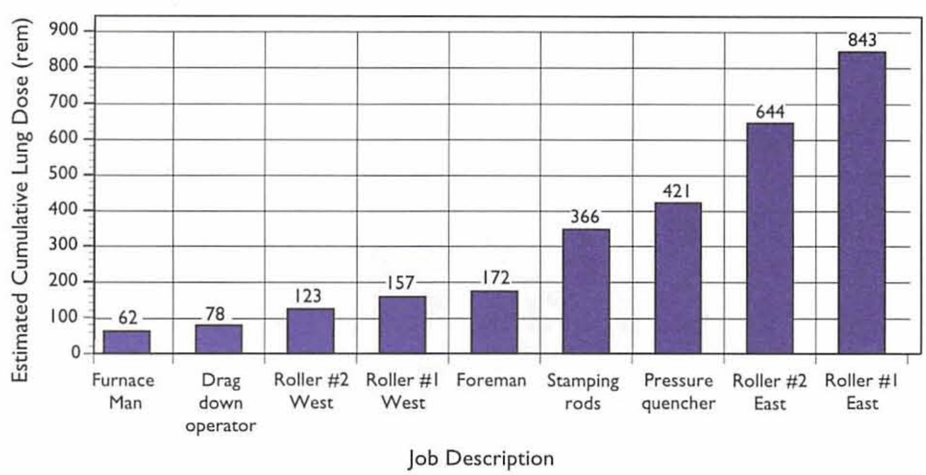
We used the available data to make estimates of doses from uranium metal processing to August 6, 1954. We do not have survey data covering the rest of the period through the end of operations in December 1956. Thus, the doses presented here are partial exposure estimates that underestimate doses to personnel who worked through the entire period of processing.

We made exposure estimates by job classification. If one person did the job for the entire period, the dose estimate represents a typical expected exposure (see below for discussion of uncertainties). If the personnel doing the job changed, this dose estimate would not apply to any particular individual, but rather to the sequence of individuals who did the particular job over the specified period.

The emissions from the operation at Simonds were typically a mixture of oxides of uranium, whose solubilities ranged from very insoluble to moderately soluble. It may take many months or years for highly insoluble materials to be eliminated once lodged in the lung, while moderately soluble materials may be eliminated within a few weeks. However, more soluble forms of uranium would also get transported to the kidney, resulting in damage due to uranium's heavy metal properties.

Figure 1 shows the lung dose estimates for a range of particular jobs. Workers in the same job may have had doses several times higher or lower than this, depending on specific working times and conditions as well as individual metabolic differences.

Figure 1: Estimated Cumulative Partial Lung Doses Due to Uranium Exposure at Simonds Saw and Steel From April 1, 1948 to December 31, 1952



Workers were also exposed to thorium dust. Even

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though the amount of thorium processed was almost a factor of one thousand less than uranium, exposures to workers who processed thorium appear to have been substantial, in part because exposure to thorium results in larger doses than uranium.

Thorium processing operations at Simonds may have taken as little as one week and possibly much longer. Based on available data, it is not possible for us to estimate the total number of full time equivalent days for which the thorium milling operation was conducted. We have therefore calculated thorium doses corresponding to one week of full time work. We estimated that bone surface doses over a one-week exposure ranged from about 400 rem to almost 2,500 rem, depending on working conditions and thorium solubility. We do not have a basis on which to select a mix of solubilities based on the available data. If the work was carried out for several weeks, then the dose estimates would be correspondingly higher.

Overall, it appears that exposures to specific workers who worked on thorium may have been severe. We were not able to assess cumulative thorium exposures in a manner similar to uranium since we lack even minimally adequate air concentration data over the requisite period of time. Our estimate of thorium exposures, based on one week's work, indicates that for some workers, thorium exposures may have been comparable to and perhaps greater than uranium exposures. Finally, if some workers worked with both uranium and thorium, those exposures would be additive.

Harshaw Chemical Co., Cleveland, Ohio

Harshaw Chemical Co. conducted a number of chemical operations to produce uranium hexafluoride (UF_6) for uranium enrichment operations. Part-time operations began during the World War II Manhattan Project, during which highly enriched uranium was used to make the nuclear bomb that was dropped on Hiroshima. UF_6 production at Harshaw was scaled up after the war and substantially expanded in 1947.

The chemical forms of uranium present at Harshaw range from the highly soluble (uranium hexafluoride) to the highly insoluble (uranium dioxide). Industrial hygiene was very poor, with air contamination exceeding the maximum allowable in some cases by several hundred fold, averaged over the entire working day.

Assuming that workers were exposed to the same mix of uranium compounds as seen at the Fernald nuclear weapons plant near Cincinnati, as would be likely for at least some portion of the plant personnel, the radiation doses to the lungs of workers in moderately exposed categories would be in the hundreds of rem, cumulative. (A bar chart of worker doses at Harshaw is shown in Figure 2.)

Our calculations assumed an eight hour work day and 20 work days per month averaged over a year. In the case of the most severely exposed workers — who worked for long periods or in highly contaminated conditions or, in the worst cases, both — cumulative lung doses were thousands of rem.

Many workers were exposed to more than the prevailing dose limit, which at that time period was 15 rem per year to the lung. The estimated mean lung dose in the highest exposure category (8,400 rem) would be equivalent to an effective dose of approximately 1,000 rem. Using the cancer risk factor established by the International Council on Radiation Protection (ICRP) of 0.04%, or four deaths per 10,000 rem, we can estimate that a worker would have a 40% chance of dying from cancer as a result of an exposure of 1,000 rem. This is an increase of 200 percent in fatal cancer risk compared to unexposed persons.

If the uranium were to be of more soluble compounds, the estimated radiation doses and cancer risk would be smaller and the likelihood of

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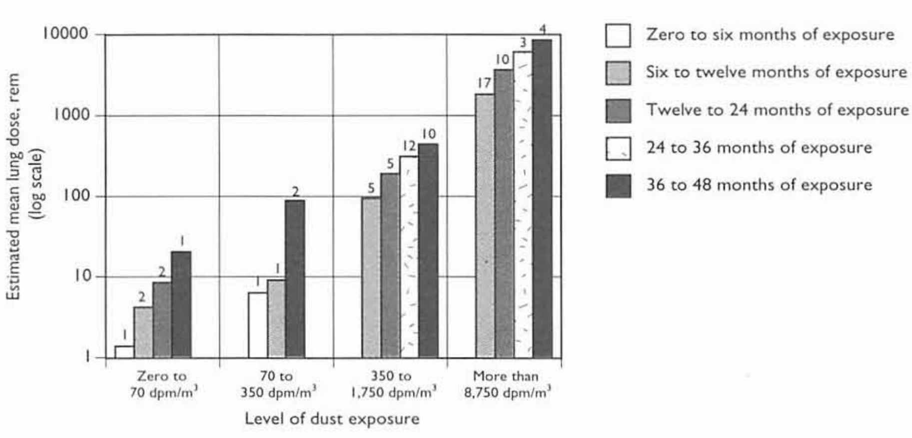
Figure 2: Mean lung doses and distribution of employees by length of employment and level of uranium dust exposure at Harshaw Chemical Co., 1945-1949



NOTES: The number above each bar corresponds to the number of workers that were found to be in that particular exposure category. The absence of a bar indicates that there were no workers in that category. dpm/m³ is disintegrations per minute per cubic meter.

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severe nephrotoxic effects would be far larger. Plant documents indicate that such kidney damage was reported.

We did not attempt within the scope of this limited study to systematically quantify external exposures. However, even a cursory review of Harshaw documents shows that for at least some workers, external exposures, in particular from thorium-234 and protactinium-234, which give rise to beta radiation exposures, may have been high, thus compounding the problems resulting from internal uranium exposure.

Also, the manufacture of uranium hexafluoride involves the use of severely toxic chemicals, including fluorine. Moreover, when uranium hexafluoride makes contact with the humidity in the air (which would be high in the Cleveland area during at least some parts of the year), it readily combines with water vapor to yield uranyl fluoride and hydrofluoric acid, which is highly toxic.

Electro-Metallurgical Co. (Electromet), Niagara Falls, New York

Uranium metal was fabricated at Electromet from uranium tetrafluoride (also called "green salt"). The process involves the mixing of green salt with magnesium metal flakes, and the insertion of the mixture into a furnace, where the green salt is reduced to metal. Historically, the process was typically troublesome, sometimes involving blow-outs, especially under the conditions of production pressure that characterized the first two decades of the nuclear era. The uranium would typically be a mixture of moderately soluble and insoluble compounds, with the former predominating, since green salt belongs in this category.

We did not have adequate data covering the entire time period of Electromet operation, which began during the Manhattan Project and ended in 1953. We know that full time uranium metal production was occurring in the late 1940s, for which we have some data on the range of air concentrations found in working areas, as well as air concentrations weighted over the working day. We performed dose calculations using these figures for one individual over 240 working days (a working year of 48 weeks, 5 days per week). Actual exposure for personnel who worked for a large portion of the period for which the plant operated can be expected to be considerably higher. However, we cannot assume that actual exposures would be a simple multiple of the calculated doses, since air concentration data are not available in the detail needed to make even an approximate calculation for the entire period.

Industrial hygiene at Electromet was very poor. Many workers were evidently severely overexposed, since highly contaminated environmental conditions persisted in the workplace for prolonged periods. We estimate that for production workers, committed lung doses due to exposure over a single twelve-month period would range from over 50 rem to well over 6,000 rem. The most severely exposed workers would have a very high probability of contracting cancer. One would also expect to find some heavy metal toxicity to the kidneys due to exposure to green salt.

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IEER TESTIFIES TO CONGRESS ON NUCLEAR WORKER EXPOSURES

On September 21, 2000, IEER's outreach coordinator, Lisa Ledwidge, presented testimony at a US congressional hearing on nuclear worker compensation. It was held by the House Judiciary Committee's Subcommittee on Immigration and Claims.

She discussed the findings of three IEER studies on nuclear worker exposures and off-site radiation releases. These included the *USA Today* study (see main article), the 1994 study on workers doses at the Fernald plant in Ohio, and the study on off-site releases from Fernald.

IEER has found that when worker exposures and off-site releases are carefully and independently studied, the results indicate that worker overexposure and environmental releases of radioactivity are larger than officially acknowledged.

In the testimony, IEER made three recommendations to Congress:

1. Because many are very sick and dying, health monitoring, treatment and where appropriate compensation of the affected workers is an urgent priority. Practical recognition of the role of the government and its contractors in their suffering is long overdue.
2. It is important to not force workers to prove their exposure to the last decimal point. The burden of proof should be on the government and its contractors, which failed to keep good records, failed to make sufficient measurements, and all too often assured workers of their safety when conditions were unsafe.
3. A process should be created for fairly and responsibly addressing the Cold War health legacy. Workers should be centrally involved in creating this process, because they were, on the whole, the most exposed group of people. But it should be acknowledged that non-workers were also exposed, including workers' family members, downwinders, those downstream, and other neighbors. The process for deciding how community exposures can be fairly and responsibly addressed should begin.

IEER's full testimony is available on-line at *http://www.ieer.org/comments/hrg0900.html.* The two Fernald studies are summarized in SDA vol. 5 no. 3, October 1996, which is also on-line, *http://www.ieer.org/sdafiles/vol_5/v5n3_1.html.*

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Uncertainties

There are two types of uncertainties in our estimates. First, there are variations in conditions experienced among the workers, differences in physiology leading to different metabolic rates, and so on. For instance, some workers at Harshaw would likely have encountered mainly insoluble types of uranium, while others would have encountered mainly soluble types of uranium. Largely because doses depend greatly on the assumed solubility of the material that is inhaled, a bewildering array of dose estimates can be produced from the same data on air concentrations.

The second type of uncertainty relates to the uncertainties in the measurements of air concentrations, in fluctuations in such concentrations from one day to the next, in the estimates of dose conversion factors for any particular chemical form of uranium, and in estimates of the effects of radiation exposure.

The estimates of partial doses within any group of workers could easily be several times lower or higher than those estimated here. Since we did not have the data to perform individual worker dose assessments, or even to determine whether such assessments could be reliably performed, a relatively low dose in a particular job category may not correspond to a low dose for a specific worker. The limited nature of the study and the preliminary and partial nature of the calculations do not justify extensive effort on a formal uncertainty analysis. We recommend that a more formal effort with a more complete set of data be undertaken. However, there is enough evidence to come to a reasonably certain conclusion that due to poor working conditions, exposures to many workers were very high and far above then-prevailing regulations.

In addition to these uncertainties, our estimates are partial since we have not included external doses, and since we have not been able to estimate doses over the entire working period in several cases. This factor would result in dose estimates that would be systematically higher than the numbers given above.

False Assurances

There is ample evidence that plant authorities as well as the government of the United States, which contracted with these private companies to process material for its nuclear weapons program, were well aware that workers at these plants were being severely overexposed over prolonged periods of time. There is also evidence that the US government deliberately misled workers about health and safety issues by concealing the facts of very poor working conditions from them and by failing to undertake the needed level of radiation dose surveillance, including frequent and widespread urine sampling, that was warranted.

A number of documents discuss inadequate controls of contamination and recommendations for improvement that were only sometimes taken into account. For example, in discussing the problems at Harshaw, one document states that:

> These findings [90% of plant workers being exposed to higher than the "preferred level" of contamination, with 76% exposed to 10 to 374 times that level] are consistent with the results of other NYOO [New York Operations Office] investigations, and show that the equipment and procedures presently used for the control of alpha-emitting dust and fumes are completely inadequate.[3]

In some cases, there was a hesitation to spend money to correct problems in plants that were expected to be placed on stand-by and no longer be in use for production. At least a year before the Electromet facility was to transition to stand-by, one Atomic Energy Commission document notes that:

> In order to provide for adequate dust control, a substantial sum of money ($50,000 to $100,000) would have to be spent. As before, whether or not extensive dust exposures are corrected will depend on policy decision as to the advisability of spending funds for the purpose of placing stand-by plants in satisfactory medical condition. ... During the next few months, minor changes in process ventilation can be expected to alleviate the dust exposure to some extent.[4]

One document points clearly to the practice of keeping information about the health risks of their jobs from the workers. In a January 1948 letter to the vice-president of Harshaw Chemical Co., the Manager of the New York Operations Office of the US Atomic Energy Commission wrote: "...it is obvious that concentrations considerably above the preferred level are common in Area C." In the same letter he states that the employees in Area C were told and would continue to be told "that all of our records indicated that no unusual hazard existed..."

Conclusions

Working conditions at these three plants were very poor and among the most terrible reported for any plant in the United States. Based on our screening calculations, doses to many workers are likely to have exceeded the dose limit to the lung of about 15 rem per year that was established in 1949. The data and our calculations also suggest that the highest exposed workers had a high probability of cancer mortality as the result of the exposure. It must be remembered that we have arrived at this conclusion even though our dose

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calculations are partial and do not cover the entire periods of plant operation and all types of doses. Other types of health problems, including kidney damage, would also be likely among those workers exposed to the more soluble forms of uranium.

We do not have comparable data from nuclear weapons plants that processed uranium in the Soviet Union during the late 1940s and early 1950s. Some external dose data for workers at a reactor and a reprocessing plant in the southern Ural Mountains have been reported. Heretofore, we have assumed based on available evidence that worker exposures were far higher in the Soviet Union that in the United States.[5] However, the partial estimates that we have made here are so high that this assumption may need to be revisited for many of the workers at these forgotten nuclear weapons plants.

We should also note that the extent of the health damage may have extended to the families of workers and to the general public in ways that we have not assessed in the preliminary report.

One new conclusion that emerges from our study of the Simonds plant is that radiation exposures as a result of thorium-232 processing were severe. Such processing occurred at several other places (including the Fernald plant, for instance). This is an issue that needs to be more carefully evaluated, since it is possible that exposures to workers, their families, and members of the general public from thorium processing may have been larger than suspected, despite the relatively small amounts (compared to uranium) of thorium that were processed.

It is clear that the effects of the nuclear weapons enterprise on society are far vaster than imagined. The tasks of health monitoring and medical care for affected populations and of clean-up appear even more complex than previously anticipated.

1. Makhijani is president of IEER. Franke is a scientific director at ifeu (Institut für Energie und Umweltforschung GmbH) in Heidelberg, Germany. Zerriffi was senior scientist at IEER during production of the report.
2. We used dose conversion factors established by the U.S. Environmental Protection Agency (K.F. Eckerman et al., *Limiting Values of Radionuclide Intake and Air Concentration and Dose Conversion Factors for Inhalation, Submersion, and Ingestion*, Federal Guidance Report Number 11. Washington, DC: US Environmental Protection Agency, 1988). For methodological details and assumptions, as well as additional references, please refer to the full report on USA Today's Web site at http://www.usatoday.com/news/poison/docdex.htm.
3. *Monthly Status and Progress Report for December 1948.* Submitted by the New York Operations Office of the Atomic Energy Commission by W.E. Kelley, Manager. January 5, 1949. p. 17
4. U.S. Atomic Energy Commission, New York Operations Office. *Health Hazards in NYOO Facilities Producing and Processing Uranium (A Status Report – April 1, 1949).* Prepared by NYOO Medical Division. Issued April 18, 1949. p. 31
5. Arjun Makhijani et al., eds., *Nuclear Wastelands: A Global Guide to Nuclear Weapons Production and Its Health and Environmental Effects.* Cambridge, MA: MIT Press 1995, Chapter 7, p. 367.

RESOURCE KIT AVAILABLE

The Institute for Energy and Environmental Research has teamed up with the Alliance for Nuclear Accountability and Physicians for Social Responsibility to compile an information kit for activists and other concerned people about newly revealed private companies in the United States where nuclear weapons related work was done.

The *Forgotten Nuclear Sites Information and Action Kit* is designed to assist neighbors and former workers of such facilities to get more information about environmental contamination and health effects that may have resulted from their operations. It also suggests ways to get the federal government to properly address these problems.

The kit includes background information, newspaper articles, and a resource list of government agencies, community groups, and technical resources. It also includes action items like sample letters to the editor and to policy makers.

Forgotten nuclear sites located in dozens of states across the country were revealed in the September 6-8, 2000, USA Today newspaper series "Poisoned Workers and Poisoned Places." IEER's analysis of three of them is summarized in the main article on page 1.

To order a kit, contact:
Alliance for Nuclear Accountability | 1914 N. 34th, Suite #407 | Seattle, WA 98103 USA
Tel.: 1-206-547-3175 | Fax: 1-206-547-7158 | on-line: http://www.psr.org

(The Alliance for Nuclear Accountability is a network of local, regional and national organizations working together to promote education and action addressing issues pertaining to the US nuclear weapons complex and related facilities. Physicians for Social Responsibility, the US affiliate of the International Physicians for the Prevention of Nuclear War, is a national organization of medical professionals and others working to eliminate weapons of mass destruction, preserve a sustainable environment, and reduce interpersonal violence.)

Characteristics of Uranium And Thorium

Varying forms of uranium are present at nuclear materials processing plants. These range from uranium hexafluoride (UF_6), to the insoluble uranium dioxide (UO_2). Uranium hexafluoride readily combines with water vapor to yield hydrofluoric acid (HF), an extremely caustic substance.[1] These same variations also accompany the use of thorium in processing plants.

	Uranium	**Thorium**
Atomic Symbol	U	Th
Source	Occurs naturally in trace amounts	Occurs naturally in trace amounts
Common Forms	Uranium is both radioactive and a chemical toxin. Uranium is comprised of three naturally occurring isotopes. U^{238} comprises 99.284% of natural uranium by weight, U^{235} 0.711%, and U^{234} 0.005%. U^{235} is the form used in nuclear weapons and power plants. However, U^{238} is often converted to Pu^{239} for such purposes.	Thorium is both radioactive and a chemical toxin. Three main isotopes of thorium occur in nature: Th^{232} is a primordial radionuclide. Th^{234} and Th^{230} exist naturally as part of the uranium-238 decay chain.
Decay[2]	Alpha, low-energy gamma	Alpha, low-energy gamma
Exposure	Uranium is found in nature and therefore minute concentrations are present in food, water, and air. Increased exposure is common in occupations where uranium dust is prevalent, like in nuclear materials processing and mining.	Thorium is found in nature and therefore may be present in air, food, and water. The highest chance of serious exposure occurs when thorium dust is present, as for example in the workplace.
Excretion	Particles in lungs may be coughed or breathed out, or may enter the blood, pass through the kidneys and be excreted as urine. Ingested uranium particles can be excreted in feces. Some particles remain in the body where they can build up lung, or enter the blood stream where it can accumulate in bone tissue.	Excretion pathways are similar to those of uranium.
Health Effects	Because alpha particles and gamma radiation emitted by uranium are relatively weak, uranium poses little health hazard outside the body. However, kidney disease has been observed in uranium miners and animals that ingest large quantities of uranium, attributable to the element' s toxic chemical properties. Due to its radioactive properties, exposure to uranium increases the risk of lung, bone, leukemia, and soft tissue cancers, particularly when inhaled or ingested. Animal studies show that uranium may affect reproduction and the developing fetus. Uranium-238 also decays into dangerous radionuclides such as radium-226 and radon-222 decay products.	Thorium dioxide is classified by the U.S. Agency for Toxic Substances and Disease Registry as a "known carcinogen." Animal studies suggest that thorium may be absorbed through skin, but thorium poses little health hazard outside of the body. Workers who are exposed to thorium have been shown to have an increased chance of lung disease, lung cancer, and pancreatic cancer. Thorium has also been shown to cause liver disease, blood disorders, and changes to genetic material. Large acute (one time) doses have been shown to lead to metal poisoning in animals. Birth defects have been observed in animals exposed to thorium.

Sources: Agency for Toxic Substances and Disease Registry, *ATSDR Public Health Statement: Uranium,* Atlanta, December 1990; and Agency for Toxic Substances and Disease Registry, *ATSDR Public Health Statement: Thorium,* Atlanta, October 1990.

1 The chemical equation for this is $UF_6 + 2H_2O \rightarrow UO_2F_2 + 4HF$ + heat. (UO_2F_2 is uranyl fluoride.)

2 The nuclei of radioactive elements are unstable, meaning they are transformed into other elements, typically by emitting particles (and sometimes by absorbing them). This process is known as radioactive decay. The decay of uranium and thorium results in the release of alpha particles and weak gamma radiation.

Summary of Historical Annual Regulatory Dose Limits for the United States

The table below shows a summary of salient portions of the worker radiation protection standards as they evolved in the United States. In general, the standards have been tightened over time. The dose limits for the public were the same as those for workers in the early years, but were reduced to one-tenth those for workers in the late 1950s and tightened further in 1988. Only the years with the most important changes are shown.

Year	Dose Limit as Specified in the Regulation[1]	Annual Dose Limit[2]	Source[3]	Comments
Before 1949	0.1 R/day[4]	36.5 R	NBS Handbook #18	30 R would be the annual dose limit on the basis of 300 working days.
1950	0.3 R/week 3.9 R/13 weeks	15.6 R	NBS Handbook #18	The two dose limits (second column) were presented by two different reports that in the end led to the same result. 15 R would be the dose limit on the basis of 50 working weeks per year.
1954	0.3 R/week (maximum) 15 rem/year[5]	15 rem	NBS handbook #59	Marks the first time rem are used in dose limits. A maximum of 0.3 R exposure is permissible for any given week.
1958	3.0 rem/13 weeks 5(N-18)[6]	5 rem per year average. See comment	Addendum to NBS handbook #59	First time the concept of a dose limit beyond one year is introduced. The average dose over a period of years should not exceed 5 rem per year. See note 6.
1988	5 rem/year	5 rem	DOE order 5480.11[7]	Internal and external doses added by calculating the whole body effective dose equivalent.

1 These dose limits were set by the U.S. Department of Energy (DOE) and its predecessor agencies: Atomic Energy Commission (AEC, 1947-1974), Energy, Research, and Development Administration (ERDA, 1974-1977), DOE (1977-on). All are limits for both external radiation doses and internal exposures for which the whole body was the critical organ except in 1988, when the dose for external plus *all* internal exposures was required to be included.

2 For the first two listed, the annual dose limit is inferred using the values for the daily or weekly limit.

3 In the 1940s and 1950s, the National Bureau of Standards (NBS) published the standards for all radiation workers, and the AEC and its successor agencies adopted these for its weapons plants by publishing internal manuals and orders on radiation protection.

4 R=rad, or *r*adiation *a*bsorbed *d*ose which is a unit of absorbed dose equivalent to the deposition of 100 ergs of energy per gram of tissue.

5 Rem=*r*oentgen *e*quivalent *m*an, or a unit of absorbed dose that takes into account the relative biological effectiveness (RBE), or relative biological damage caused by the various ways that ionizing radiation deposits its energy in tissue.

6 The average dose limit was computed for workers over a period of years. It was assumed that workers would be over the age of 18. The formula 5(N-18) gives the cumulative maximum allowable dose to the worker of age N years. The average dose limit per year is five rem.

7 Until DOE 5480.11, the total dose limit was to include any internal exposures for which the whole body was the critical organ. For DOE 5480.11, the committed dose equivalent for *all* internal exposures was to be included. Before 1988, effective dose equivalents were not calculated as part of compliance.

accident consequences are not evaluated. They merely examine accident probabilities—only half of the risk equation. Moreover, the accident probability calculations are seriously flawed. They rely on assumptions that contradict actual operating experience.

All probability analyses make assumptions. For example, when you calculate that the probability of getting heads upon a single flip of a quarter is 50 percent, you are assuming that the coin will not land on its edge. Nuclear plant probabilistic risk assessments (PRAs) rely on numerous unrealistic assumptions that fly in the face of the actual data from operating nuclear power plants: [4]

Assumption: The plants are operating within technical specifications and other regulatory requirements.

Fact: There are more than 1,000 violations of technical specifications and regulatory requirements each year. As a result of this unrealistic assumption, the core damage frequencies (CDFs) calculated in the PRAs are too low. By assuming that emergency equipment meets safety requirements when in fact it does not, the PRAs calculate better response capabilities than supported by reality. In other words, the core damage frequencies are really higher than reported by the PRAs.

Assumption: Plant design and construction are completely adequate.

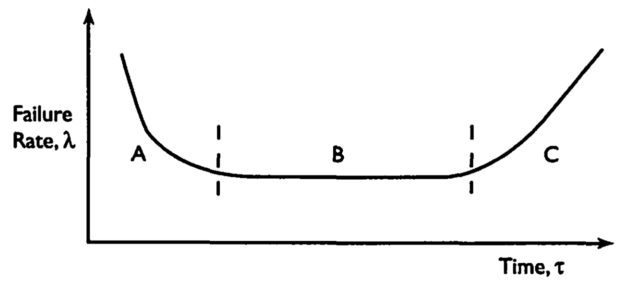
Fact: The risk assessments assume that there are *zero* design and construction problems when hundreds of problems are discovered every year. The NRC's Office for Analysis and Evaluation of Operational Data documented 3,540 design errors reported between 1985 and 1994.[5] That means a design error was discovered at a nuclear power plant in the United States almost every single day for an entire decade.

Assumption: Plant aging does not occur; that is, equipment fails at a constant rate.

Fact: The NRC has issued more than one hundred technical reports about the degradation of valves, pipes, motors, cables, concrete, switches, and tanks at nuclear plants caused by aging.[6] These reports demonstrate that parts in nuclear plants follow the "bathtub curve" aging process illustrated in the figure. A telling demonstration of the effects of age occurred in 1986. Four workers were killed at a nuclear power plant in Virginia because a section of pipe eroded away with time until it broke and scalded them with steam.[7] Yet most PRAs assume *no* aging effects.

Assumption: The reactor pressure vessels never fail.

Fact: Experience has shown that this assumption has as many cracks and flaws as the reactor pressure vessels themselves. In 1995, UCS issued a report on the fragile condition of reactor pressure vessels at nuclear power plants. [8] For example, the Yankee Rowe plant in



"Bathtub" Curve of Failure Rate

Massachusetts closed in 1992 because its reactor pressure vessel had become brittle over time. Brittle metal can shatter, much like hot glass, when placed in cold water. Despite the closure of the Yankee Rowe plant and documented embrittlement at many other nuclear plants, the risk studies continue to assume a *zero* chance of reactor pressure vessel failure.

Assumption: Plant workers make few serious mistakes.

Fact: A report issued in February 2000 by the Idaho National Engineering and Environmental Laboratory (INEEL) demonstrates that unjustified assumptions about worker behavior continue to be a problem. Researchers at INEEL examined 20 recent operating events at nuclear power plants and concluded that "Most of the significant contributing human performance factors found in this analysis of operating events are missing from the current generation of probabilistic risk assessments....[which] does not address well the kinds of latent errors, multiple failures, or the type of errors determined by analysis to be important in these operating events."[9]

Assumption: Risk is limited to reactor core damage.

Fact: The PRAs only determine the probabilities of events leading to reactor core damage. They do not calculate the probabilities of other events that could lead to releases of radiation, such as fuel going critical in the spent fuel pool or rupture of a large tank filled with radioactive gases. Some of these overlooked events can have serious consequences. For example, researchers at the Brookhaven National Laboratory estimated that a spent fuel pool accident could release enough radioactive material to kill tens of thousands of people. [10]

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RISK STUDIES

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History shows there is a greater probability of a flipped coin landing on its edge than of these assumptions being realistic. Unrealistic assumptions in the PRAs make their results equally unrealistic. In computer programming parlance, "garbage in, garbage out."

Furthermore, the NRC requires plant owners to perform the calculations, but fails to establish minimum standards for the accident probability calculations. Thus, the reported probabilities vary widely for virtually identical plant designs. Four case studies clearly illustrated the problem:

- The Wolf Creek plant in Kansas and the Callaway plant in Missouri were built as identical twins, sharing the same standardized Westinghouse design. But some events at Callaway are reported to be 10 to 20 times more likely to lead to reactor core damage than the same events at Wolf Creek.
- The Indian Point 2 and 3 plants share the same Westinghouse design and sit side by side in New York, but are operated by different owners. On paper, Indian Point 3 is more than 25 percent more likely to experience an accident than her sister plant.
- The Sequoyah and Watts Bar nuclear plants in Tennessee share the same Westinghouse design. Both are operated by the same owner. The newer plant, Watts Bar, was originally calculated to be about 13 times more likely to have an accident than her sister plant. After some recalculations, Watts Bar is now only twice as likely to have an accident.
- Nuclear plants designed by General Electric are equipped with a backup system to shut down the reactor in case the normal system of control rods fails. On paper, that backup system is highly reliable. Actual experience, however, shows that it has not been nearly as reliable as the risk assessments claim.

To make matters worse, the NRC is allowing plant owners to further increase risks by cutting back on tests and inspections of safety equipment. The NRC approves these reductions based on the results from incomplete and inaccurate accident probability assessments.

When the NRC learns that a nuclear plant does not meet federal safety regulations, it relies on the calculated accident probabilities to assess the risk. The NRC—under constant pressure from the nuclear industry—has recently accepted a concept of "risk-informed regulation," in which many safety regulations are eliminated and the scope of other regulations is significantly reduced based on the results of risk assessments. A critical question, then, is whether risk assessments are accurate enough to rely on for these purposes.

In sum, the risk of a major accident at any nuclear power plant is unknown, because although the probability of an accident has been assessed (albeit with flawed assumptions, and inconsistent definitions and procedures), the consequences have not been assessed. The following will draw on other sources to provide the missing piece of the risk puzzle.

The incomplete and inaccurate state of nuclear plant risk assessments does not provide a solid foundation for the NRC to move towards risk-informed regulation.

A nuclear plant accident can harm the public by releasing radioactive materials. Radioactive materials emit alpha particles, beta particles, gamma rays, and/or neutrons. These emissions are called "ionizing radiation" because the particles produce ions when they interact with substances.[11]

Following the Three Mile Island (TMI) accident in 1979, the Sandia National Laboratory estimated the potential consequences from reactor accidents that release large amounts of radiation into the atmosphere. For each nuclear plant then in operation and nearing completion, Sandia determined the amount of radiation that could be released following a major accident, the area's weather conditions, and the population downwind of the plant. Then Sandia estimated how many people would die and be injured within the first year due to their radiation exposure. Sandia also estimated how many people would later die from radiation-induced illnesses like cancer. Early fatality estimates ranges from 700 for a small reactor to 100,000 for one of the larger ones. Cancer death estimates ranged from 3,000 to 40,000. Injury estimates ranged from 4,000 to 610,000. For comparison, the atomic bomb dropped on Hiroshima killed 140,000 people and the one dropped on Nagasaki killed 70,000 people.[12]

The incomplete and inaccurate state of nuclear plant risk assessments does not provide a solid foundation for the NRC to move towards risk-informed regulation. Before the NRC allows takes another step towards risk-informed regulation, the NRC must complete the following tasks:

1. Establish a minimum standard for plant risk assessments that includes proper methods for:
   a. handling the fact that nuclear plants may not conform with all technical specification and regulatory requirements;

SEE **RISK STUDIES** ON PAGE 12

RISK STUDIES

FROM PAGE 11

b. handling the fact that nuclear plants may have design, fabrication, and construction errors;

c. handling equipment aging;

d. treating the probability of reactor pressure vessel failure;

e. handling human performance;

f. handling events other than reactor core damage in which plant workers and members of the public may be exposed to radioactive materials (e.g., spent fuel pool accidents and radwaste system tank ruptures);

g. handling nuclear plant accident consequences to plant workers and members of the public;

h. justifying the assumptions used in the risk assessments; and

i. updating the risk assessments when assumptions change.

2. Require all plant owners to develop risk—not probability—assessments that meet or exceed the minimum standard.
3. Require all plant owners to periodically update the risk assessments to reflect changes to the plant and/or plant procedures.
4. Require all plant owners to make the risk assessments publicly available.
5. Conduct inspections at all nuclear plants to validate that the risk assessments meet or exceed the minimum standards.
6. Disallow any use of risk assessment results to define a line between acceptable and unacceptable performance until all of the steps listed above are completed.

The NRC must be made more independent of the nuclear industry

It will take considerable effort on the part of the NRC to implement these recommendations. Unfortunately, the NRC may be unable to take these safety steps because it is under attack from the US Congress to reduce its budget. Why? The NRC is a fee-based agency. Most of the NRC's budget is paid not by taxpayers but by the plants' owners. These plant owners lobbied Congress to slash the NRC's budget. Congress listened and slashed. In 1987, the NRC had 850 regional and 790 headquarters staff members. Ten years later, chronic budget cuts had reduced the NRC to 679 regional and 651 headquarters staff members.[13] During a decade that began with 101 licensed nuclear power plants and ended with 109 plants, the NRC lost 20 percent of its safety inspectors.[14]

The NRC must be made more independent of the nuclear industry in its funding so that it can properly regulate the industry before it is too late.

1 David Lochbaum is Nuclear Safety Engineer at the Union of Concerned Scientists (UCS). This article is based on the UCS report he authored, *Nuclear Plant Risk Studies: Failing the Grade* (Cambridge, Mass.: Union of Concerned Scientists, August 2000), which can be ordered from UCS (Tel. 1-617-547-5552) or downloaded from its Web site, http://www.ucsusa.org.

2 US House of Representatives, Committee on Interior and Insular Affairs Subcommittee on Oversight & Investigations, "Calculation of Reactor Accident Consequences (CRAC2) for US Nuclear Power Plants (Health Effects and Costs) Conditional on an 'SST1' Release," November 1, 1982; and Nuclear Regulatory Commission, "A Safety and Regulatory Assessment of Generic BWR and PWR Permanently Shutdown Nuclear Power Plants," NUREG/CR-6451, Washington, D.C., August 1997.

3 Richard L. Hudson, "Cost of Chernobyl Nuclear Disaster Soars in New Study," *Wall Street Journal*, March 29, 1990.

4 Nuclear Regulatory Commission, "Individual Plant Examination Program: Perspectives on Reactor Safety and Plant Performance," NUREG-1560, Vol. 2, Parts 2–5, p. 14-3, Washington, D.C., November 1996.

5 Sadanandan V. Pullani, "Design Errors in Nuclear Power Plants, " AEOD/T97-01, Washington, D.C.: NRC Office for Analysis and Evaluation of Operational Data, January 1997.

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7 Brian Jordan, "NRC Finds Surry Accident Has 'High Degree' of Safety Significance," *Inside NRC*, Washington, D.C.: McGraw-Hill, January 5, 1987.

8 Robert Pollard, "US Nuclear Power Plants—Showing Their Age—Case Study: Reactor Pressure Vessel Embrittlement," Cambridge, Mass.: Union of Concerned Scientists, December 1995.

9 Jack E. Rosenthal to John T. Larkins, "Meeting with the Advisory Committee on Reactor Safeguards Human Factors Subcommittee, March 15, 2000, on SECY-00-0053, NRC Program on Human Performance in Nuclear Power Plant Safety," Washington, D.C.: Nuclear Regulatory Commission, March 6, 2000. (Ed. note: This report was prepared by INEEL for the NRC.)

10 Nuclear Regulatory Commission, "A Safety and Regulatory Assessment of Generic BWR and PWR Permanently Shutdown Nuclear Power Plants," NUREG/CR-6451, Washington, D.C., August 1997. (Ed. note: This report was prepared by Brookhaven National Laboratory for the NRC.)

11 Code of Federal Regulations, Title 10, Energy, Section 20.1003, Definitions.

12 Richard Rhodes, *The Making of the Atomic Bomb*, New York: Simon & Schuster, pp. 734 and 740, 1986.

13 NRC Office of Nuclear Reactor Regulation, "Regulatory Trends," Washington, D.C., April 1997.

14 Sadanandan V. Pullani, "Design Errors in Nuclear Power Plants, " AEOD/T97-01, Washington, D.C.: NRC Office for Analysis and Evaluation of Operational Data, January 1997.

CONGRESS PASSES NUCLEAR WORKER COMPENSATION LEGISLATION

In October 2000, the US Congress passed and President Clinton signed into law the Energy Employees Occupational Illness Compensation Act, a legislative package designed to provide health care and compensation to certain nuclear weapons workers who were injured from occupational exposure to radiation, beryllium, or silica.

This is a landmark federal compensation program. It provides help for many workers whose occupational illnesses were for so many years denied by the government. It also has amplified calls for a process to begin that will address the harm done to neighbors of nuclear weapons facilities. Nonetheless, the legislation is not perfect and it will not cover all the nuclear weapons workers who were harmed from workplace exposure to radiation and toxic substances.

Provisions of the program include:

- **Compensation.** Eligible workers or their survivors will receive a lump sum payment of $150,000. Those eligible include certain Department of Energy (DOE), DOE contractor, and DOE vendor employees who were injured from exposure to radiation, beryllium, or silica while working in DOE nuclear weapons related programs. Survivors can make claims on behalf of covered employees.

- **Medical benefits.** The federal government will provide medical benefits to eligible workers for their occupational illness.

- **Benefit of doubt for a "special exposure cohort."** For a "special exposure cohort" of workers with a radiogenic cancer,[1] it is presumed that their illness resulted from workplace exposure to radiation. The special exposure cohort includes certain gaseous diffusion plant workers in Tennessee, Kentucky, and Ohio (the Oak Ridge, Paducah, and Portsmouth plants, respectively) and workers who were employed during nuclear testing at the Amchitka Island Test Site in Alaska. Additional classes of employees could be designated as members of the special exposure cohort if the US President, designated to implement the program, determines that "(1) it is not feasible to estimate with sufficient accuracy the radiation dose that the class received; and (2) there is a reasonable likelihood that the radiation dose may have endangered the health of members of the class."

- **Determining eligibility.** Individuals with a radiogenic cancer who are not part of the "special exposure cohort" would be eligible only if the cancer was "at least as likely as not" related to their nuclear weapons related work. This means that there would have to be at least a doubling of the risk for that worker to be eligible (in other words, the worker would have to be twice as likely as an unexposed person to contract the particular cancer). This standard of proof may result in many exposed workers being excluded from compensation even though they are at risk of contracting a compensable disease as a result of their exposure and even though their exposures may have been higher than legally allowed. The effect of this test may be mitigated by the benefit-of-the-doubt provision discussed above, depending on the guidelines for its implementation (see below). According to the legislation, the risk of contracting a cancer due to a given radiation dose will be estimated using the "upper 99 percent confidence interval of the probability of causation in the radioepidemiological tables." This means that the probability of causation used for estimating the risk will be higher for a given dose than if the median estimate were used. This will also mitigate to some extent the effect of the high bar set for eligibility by the doubling of risk standard.

- **Entitlement.** Funding for benefits is guaranteed through an entitlement spending program. This means that Congress will not decide year after year how much money to put in the fund, but that spending will be mandatory and immune from the annual appropriations process. (Another example of an entitlement program in the US is the Social Security program.)

- **Uranium worker benefit enhancement.** Compensation to sick uranium miners, millers, and ore transporters — who are covered under a separate law, the Radiation Exposure Compensation Act — will be increased from $100,000 to $150,000; plus the new legislation provides them health insurance.

- **Implementation.** The legislation specifies that the President shall submit to Congress by March 15, 2001, a legislative proposal to implement the compensation program. The proposal would include the types of compensation to be provided, whether to expand the special exposure cohort to include new classes of employees, and whether to expand the program to include other illnesses associated with exposure to toxic substances. Congress will have until July 31, 2001, to act on the President's proposal. If the government does not act before that date, certain sections of the existing legislation will automatically take effect July 31, 2001, including those providing compensation and medical benefits to certain nuclear workers and uranium workers.

- **Indemnification.** If they accept the lump sum payment and medical benefits, workers or their families would not be allowed to sue the government or its contractors. The payment under this legislation would be regarded as a full settlement of claims against the United States, a DOE contractor or subcontractor, beryllium vendor, or atomic weapons employer for the covered illness.

The legislation does not address the issue of non-workers impacted by nuclear weapons production and testing. Nor does it include medical benefits for family members of workers who may have become ill as a result of exposure. As it stands, the legislation does not reimburse workers for lost wages due to occupational illness. Also, it is unclear if all workers — including those who worked at private facilities like those described in the main article on page 1 — will be eligible.

The government estimates that 4,000 former nuclear weapons workers nationwide will be eligible for the program. To start it off, Congress authorized $275 million to go toward the program in the coming year. The Congressional Budget Office estimates that under the program workers will receive $1.4 billion in benefits over the next 10 years, and uranium workers will receive an additional $450 million. The program was adopted as part of the defense authorization bill for fiscal year 2001.

For further information, visit the DOE's Web site on the Energy Employees Occupational Illness Compensation Program at http://tis.eh.doe.gov/portal/feature/titlexxxvi.html, or call the DOE worker compensation helpline at 1-877-447-9756.

1 Radiogenic cancers are defined as cancers of the bile duct, bone, brain, breast, colon, esophagus, gall bladder, kidney, liver, lung, ovary, pancreas, pharynx, salivary gland, small intestine, stomach, thyroid, and urinary bladder, as well as leukemia (except chronic lymphocytic leukemia), lymphomas (except Hodgkins), and multiple myeloma.

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It pays to increase your jargon power with Dr. Egghead

Committed dose

a. Amount of radiation administered at a mental health clinic.

b. A dose that chooses to remain faithful to only one other.

c. The dose of radiation considered over the entire time that the radioactive substance remains in the body (up to fifty years). When a radioactive material is inhaled it is eliminated gradually from the body and thus the dose is received over a certain period of time. The dose is therefore related to the processes by which the body eliminates the substance and also to the substance's own radioactive decay while it is in the body. The committed dose depends on the kind of radionuclide taken into the body, solubility of the chemical form that is incorporated, the particle size, and the route of incorporation into the body (inhalation, ingestion, through wounds, or absorption through the skin).

Mean lung dose

a. Opposite of nice lung dose.

b. A deliberate exposure of one's respiratory tract to ionizing radiation.

c. Average lung dose, calculated by adding the values of n number of individual lung doses, then dividing that sum by n.

Solubility

a. Being able to sell one's assets very quickly.

b. The ability to tan easily, derived from the Latin word for sun (sol).

c. The mass of a substance (called "solute") that is evenly dispersed in a medium (solvent) without the mixture (solution) becoming saturated. The more soluble a solute, the larger the mass a given amount of solvent will be able to hold without the solute precipitating out of the solution. The most common solvent is water, but organic liquids, such as carbon tetrachloride and trichloroethylene, are commonly used as solvents in metal-working and other processes.

Probability

a. How some politicians pronounce "probably."

b. The ability to probe.

c. The measure of how likely an event is.

Risk

a. Slang for a computer disk infected with a virus.

b. A family board game involving play money, fake property deeds, and little plastic hotels.

c. The expected damage to life, health, or property due to adverse external events.

Acceptable risk (as defined by the US Nuclear Regulatory Commission)

a. An activity in which a person would choose to engage despite its potential harm.

b. A euphemism for the act of voting for the best of three political candidates even though it may contribute to the victory of the worst.

c. A situation in which: (1) the risk of an immediate fatality to an average individual in the vicinity of a nuclear power plant that might result from reactor accidents should not exceed 0.1% of the sum of the immediate fatality risks that result from other accidents to which the US population is generally exposed, and (2) the risk of cancer fatalities to the population near a nuclear power plant should not exceed 0.1% of the sum of cancer fatality risks from all other causes.

Answers: c, c, c, c, c, c

ERRATA

In *Science for Democratic Action* volume 8 number 1 (November 1999), the source of the photograph of the fuel cell-powered bus on page 13 should have been identified. It is Ballard Power Systems.

Sharpen your technical skills with Dr. Egghead's
Atomic Puzzler

Gamma, the radiation sniffing dog, has gone back in time and nearly choked himself to death on uranium dust in some private factories that were hired by the U.S. Atomic Energy Commission to process natural uranium during the 1940s and 1950s. But Gamma lived to tell the tale. From the deposition of uranium on his fur, he has concluded that:

- the uranium in air the that workers were breathing was 1,200 dpm per cubic meter (a cubic meter is about 264 gallons)
- the solubility of the uranium was moderate, so that breathing in 1 bequerel of uranium dust (=60 dpm) gives a radiation dose to the lung of about 4.2 millirem. (This is called the lung dose conversion factor for inhalation – this specific number relates to uranium of a particular solubility.)

Remember:

- dpm means disintegrations per minute
- bequerel (abbreviated Bq) means disintegrations per second (dps)
- 1000 millirem (abbreviated mrem) = 1 rem

Gamma then proceeded to estimate the following:

1. The number of bequerels that a worker would inhale in an 8 hour working day, if he breathes in 1.2 cubic meters per hour.
2. The number of bequerels that a worker would breathe in over a three-year period if he worked 230 days per year.
3. The daily radiation dose to the lung.
4. The total radiation dose to the lung over the work period of 3 years.
5. Gamma also compared the lung dose to then then-prevailing standard (maximum allowable dose) of 15 rem per year. How many times the maximum allowable dose did this worker get every year?

Answer problems 1-5 so Gamma can check his work against yours.

Send us your completed puzzler via fax (1-301-270-3029), e-mail (ieer@ieer.org), or snail mail (IEER, 6935 Laurel Ave., Suite 204, Takoma Park, MD 20912 USA), postmarked by **January 16, 2001**. IEER will award a maximum of 25 prizes of $10 each to people who send in a completed puzzler (by the deadline), right or wrong. There is one $25 prize for a correct entry, to be drawn at random if more than one correct answer is submitted. International readers submitting answers will receive, in lieu of a cash prize (due to exchange rates), a copy of IEER's report, *Preliminary Partial Dose Estimates from the Processing of Nuclear Materials at Three Plants during the 1940s and 1950s,* plus supporting documents and IEER congressional testimony.

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