SCIENCE FOR DEMOCRATIC ACTION

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Health and Environmental Impacts of Nuclear Weapons Production

Assessments of the harm done by nuclear weapons plants to both workers and neighbors of the plant have generally relied on the radiation data provided by the Department of Energy (DOE) and its contractors. Detailed studies of the DOE's uranium processing plant near Fernald, Ohio, (commonly called the Fernald plant), show that DOE and contractor assessments are fundamentally flawed in numerous ways and that harm to both neighbors and workers was far greater than the DOE acknowledged. Further, preliminary indications are that the conditions that gave rise to the DOE's false reassurances of safety and environmental compliance are also likely to be present at a number of other nuclear weapons plants.

This issue of the newsletter has three articles on health and environmental impacts of nuclear weapons production:

- a case study of the Fernald plant regarding radiation exposure and health risk to its neighbors,
- a case study of worker exposure at the Fernald plant, and
- a general overview of how health and dose reconstruction studies are done

We will continue this series in future newsletters. Note that these evaluations only address exposures for the period when nuclear weapons plants were operating. They do not include risks posed by the wastes that have been created since, or from decontamination and decommissioning operations that are needed at all weapons plants and test sites.

Radioactivity in the Fernald Neighborhood

by Arjun Makhijani

The Department of Energy's Feed Materials Production Center (the Fernald plant), located near Fernald, Ohio, produced uranium metal mainly for use in plutonium production at the Savannah River Site in South Carolina and at Hanford in Washington state. The plant was operated by National Lead of Ohio (NLO) from 1951 through 1985. In 1986 it was taken over by Westinghouse. NLO had a number of subcontractors, (the Alba Craft plant in Oxford, Ohio, for example), who performed a variety of tasks such as machining of uranium metal. The Fernald plant closed in 1989, and the site now has a new name: the Fernald Environmental Restoration Management Corporation (FERMCO). It is currently being remediated by the DOE contractor, Fluor Daniel.

The Fernald plant consisted of 10 production operations (called "plants") as well as other support buildings. In these facilities, uranium in various forms, including ore concentrates, scrap, and recycled material containing uranium, were processed to

See **Neighborhood**, *page 2*

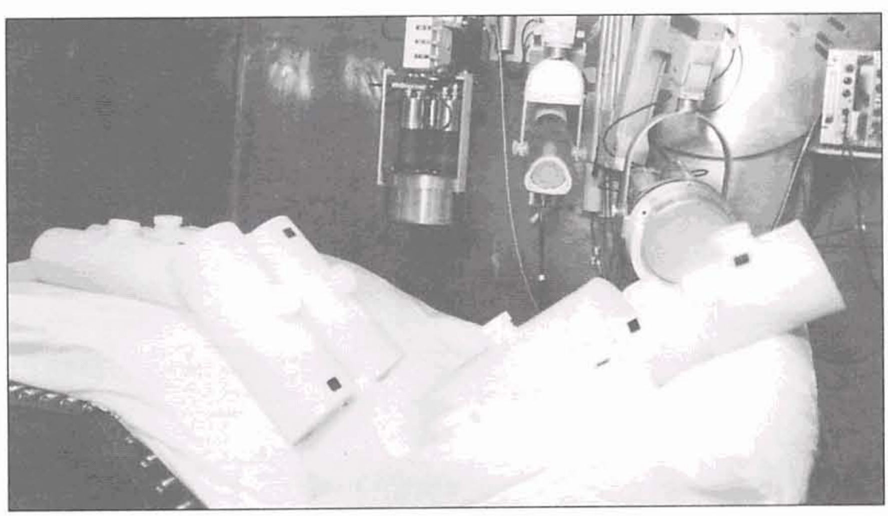


PHOTO COURTESY OF U.S. DEPT. OF ENERGY

Meet BOMAB, or "BOttle MAnnequin ABsorber Phantom." Where does this phantom get his radiant glow? He's filled with measured radioisotopes, testing to see if DOE's whole-body counters can accurately detect contamination in exposed workers. See story regarding Fernald workers on page 3.

Neighborhood, *from page 1*

produce uranium metal. The six waste pits at the site contain both radioactive and non-radioactive chemicals, including uranium isotopes, thorium-230 (a waste material from the uranium production process), thorium-232, and barium salts. In addition, the K-65 silos located on the site contain radium-226, a decay product of uranium which emits radon. Figure 1 shows a schematic diagram of uranium processing operations at Fernald.

Throughout the history of the plant's operation the DOE and its contractors consistently asserted that the offsite residents were not harmed by its operation and that exposures were within allowable limits. These assertions were challenged in a 1985 class-action lawsuit brought against NLO by neighbors of the plant. In that year, Lisa Crawford, the lead plaintiff, had discovered that the well that she and her family had been using for drinking water was contaminated with uranium. She also found out that the DOE and NLO had discovered the contamination four years earlier but had not informed her. Ms. Crawford realized her well was contaminated after she requested monitoring data in the aftermath of a highly publicized accidental uranium release from the plant in late 1984.

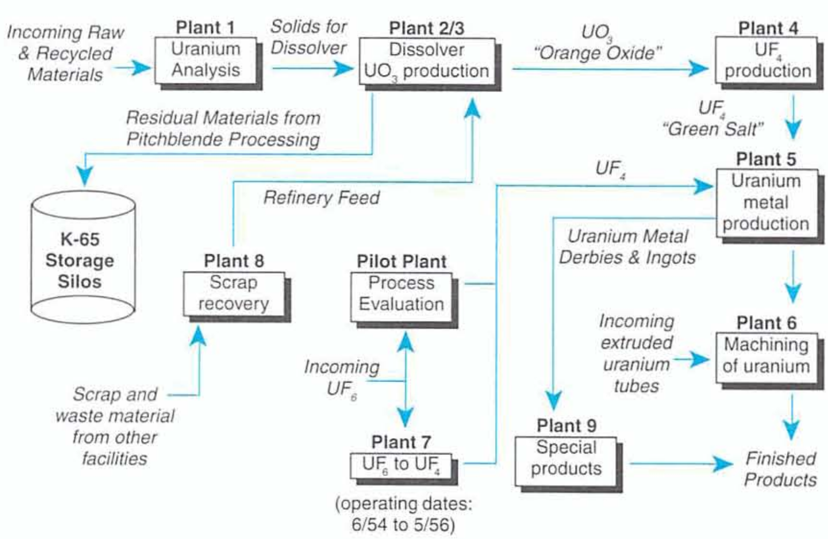
The Fernald plant had, in fact, released a number of radioactive and non-radioactive pollutants to the air and water, but DOE had very partial data for releases of some of these materials, and none at all for many others. Among the pollutants were: uranium, thorium, radon gas, radium, technetium-99, ammonia, hydrofluoric acid, fluorine, nitric acid, kerosene, chromium, and lead. The most important radioactive pollution consisted of releases of uranium and radon gas to the air. Detailed evaluations of non-radioactive pollutant releases have not yet been done and few data exist on which such evaluations can be based.

Uranium releases

Internal evaluations of the plant's operations were initiated in 1985 and they continued until the plant was shut down in 1989. In early 1985, NLO estimated that the releases of uranium

See **Neighborhood**, *page 5*

FIGURE 1: Uranium Processing at the Fernald Plant



Voillequé et al., *Fernald Dosimetry Reconstruction Project, Tasks 2 and 3: Radionuclide Source Terms and Uncertainties* (Neeses, SC: Radiological Assessments Corporation, 1995), p. B-2

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Fernald Workers' Radiation Exposure[1]

by Arjun Makhijani

Like workers at other nuclear weapons plants, workers at the Feed Materials Production Center near Fernald, Ohio (commonly called the Fernald plant) were routinely assured that they were being protected and that, in general, their exposures to radiation were under the maximum legal allowable limits. These assurances, given by the Department of Energy and its contractors, have been based on records of worker doses. A careful analysis of Fernald plant data indicates that these claims are incorrect.

Three categories of radiation data were collected for workers at Fernald:

1. Direct measurements of worker external radiation doses. (Collected using film badges worn by workers, for instance.)
2. Measurements of radioactive materials inside workers' bodies. The methods included analyzing urine samples and measuring gamma radiation emanating from radionuclides trapped in workers' lungs (called "lung counting").
3. Measurements of radioactivity in the workplace environment. These are made by sampling the air in the general area where the work is done and in the "breathing zones" close to workers' faces.

The third category is not a direct measurement of dose but provides an indication of working conditions leading to exposure. Standards are set limiting the concentrations of radionuclides in the air so that the radiation doses to workers might be kept below allowable maximum limits.

IEER performed an independent assessment of radiation exposure to workers as part of a class action lawsuit filed by the plant's workers against National Lead of Ohio, DOE's contractor until 1985.

Working conditions at Fernald were typified by high air concentrations of uranium which often exceeded allowable limits.

Working conditions at the Fernald uranium processing plant near Cincinnati were appalling, especially in the 1950s and early 1960s. They were typified by high air concentrations of uranium in many areas of the plant which often exceeded the Maximum Allowable Concentration (MAC) by tens of times, hundreds of times, and even thousands of times. One 1960 plant document lists the air dust concentration in the breathing zone of an operator cleaning under a burnout conveyor as 97,000 times the MAC.[2]

Work procedures also contributed to the high air dust concentrations in the plants. For example, a 1968 plant document described the procedure for emptying a dust collector:

> The dust is emptied from the collector on the second floor and falls down a chute to a nonventilated drum on the first floor. The operator on the first floor signals to the operator on the second floor that the drum is full by pounding on a metal beam with a hammer. Because of the noisy conditions prevalent in the plant, the second floor operator does not always hear the signal. This results in an overflowing drum of dusty material causing a cloud of radioactive dust to fill the area which also goes up the stairwell into the second floor.[3]

In many plant situations, proper respiratory protection to prevent inhalation of this radioactive dust was not available. IEER's review revealed that workers were not properly trained regarding when to use respirators, and consequently did not wear them in many situations when air dust concentrations were high. In fact, in the early years of plant operation, workers were not even issued respirators as long as air concentrations of radioactivity remained less than ten times the MAC. In addition, a significant number of respirators cleaned for reissue remained contaminated. In some cases, the insides of respirators were contaminated. A plant doctor on an impromptu plant tour characterized some of the respirators as "the epitome of filth."[4]

Internal exposure estimates

Fernald worker dose records are highly misleading because they contain no mention of radiation doses due to the uranium that workers inhaled which then irradiated their bodies, notably their lungs. These doses were not included in worker records despite the urine sampling that was done throughout the plant's history and the lung counting that was done after 1968. Thus, when workers requested dose records, they were only given information on external doses (see below).

The urinalysis program used at the Fernald plant had several shortcomings. Twenty-four hour urine samples provide a good indication of how much uranium is in a person's

See **Workers**, *page 4*

1 This article is based on the following IEER report: Bernd Franke and Kevin Gurney, *Estimates of Lung Burdens for Workers at the Feed Materials Production Center*, Fernald, Ohio. (Takoma Park: Institute for Energy and Environmental Research, 1994).

2 Memo from F.J. Klein to R.H. Starkey, "Subject: Cleaning Under Burnout Oxide Conveyors—Plant 5," National Lead Company of Ohio, December 7, 1960, p. 2

3 Memo from C. W. Zimber to Leininger, "Subject: Employing Rotex Dust Collector No. 6018," National Lead Company of Ohio September 10, 1968, p. 1

4 Memo from J.A. Quigley to C. Dees, National Lead Company of Ohio, October 12, 1953, p. 3

Workers, *from page 3*

body. However, 24-hour samples were not regularly taken at Fernald. Instead, the program relied on "Monday morning" single samples. It was not recorded which workers drank coffee and therefore possibly diluted their urine samples.

Another problem with the program was the infrequency of the samples, especially in the early years of plant operation. After uranium is inhaled, it is excreted from the body in diminishing amounts over a period of time. The amount of time it takes for an inhaled material to be excreted depends on its chemical form. When samples are taken only every few months or even just once a year, as they were in early years of Fernald operations, it is possible for large exposures to go undetected. As a result, infrequent monitoring makes it impossible to accurately determine the magnitude of the exposure.

IEER developed a method to estimate radiation doses to the lung from urine data by calibrating that data to the direct lung count data that was available after 1968. The concept was developed by Bernd Franke in collaboration with an IEER consultant, Mike Thorne, who also created the mathematical formulation of the method. Kevin Gurney wrote the computer program to manage the enormous volume of data and run it through the mathematical model.

IEER's conclusions were that doses due to uranium inhaled by workers were above then-allowable limits (15 rem per year) in more than fifty percent of the cases in every year but one between 1952 and 1962. Significant proportions of workers continued to suffer overexposure after that. A chart of the proportion of workers exposed to more than the allowable limits due to lung burdens of uranium is shown below.

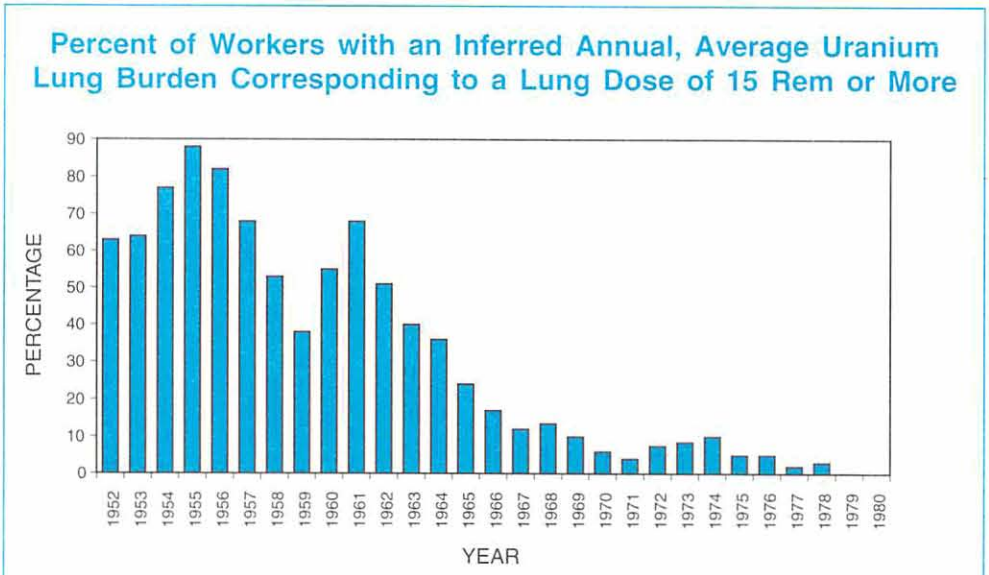
The presence of large and variable amounts of radon during lung counting appears to have created measurement errors in the records of many workers. Fernald's procedure for lung counting included subtraction of ambient external radiation readings, including radiation from radon and its decay products. However, differences in radon levels between the time that background measurements were taken and the time that the lung counting was done could mean that the actual lung burden may have been higher or lower than reported. Such fluctuations would tend to cancel out in population dose estimates, such as the ones that IEER made, which are presented in this article. Further, the result of subtracting high background readings resulted in many negative estimates of lung burden, which must necessarily be rejected as false, as well as a large number of low values below 5 milligrams, which IEER considered to be too unreliable to use. IEER's work took these statistical problems in lung count data into account by omitting all lung burden estimates below 5 milligrams. Worker doses from radon and its decay products would be in addition to those from uranium lung burdens discussed above. These remain to be estimated.

External exposures

In general, external exposures were also not carefully monitored at the Fernald plant. For instance, there was a high potential for some workers to experience significant external exposures, especially to their hands. Hand exposures were not calculated at all until 1970, when some workers began to wear wrist dosimeters. In many cases, external dose records indicate readings of zero. Without further records and investigation, its is not possible to assess whether these meant that there was no significant reading above background, whether there were other problems with the data, or even whether some of the data were fabricated (as was the case with some of the uranium release data).

One example of the problems of the external radiation dose record dates from the early 1980s, when thermo-luminiscent dosimeters (TLDs) were introduced in place of film badges. Contamination of the TLDs by uranium prevented

See **Workers**, *page 5*



Source: B. Franke and K.R. Gurney, "Estimates of Lung Burdens for Workers at the Feed Materials Production Center, Fernald, Ohio," (Takoma Park: IEER, 1994), p.8

Workers, *from page 4*

accurate readings and so a "correction factor' was introduced to the raw dose reading. However, NLO used the same correction factor for all workers regardless of the working conditions and duration of exposure during the month. The result was that some workers were, after "correction," estimated to have negative radiation doses. These records were apparently referred to the Health Physics section for further action, but it is still not known what was done with the estimates. One possible outcome is that a zero was entered into the dose record.

Concluding observations

Just after the presentation of IEER's findings in court in 1994, the DOE settled the lawsuit on behalf of NLO, providing workers with lifetime medical monitoring, and other benefits. But the DOE has still not acknowledged that worker dose records are severely flawed and incomplete. So far as IEER has been able to determine, DOE and its contractors still routinely fail to include estimates of internal doses in worker dose records. Therefore, in the nuclear weapons plants were workers have been exposed to conditions that might cause internal exposures, the dose records would be systematically incomplete and underestimate worker exposure.

In many epidemiological studies, the assumption that film badge data are a useful proxy for actual total exposure may not be valid. Inaccurate external dose records, lack of dose records for many high internal exposures, and the highly variable conditions of uranium dust to which workers were exposed make film badge data suspect. Finally, worker records contain almost no information about exposures to non-radioactive toxic materials, such as acids, metals, and solvents, which are routinely used in large quantities in weapons plants.

Nuclear weapons production in the U.S. has involved about 600,000 workers, many of whom worked in uranium and plutonium processing facilities, where there were risks of internal exposures. Identifying those most at risk by estimating internal exposures is a matter of elementary justice and health protection. Efforts must also begin to find groups at high risk due to chemical exposure. Such evaluations can lead to identifying high risk worker groups. Medical monitoring may provide early detection for such workers who may otherwise not suspect that they are at risk until it is too late for them.

Neighborhood, *from page 2*

over the 34-year period from 1951 (when parts of the plant were started up) to 1984 were about 200,000 pounds. The NLO estimate was increased to 300,000 pounds by 1987 after inclusion of estimates of some of the most serious emissions during the 1950s. There were a number of evident deficiencies in these official estimates. Among the more egregious errors were:[1]

- An assumption that releases were zero when there were no data.
- An assumption that scrubbers designed to remove uranium from highly acidic exhaust always operated within manufacturer specified efficiency, despite internal plant data to the contrary.
- The use of an incorrect formula to calculate scrubber releases under conditions of variable efficiency.
- Inclusion of fabricated data that showed that releases were zero at locations and times when no measurements were being made.
- A failure to account for poor dust collector efficiency and frequent problems with dust collector equipment.
- Poor industrial hygiene practices, such as leaving radioactive materials to dry in trays in doorways, and operating equipment that was in poor condition.

IEER was retained in 1987 by the law firm of Waite, Schneider, Bayless, and Chesley to do some of the expert studies for the class action lawsuit. IEER's review of the historical documents showed that plant officials were aware of many of these deficiencies. For instance, the use of the incorrect formula for scrubber releases was pointed out in a 1971 memo by a plant engineer, who called it "inherently deceptive" because it resulted in release estimates that grew smaller as the scrubber efficiency deteriorated — the opposite of the truth. Figure 2 (next page) shows the actual releases of uranium compared to the NLO estimates for an example in which uranium in the air going into the scrubber was 100 kilograms.

A 1955 document pointed to early problems with uranium release estimates: "We realize in most instances that these estimates [for stack losses from plants 4 and 7] are far below your true stack losses."[2] Plant 7 was shut down in 1956 due to operational

See **Neighborhood**, *page 6*

1 For details see Arjun Makhijani, *Release Estimates of Radioactive and Non-Radioactive Materials to the Environment by the Feed Materials Production Center 1951-85*, (Takoma Park: Institute for Energy and Environmental Research, 1988); and Arjun Makhijani and Bernd Franke, *Addendum to the Report 'Release Estimates of Radioactive and Non-Radioactive Materials to the Environment by the Feed Materials Production Center 1951-85,'* (Takoma Park: Institute for Energy and Environmental Research, 1989).

2 R.H. Starkey, memorandum to A. Meredith, "Estimated Stack Losses for December [1955]", National Lead of Ohio, 10 January 1956.

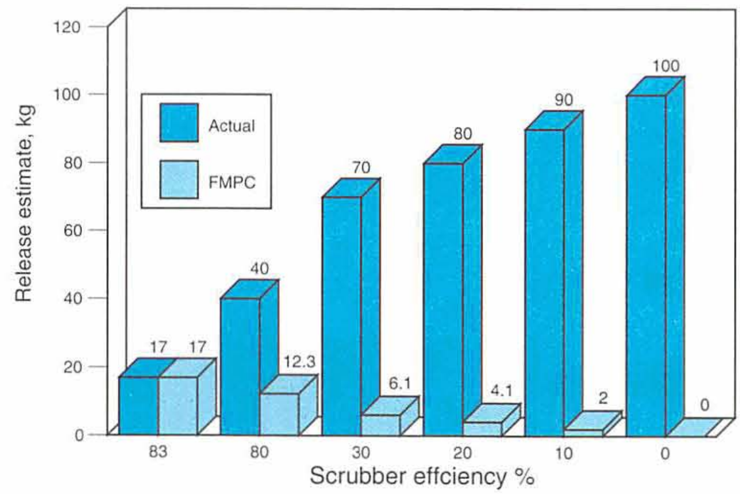
Neighborhood, *from page 5*

problems. Plant 4 continued to operate until Fernald shut down, and the problem of corrosion of some dust collector equipment by acidic exhaust continued for decades.

The following example also illustrates the poor industrial hygiene practices at the plant:

> Probably the worst housekeeping problem in the facility is the Ball Mill. The equipment leaks excessively at practically every joint. All horizontal surfaces have a thick covering of dust . . . . Since the ventilation is inadequate and there is no proper enclosure, a bucket was placed under the largest leak to help contain the spilled dust.[3]

FIGURE 2: Variation of Efficiency of Airborne Uranium Releases from FMPC Scrubbers for an Assumed Inlet Uranium Loading of 100 Kg*



Source: Makhijani and Franke, 1989

* This is the amount of uranium in the gas going into the scrubber.

Such discharges of radioactive materials were not measured and were disregarded in the official release estimates and public reassurances.

Under the glare of public scrutiny and the class-action lawsuit, Westinghouse, the new contractor (and not named as a defendant), revised the official figures for the 1951–1985 period again and stated that the releases were in the range of 395,000 to 552,000 pounds. While these estimates were higher, they still disregarded many known facts. For instance, unmeasured losses over the plant's entire 37-year history were estimated at about 700 pounds, while an internal plant document stated that *unmeasured losses were more than that in a single month.*

Radon exposures due to huge releases of radon gas from the K-65 silos were the main source of measured radiation risk to the population.

During work on the lawsuit in 1988 and 1989, IEER focused its work on estimating uranium losses, since that was the main material processed and data on other materials released to the air were scarce or non-existent. We re-estimated losses from several important sources, notably scrubbers in the scrap recovery plant (Plant 8). We also made an estimate of uranium releases based on measurements of uranium in the soil around the plant. Our work was admittedly very preliminary, mainly since IEER was unable to obtain most of the crucial documents regarding plant operation and pollution control equipment efficiencies. Moreover, the quality of the data that we had was poor and some of it was internally inconsistent.

Still, we concluded that the official estimates were almost certainly wrong, that the releases were higher than the upper end of the official estimate of 552,000 pounds, and that uranium air concentration standards had been violated on at least some occasions. IEER estimated that uranium releases were in the range of 600,000 to 3 million pounds, with a middle estimate of 900,000 pounds. IEER also recommended further detailed work, since these estimates were of a very preliminary nature.

The DOE, which defended the lawsuit on behalf of the contractor, NLO, settled the suit for $78 million in mid-1989, but admitted no wrongdoing, or even any technical problems in its own or its contractors' work. (Under the terms of its contract with the government, NLO was immune from all liability, including that arising from negligence or violations of regulations.)

But the Centers for Disease Control and Prevention (CDC) initiated an independent study of the radiation doses to the public arising from Fernald's operation.[4] The final draft report of that $4 million study, prepared by Radiological Assessments

See **Neighborhood**, *page 7*

3 K.N. Ross to J.E. Beckelheimer, "Thorium Metal Production Housekeeping," National Lead of Ohio, 8 June 1970.

4 Unfortunately, the CDC did not ask for an evaluation of exposures to non-radioactive materials in its request for proposals.

5 RAC prepared a number of draft and final reports leading up to the draft 1996 report. The ones most relevant to this article are: Voillequé et al., *Fernald Dosimetry Reconstruction Project: Tasks 2 and 3: Radionuclide Source Terms and Uncertainties*, Draft Report (Neeses, South Carolina: Radiological Assessments Coporation, 1993); and Killough et al., *Fernald Dosimetry Reconstruction Project: Task 6: Radiation Doses and Risks to Residents from FMPC Operations from 1951-1988*, Draft Report (Neeses, South Carolina: Radiological Assessments Coporation, 1996).

Neighborhood, *from page 6*

Corporation (RAC), was released in August 1996.[5] It corroborated IEER's critique of the official estimates of uranium releases to the air and greatly narrowed the range, estimating it to be 660,000 to 880,000 pounds, with a best estimate of 750,000 pounds.

The table below summarizes the various estimates for uranium releases from Fernald. Only the best estimate, or middle estimate, made the by source is shown.

The K-65 silos at Fernald were used to store radium-bearing wastes which emitted large amounts of radon gas, exposing both residents and workers to radiation.

Radon releases

The RAC study also estimated releases of other radioactive materials. The most important was radon-222 releases from the K-65 silos used for storing high radium-content waste from Belgian Congo ores. The radium-226 in the silos decayed into radon gas (as it continues to do). The deteriorating structures and poor storage conditions and practices (which were partly rectified in 1979 and then again in the 1990s) led to huge radon releases from the silos, notably in the period from 1953 to 1979. There were a few environmental measurements of radon made in 1979. IEER's preliminary work, which was focused on uranium releases and plant compliance with regulations, missed this significant source term. RAC's estimate of the radon source term for the period up to 1979 is several thousand curies per year. The cumulative radon source term estimate is 170,000 curies for the 1951–1988 period.

Radiation doses

While official DOE and contractor reports claimed that no harm had been done and that exposures to the neighbors of the plant were well under allowable limits, IEER's work found that hypothetical maximally exposed individuals near the site boundary were likely to have been exposed above allowable limits, especially during accidents. Because IEER lacked the documents regarding pollution control efficiencies, particle sizes, and chemical composition of the pollutants, as well as other factors, a reliable detailed evaluation of population risk could not be made. Moreover, the main goal of IEER's work was compliance assessment rather than population risk assessment.

In August 1996, the Radiological Assessments Corporation made public its estimates of exposures to various hypothetical individuals in scenarios designed to typify living and working patterns of people in the area. The findings were that radon exposures due to huge releases of radon gas from the K-65 silos were the main source of increased radiation risk to the population, especially for people who lived there prior to 1980.

See **Neighborhood**, *page 12*

SUMMARY OF ESTIMATES OF URANIUM RELEASES

Institution	Uranium releases to the air, pounds	Uranium releases to surface water, pounds
NLO, early 1985	200,000	160,000
Westinghouse 1987	300,000	160,000
Westinghouse, 1989	400,000	160,000
IEER 1989	900,000	not made
RAC 1993	1,000,000	180,000
RAC 1996	750,000	180,000

Sources: For discussion of all release estimates and detailed references, except RAC 1993 and RAC 1996, see Makhijani 1988 and Makhijani and Franke 1989. Note that RAC published draft estimates in 1993, which it revised in 1995 and again (slightly) in 1996.

Note: Figures are rounded to one or two significant digits, as indicated.

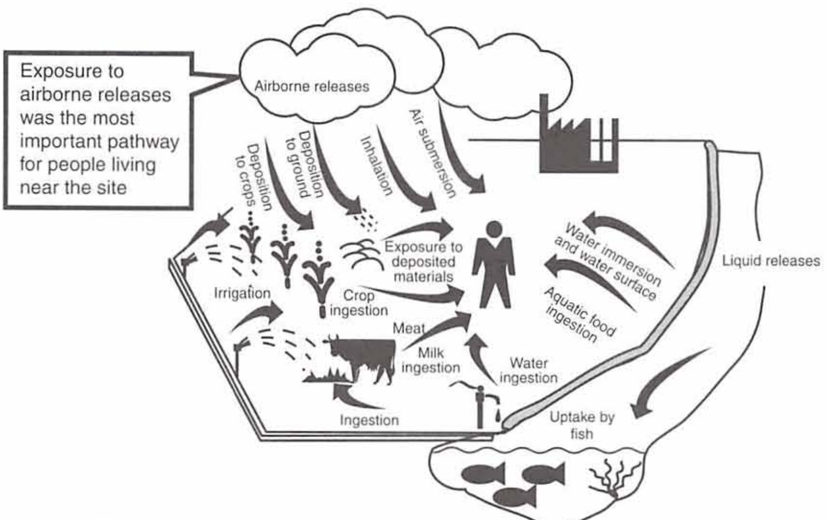
A CENTERFOLD FOR TECHNO-WEENIES

Radiation Exposure at Fernald: The Dirty Details

This centerfold examines conditions at the Fernald plant which led to off-site releases of uranium and other pollutants to neighbors of the plant. As is evident from internal memos by plant personnel (some of which are quoted here), maintenance of pollution-control devices was substandard, poor record-keeping on uranium releases was common, and large off-site releases were known to have occurred.

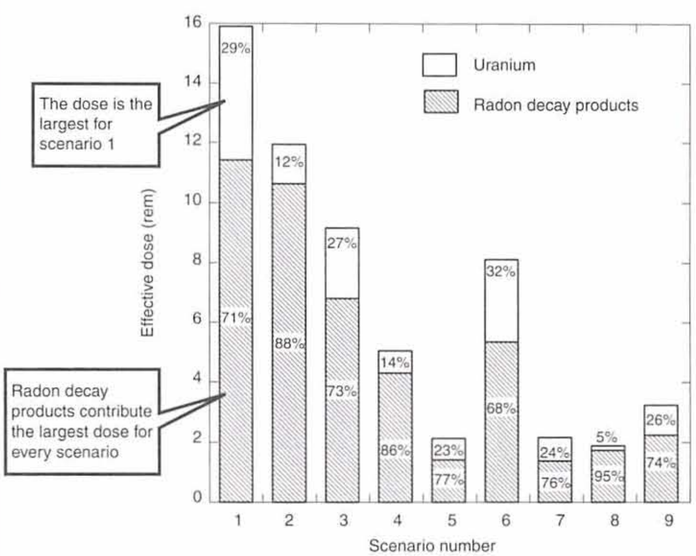
Airborne and liquid releases resulted in exposure to neighbors of the plant through inhalation, uptake through crops, ingestion of milk from livestock grazing on contaminated grass, ingestion of fish or drinking water from streams and rivers contaminated with radioactive releases, and through other pathways. Inhalation was by far the most important pathway. An analysis of inhalation doses to hypothetical populations resulting from these exposures appears in the chart below. Radon from the decay of radium-226 in the K-65 silos located on the site was the cause of the largest off-site doses. Inhalation of uranium dust was the next most important.

Environmental Pathways by which People were Exposed to Radioactive Materials Released from the Fernald Site



Source: RAC 1996 Summary, p. 4.

Cumulative Effective Dose Contributions from Uranium and Radon Decay Products



Scenarios:

1. realistic maximum inhalation exposure (within 1 mi. NE of site)
2. resident close to K-65 silos (1.2 mi. W of site)
3. ingestion of uranium-contaminated well water (within 1.2 mi. S of site)
4. realistic average inhalation exposure from 1960-1988 (2.4 mi. NE of site)
5. realistic low exposure to individual working outside area (5 mi. N of site)
6. garden irrigated with Great Miami River water (1.9 mi. SE of site)
7. garden irrigated with Great Miami River water further from site (6.2 mi. S of site)
8. child exposed from 1975 to 1988 (2.5 mi. NE of site)
9. child attending school near plant, (2.5 NE of site), living further away (6.2 mi. N)

Source: RAC 1996, p. 84.

"

Scrubber stack losses are now calculated by weighing and analyzing the liquor from the scrubber each time it is drained . . . . This method of calculation can be in error by a considerable amount because of changes in operating conditions. The figures obtained are inherently deceptive, because a scrubber operating at a very low efficiency for a month would collect little uranium, thus showing a low loss. It were then repaired and operated carefully for the next month. the calculations would show a high loss, provided the process conditions did not change.

"

— "Investigation of Methods of Measuring and Reporting Uranium Losses to the Atmosphere." Memo to A.F. Pennak from E.W. Randle. National Lead Co. of Ohio, 3/12/71.

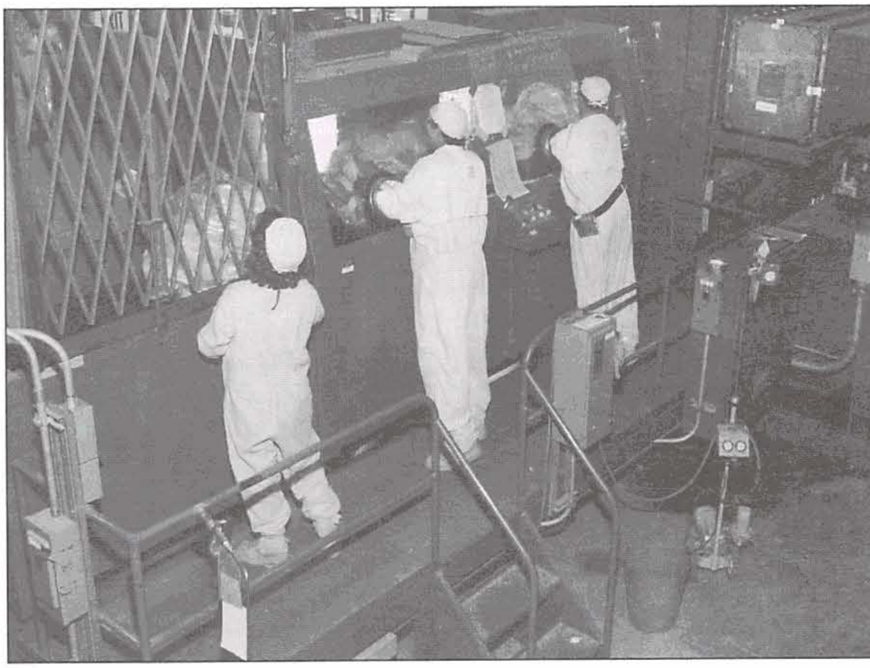


PHOTO COURTESY OF U.S. DEPT. OF ENERGY

Workers at Fernald's low-level radioactive waste super compactor.

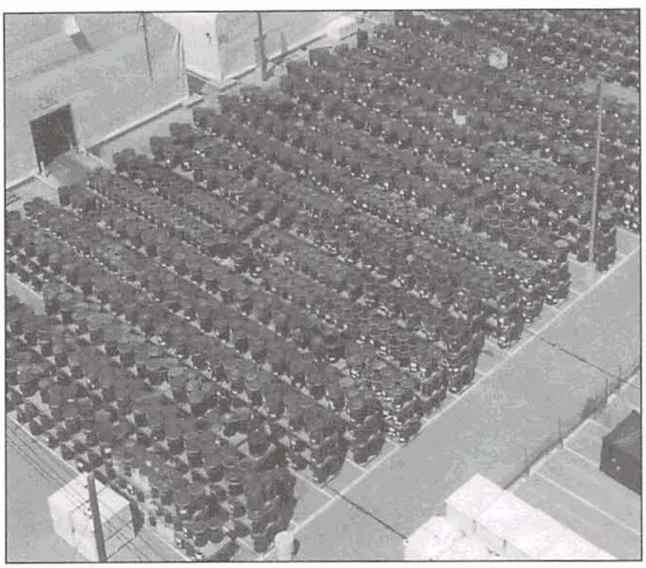


PHOTO COURTESY OF U.S. DEPT. OF ENERGY

Low-level radioactive waste stored outdoors in 55-gallon drums at Fernald.

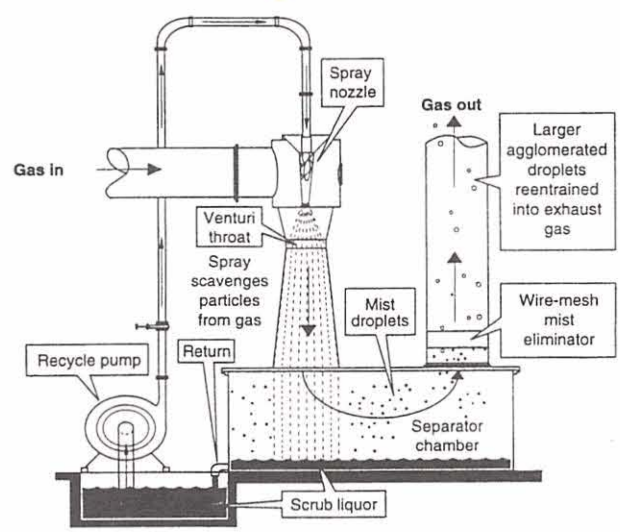
"

Between March 15, 1978 and June 14, 1978 "a significant dust loss occurred in the Plant 9 dust collector serving the NPR furnace and the crucible burnout area." The cause of the loss was "extensive damage to the blow ring assembly and two bags pulled loose from their upper mountings."

"

— W.J. Adams, "Incident Report Covering the Dust Loss in the Plant 9 G-901-1034 dust collector," memorandum to S.F. Audia, July 14, 1978.

Schematic Diagram of a Scrubber



Plant 8 scrubbers were the largest source of discharges of uranium at the Fernald Plant.

Source: RAC 1996, p.15.

"

The 1955 discharge of 15.4 kg U . . . for Plant 1 is the total measured from the start of sampling in September through December. No production records are available which would provide a basis for extrapolating the four-month measured loss to an estimate for the entire year. Therefore, the discharge measured in September-December is assumed to be the discharge for the entire year.

"

— MW Boback: *History of FMPC Radionuclide Discharges*, Nov. 1985.

Dose Reconstruction and Epidemiological Studies

by Arjun Makhijani

The basic objective of health studies is to determine the nature and degree of harm done to the health of exposed populations. Broadly speaking, there are two different types of studies that can be done, though there are variants within each category:

1. **Epidemiological studies**. They analyze disease patterns in exposed versus unexposed populations.
2. **Dose reconstruction studies**. These attempt to determine the risk of disease by estimating the exposure to a disease-producing agent like radiation.

Epidemiological studies (or "epi" studies for short) may be done without reference to dose reconstruction studies by simply examining disease patterns in populations working in or living near facilities. Epi studies may also be done subsequent to dose reconstruction studies. Dose reconstruction can help epi studies group together exposed populations more precisely and thus reveal disease patterns that may remain hidden without such dose data.

Dose reconstruction studies are not dependent on epi studies. However, since there are often great uncertainties in exposure estimates, dose reconstruction studies by themselves sometimes do not settle the issue of whether the exposures resulted in demonstrable harm to the exposed populations. Sometimes it may be desirable to do an epi study after a dose reconstruction study. This is a difficult decision that depends on a judgment about the prospects of determining with reasonable certainty whether or not one or more of the exposed groups have suffered increased risk of one or more diseases.

There are a number of basic complications that arise in doing both epi and dose reconstruction studies about DOE facilities:

- While some data on the principal radionuclides (such as uranium or plutonium isotopes) generally exist, there are often no data on non-radioactive toxic materials, nor on many radioactive materials that were used, processed, or incidentally present.
- Populations are often exposed to more than one disease-producing agent, and the synergistic effects of these agents are essentially unknown. Sometimes people are exposed to the same disease producing agent from multiple sources.
- Non-cancer effects of toxic materials are, in many cases, only now beginning to be understood, and are all too often ignored due to lack of knowledge.
- For a variety of reasons, there are usually large uncertainties about the effects of low levels of exposure.

Studies of off-site populations are generally more difficult than those of workers because there are no direct measurements of doses for such populations. Worker doses can be estimated from a variety of data such as film badge readings, urinalyses, and direct measurements of body burdens of radioactive materials via whole-body or lung counting instruments. For off-site populations, such direct measurement data generally do not exist. Therefore, dose reconstruction studies for off-site populations must begin with examination of data regarding releases of harmful substances ("source term" data) as well as measurement of these substances in the environment ("environmental monitoring" data). Source term and environmental monitoring data are complementary and can provide checks on each other. They must be coupled with knowledge of the behavior of the harmful substances in the environment and the manner in which each pollutant reaches people ("pathway analysis").

As if the problems of doing dose reconstruction and epi studies were not complex enough, studies involving DOE weapons plants are typically plagued by additional complications. The lack of sufficient data, poor quality of data, poor record keeping practices, and even data fabrication in some cases, create severe complications. Classification of and restricted access to data frequently pose additional challenges.

What should community groups look for in health studies? And how can you tell what kinds of studies should be done? Sometimes the question is even more basic: should the studies be done at all or would the money be better invested in medical monitoring, for instance?

There are no simple, general answers to these questions, but there are some guidelines for determining whether the studies are being carried out in a scientifically sound manner.

Determining Exposures

It is essential that exposure estimates be based on the raw data, whether this is exposure data for workers, or some combination of environmental monitoring data and source term data for off-site populations. The expression "source-term" means the amount of a harmful substance released by a facility. The quality of the data and its adequacy in establishing meaningful estimates must be carefully assessed. For instance, until about 1970, it was

See **Doses**, *page 11*

Doses, *from page 10*

not uncommon to monitor the air at specific locations off-site for only an hour or even less each month. Such monitoring would not be able to detect process releases that are expected to occur only over short periods of time, or accidental releases that by their nature usually occur over short periods. If, moreover, source term data are of poor quality, as they typically were in DOE installations that IEER has studied, then estimation of doses becomes very difficult. (See the accompanying article on the neighbors of the Fernald plant.)

In general, individual or small population doses are far more difficult to estimate than large population doses. In such circumstances it is less difficult and sometimes more pertinent to examine whether then-prevailing or current standards for exposure to radioactive or non-radioactive toxic materials may have been violated. For instance, the average air concentration at the plant boundary for uranium or some other radioactive material might be determined and compared to regulations.

In assessing doses to off-site populations, one should:

1. Examine environmental monitoring data for air, water, and soil as well as source term data over time.
2. Compare environmental monitoring data and derived environmental concentrations (from models) to then-prevailing and current environmental standards. These standards are derived from dose limits, so that it is possible to infer hypothetical doses to a person exposed to such concentrations by comparing measurements with the regulatory concentration limits.
3. Evaluate data for accuracy and completeness:
   - Have all the relevant radioactive materials been measured?
   - Have all the relevant non-radioactive materials been considered?
   - If data are not available for some materials, has there been an attempt to infer the potential magnitudes of the releases or potential air concentrations from other data? If not, has there been some way to assess the importance of the material in question to the exposure?
4. Determine whether all exposure pathways have been considered and the relative importance of each has been estimated. The pathways include direct exposure via air and drinking water, exposure in various ways via contaminated soil, exposure via contaminated food, and exposure after concentration in the food chain (as happens, for instance, with iodine-131 or with some organic, non-radioactive pollutants).
5. Examine whether non-cancer and synergistic effects have been analyzed or even mentioned.
6. Examine whether the accidental releases from the plant were accounted for and if their effects on maximum exposure been considered.
7. Compare the risk factors that are used for exposure to low-levels of radiation or to non-radioactive toxic materials with the regulatory literature.
8. Look for a discussion of uncertainties both ways: that is, ways in which doses and risks could be higher and lower than those calculated and whether these uncertainties have been quantified.

It is essential that exposure estimates be based on raw data.

A community is often faced with a question of whether an epi study should be done following a dose reconstruction study. This question cannot be answered in general, except in the case of "small" populations, where there are not enough people for a statistically sound study to be carried out. An epi study is not unlike an opinion poll, only it is a poll of the body's functioning. Since there are considerable differences in the way different people respond to disease-producing agents, there must be sufficient numbers of people in an epi study to determine with a reasonable certainty if there is an increased risk.

Second, an epi study is not likely to yield a statistically significant result if there are great uncertainties in the estimates of doses in the exposed populations. If the exposed people cannot be grouped into appropriate dose ranges, then estimation of increase in risk becomes very difficult. This is especially the case if a small proportion of highly exposed people are mixed in with a far larger number of people with relatively low exposure. Studies must structured so as to provide reasonable assurance that exposure to materials for which data do not exist will not vitiate their results.

IEER's experience studying off-site populations by performing dose reconstruction studies indicates that at least for the U.S. nuclear weapons complex, the environmental monitoring records and source term estimates are often too poor to yield satisfactory estimates of doses to exposed populations. It is quite possible to estimate compliance with regulations, but such estimates cannot be

See **Doses**, *page 16*

Neighborhood, *from page 7*

It is noteworthy that radon was not even evaluated as a source of pollution caused by the Fernald plant until the series of RAC studies in the 1990s. Radon probably also caused significant exposures to workers at the plant, a matter that remains to be addressed (see accompanying article on workers).

Doses due to uranium exposure by inhalation were the next most important factor, with other radioactive materials and pathways being judged relatively low. The table, "Comparison of Cumulative Effective Dose Contributions from Uranium Exposure Mode and Radon Decay Products" in the centerfold shows the exposures for various scenarios as calculated by RAC. The increased risks of cancer—especially lung cancer—are substantial in all cases. In many cases, they are comparable to the risks from smoking.

Concluding observations

The history of studies of exposure to Fernald's neighbors show that the reassurances of the DOE and its contractors—that the nuclear weapons plants were operated safely and in compliance with applicable health and safety laws and regulations—should not be taken at face value. The work of IEER, RAC, and others at other nuclear weapons plants indicates that DOE and contractor estimates of releases of radioactive materials are generally underestimates, and are riddled with faulty data, poor science, and calculational mistakes and inaccuracies.

Despite the settling of the lawsuit against the contractor of Fernald for $78 million of taxpayer money, concerns remain. Many studies have repudiated DOE and contractor work, showing elementary scientific flaws in it, but neither the DOE nor any of its contractors have discussed what went wrong, much less how the recurrence of scientifically dubious and misleading studies might be prevented. Many issues, such as the exposure of residents to non-radioactive pollutants and non-compliance of the plant with environmental regulations, remain unaddressed.

The DOE and its contractors need to put their work in the perspective of the findings of the independent Fernald studies. That should be the first in a series of steps they take to create a system that would produce sound environmental science.

SELECTED PUBLICATIONS

Prices include shipping and handling within the U.S.

IEER Books

***Nuclear Wastelands:** A Global Guide to Nuclear Weapons Production and Its Health and Environmental Effects*
MIT Press, 1995 • Hardbound, 666 pages • List price: $55 • SDA readers price: $40

***Fissile Materials in a Glass Darkly** (now available in Russian!)*
IEER Press, 1995 • Paperback, 126 pages • Price: $12

***Mending the Ozone Hole**: Science, Technology, and Policy*
MIT Press, 1995 • Hardbound, 355 pages • List price: $35 • SDA readers price: $27.50

High-Level Dollars, Low-Level Sense
Apex Press, 1992 • Paperback, 138 pages • Price: $15

IEER Reports

The Nuclear Safety Smokescreen	$10
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Risky Relapse into Reprocessing	$10
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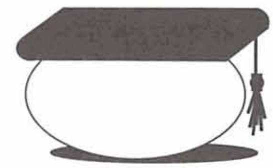
It Pays to Increase Your Jargon Power



by Dr. Egghead

1. Epi Studies

a. The scientific examination of epigrams and other witty sayings.

b. The teachings of the Episcopal Church.

c. A very narrow subfield of seismology which concentrates on predicting within a few yards where the epicenter of earthquakes will be.

d. Short for "Epidemiological Studies." Epi studies analyze disease patterns in exposed versus unexposed populations.

2. Thermoluminiscent Dosimeter (TLD)

a. The latest Seattle grunge band.

b. A thermos bottle with a light meter that indicates when you've had too much coffee.

c. L.L. Bean's line of neon long johns.

d. A device to measure external gamma radiation which is used for personnel and environmental monitoring and which can be re-used after the dose is read.

3. Radon

a. A new brand of designer sunglasses.

b. The little-known singing/comedy group started by Ray Charles and Don Rickles.

c. A corrupted form of "Raid On," used during Viking days to give the signal to the conquering troups to attack villages.

d. An invisible, ordorless radioactive gas which is the result of the radioactive decay of radium-226. Wastes from uranium production from ore contain radium-226 and hence emit radon-222 gas.

4. Dose Limits

a. The opposite of "dese limits."

b. What you've reached when you just said no.

c. The maximum amount of napping an individual can tolerate.

d. Regulatory limit set on the amount of radiation that an individual may receive from artificial sources (excluding medical devices). Worker radiation exposure limits are higher than general population limits.

5. Film Badge

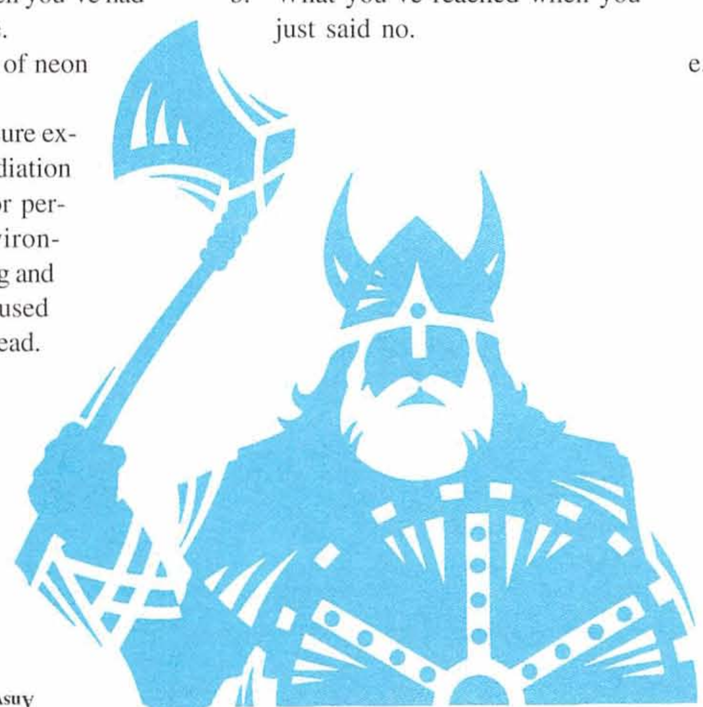
a. What one receives after surviving a marathon film festival.

b. What you win for having the most impressive bathtub ring.

c. What censors wear when they're monitoring the entertainment industry.

d. What someone wears when they're not a real cop, but they play one on TV.

e. A device containing film strips which are sensitive to gamma and beta radiation, and which are mounted on a holder and worn by workers to measure the external radiation dose they receive.



"Raid On!"

Answers: 1) d; 2) d; 3) d; 4) d; 5) e.

"Dear Arjun"

A justifiably confused reader from Los Angeles, CA writes:

Dear Arjun,

What is this new unit, the "Selvin," which crops up in the literature nowadays?

—JCW in Los Angeles

Dear JCW,

The term was a new one to me, but I see that it was included in two letters to the editor in the 3 May 1996 issue of *Science* magazine:

> The annual dose increases by about 50 **micro Selvins** for each 1000-foot increase in the altitude . . .

And:

> . . . most of the excess cancer deaths . . . pertain to survivors with very high doses, that is, doses greater than 1 **Selvin (Sv)** . . .

After some thought on this new term I wondered if someone had confused "sieverts" and "kelvin" to erroneously create the new term, "selvins." Sure enough, two weeks after the letters were printed, *Science* ran a correction, admitting the error was introduced during editing.

But as long as we're on the subject, you might ask:

Dear Arjun,

Just what is a *sievert*, and where can I get one?

Many years ago, before the invention of Dramamine, sea sickness sufferers endured nightmarish journeys when their commutes required boat travel. At first the problem was not well understood. It was thought that they simply suffered from vertigo which happened to strike at inopportune times during ocean travel. Eventually the term "Sievert" was adopted to describe this condition of "vertigo at sea."

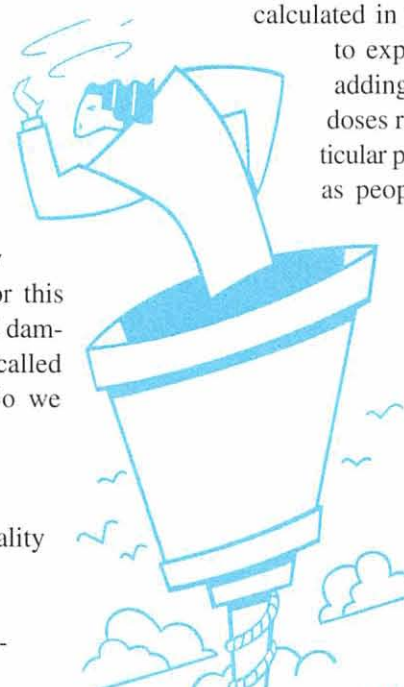
These days, **sievert** means something a bit different. A sievert (abbreviated Sv) is a unit of equivalent radiation dose equal to 100 rems. Sieverts measure the biological damage done by ionizing radiation. When high energy electromagnetic radiation (called X-rays and gamma rays), electrons, positrons, neutrons, or alpha particles (helium nuclei) strike living cells they deposit energy in those cells and cause damage. The amount of energy deposited is measured in grays or rads (1 gray = 100 rads). The biological damage depends on the kind of radiation. Generally neutrons and alpha particles cause more damage *per unit of energy deposited.* The radiation dose measured in energy units is multiplied by a "quality factor" to account for this variation in biological damage to yield a unit called sieverts (or rems). So we have:

sieverts = grays multiplied by the quality factor;

rems = rads multiplied by the quality factor.

One sievert is a large radiation exposure. A sudden exposure to one sievert would produce observable symptoms (also called non-stochastic effects) such as hair loss, nausea, and lowered white blood cell counts. Radiation doses below 0.1 to 0.5 sievert (10 to 50 rem) do not produce immediate observable effects, but increase cancer risk and risk of genetic damage. The first observable effect is lowered white blood cell count and occurs at about 0.1 sievert. Radiation doses delivered slowly (over a period of days or longer) generally do not produce non-stochastic effects. Natural background radiation from all sources at sea-level is about 0.001 sievert per year.

Cumulative low dose radiation can add up to quite large doses without producing non-stochastic effects. The effects of such low dose radiation are calculated in terms of cancer risk to exposed populations by adding up all the individual doses received within a particular population group (such as people living in an area or workers in a particular plant). Such total population doses are measured in "person-sieverts," simply to indicate that doses of many individuals are being added up, without consideration for differences in individual response.



Vertigo at Sea

ATOMIC PUZZLER

A Message from Dr. Egghead

Dear Readers:

I'm afraid I've been feeling a little scrambled lately since I haven't had much mail. I understand many of you fill out the Puzzler, but often don't send it in! I have many unclaimed $10 prizes here—just waiting to be sent to all you puzzle-playing activists. (Or if you don't want the $10, you can send in your answer with a note saying so.) But don't hesitate to submit your answer! Remember, these days you can reach me by fax or e-mail in addition to regular mail, pony express, carrier pigeon, or whichever method you prefer. I hope to hear from you soon! I. M. Egghead

The Puzzler

How about a few numbers for a change of pace? In this puzzler, you can sharpen your math skills by calculating uranium releases from a DOE plant. Don't fear—Dr. Egghead has asked Gamma, the trusty dog, to help you out. Details for submitting your answers are below. Good luck! We look forward to hearing from you!

An air pollution control device typically consists of some kind of filter that traps pollutants. Consider a bag filter into which polluted air is flowing at the rate of 20 cubic meters per minute with a uranium dust loading of half a gram per cubic meter. (That is, there is one half gram of uranium dust per cubic meter of air.) The filtered air is exhausted through a stack. The filter has an efficiency of 70%.

Regulations require the plant to keep its daily stack emissions below 1.5 kilograms per day. The plant's managers have calculated that they are in compliance. But your sleuthing dog Gamma says they didn't do their math right. Is Gamma right? How much is the plant emitting?

(Assume 24-hours per day operation and remember 1 kilogram = 1,000 grams.)

Advanced question: Assume that the air coming out of the stack is diluted by a factor of 10,000 by the time it reaches the plant boundary. The standard for air quality at the boundary for uranium is 0.005 picocuries per liter. Will the standard be violated? (Assume the uranium is natural uranium. Remember that the specific activity of natural uranium is 0.67 microcuries per gram. Also remember 1 cubic meter = 1,000 liters.)

Complete the puzzle and submit answers by mail, fax, or e-mail by November 25, 1996 to Pat Ortmeyer, 6935 Laurel Avenue, Takoma Park MD 20912. Fax: (301) 270-3029; e-mail: ieer@ieer.org. IEER will award 25 prizes of $10 each to people who send in solutions to the puzzle, 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. There will be an extra $25 prize for a correct entry to the advanced question.

Answers to the Last Atomic Puzzler (Vol. 5, No. 2) **Across:** 3. Reykjavik; 5. Uranyl; 7. Radiographic; 9. Safety and Reliability; 13. Class A; 15. Information; 18. NIF; 19. New; 20. Oxide; 21. Zero; 24. Remanufacturing; 25. Kidder; 27. 777; 29. Inertial Confinement. **Down:** 1. Hydrodynamic; 2. DARHT; 4. Primary; 6. Livermore; 8. Japan and India; 10. Neptunium 237; 11. Low; 12. Transuranic; 14. SBSS; 16. Intent; 17. Hexafluoride; 22. One point; 23. Density; 26. Aging; 28. Yield. *Winner of $25 prize: Percy Fountain of Bowie, MD.*

Doses, *from page 11*

satisfactory bases for epi studies. Thus, the prospects for epi studies of off-site populations yielding reliable results are in many cases not very good. This conclusion must be a tentative one since we have not studied the majority of DOE plants.

In sum, while dose reconstruction efforts to determine the broad outlines of potential damage seem worthwhile, epi studies of off-site populations should be approached with much more caution as they are likely to yield inconclusive results and may even yield falsely negative results. That is, they may indicate no harm, when some individuals have, in fact, been harmed. When there are large uncertainties due to lack of sound data, it is important to give the communities the benefit of the doubt.

Epi studies on workers should be done only after a thorough re-evaluation of exposures, including internal exposures. In our study on Fernald workers, we found that worker dose records did not include doses that could be inferred from available urine and lung-counting data. Radon exposures were also not included. (See the accompanying article in this issue.) The DOE and its contractors need to update worker dose records so that estimates of internal doses are included in them. Such corrected records would provide a far better basis for worker health studies and health protection than is currently available.

COMINGS AND GOINGS AT IEER

IEER has said goodbye to some good friends this year and has been joined by two new staff members in the last several months. **Hisham Zerriffi**, author of IEER's Tritium report and our study on the SBSS program (see SDA Vol. 5 Nos. 1 and 2), left IEER in May to pursue a graduate degree at McGill University in Montreal. We all miss Hisham and wish him well in his studies.

In July, **Marc Fioravanti** joined IEER as the new Staff Engineer. Marc holds an undergraduate degree in Civil Engineering, an MA in Environmental Fluid Mechanics and Hydrology, and an Engineer Degree in Environmental Engineering—all from Stanford University. His particular interests are alternative energy, environmental technology, and community-based work. His current work includes research on the cleanup of the DOE weapons complex, and technical support of IEER projects.

In June **Anita Seth** joined the staff as Global Outreach Coordinator and managing editor of our international newsletter, *Energy & Security*. Prior to her work at IEER, Anita was a junior fellow at the Carnegie Endowment for International Peace working on Russian and Ukrainian security issues.

Finally, IEER's Executive Director, **Bernd Franke**, who is also president of the *ifeu* Institute in Heidelberg Germany, moved to the U.S. in August. Bernd will be working primarily on radiation studies. In addition, he is continuing his work on municipal solid waste issues and life-cycle assessment projects with *ifeu*.

For a complete list IEER's staff, see page 2 of this newsletter.

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