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Setting Cleanup Standards to Protect Future Generations

The Scientific Basis of the Subsistence Farmer Scenario and Its Application to the Estimation of Radionuclide Soil Action Levels (RSALs) for Rocky Flats

BY ARJUN MAKHIJANI AND SRIRAM GOPAL

Vast areas of land and huge amounts of water remain contaminated with dangerous long-lived radioactive and non-radioactive pollutants from operations of nuclear weapons facilities. This poses a difficult enough problem for the generations of people who have created them, but how can we ensure the health of future generations, of land and water resources, and of ecosystems thousands of years into the future?

The nature of the problem requires the utmost care in the selection of the scientific tools that will be used to assess the health of future generations in order to both ensure a sound result and promote effective expenditures. The scientific merits of any approach must take into account the historical experience that institutional memory about contamination tends to fade in a matter of decades. Laws change, as do norms. Assessment of the risks of particular materials and of combinations of materials has evolved. Over the past several decades, the trend in official assessments has been to conclude that radioactivity is more dangerous per unit of exposure than initially believed. In general, standards for environmental protection have become more stringent and public support for such protection has increased.

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PHOTO BY ROBERT DEL TREDICI

Suburban sprawl approaches the Rocky Flats Environmental Technology Site, indicated by the arrow. The former nuclear weapons production site is located about 15 miles northwest of Denver, Colorado, a rapidly growing metropolitan area. More than 2 million people live within a 50 mile radius of the site. Of those, 300,000 live in the Rocky Flats watershed.

COGEMA: Above The Law?

Some Facts about the Parent Company of a U.S. Corporation Set to Process Plutonium in South Carolina

BY ANNIE MAKHIJANI, LINDA GUNTER* AND ARJUN MAKHIJANI

"[E]nforcement [of French nuclear waste law] comes into conflict with a technocratic structure [COGEMA] that considers itself above the law."

— Christian Bataille, French parliamentarian and author of the French law on the management of nuclear waste.[1]

"Whatever their record in Europe, good, bad or indifferent, it isn't going to affect our decisions."

— Melanie Galloway, Enrichment Section Chief of the U.S. Nuclear Regulatory Commission, on COGEMA.[2]

The U.S. subsidiary, COGEMA Inc., of a French corporation, COGEMA, is set to process U.S. surplus weapon-grade plutonium into plutonium fuel for use in U.S. commercial reactors. The U.S. Department of Energy (DOE) has awarded

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The U.S. Department of Energy (DOE) is embarked on a process of setting standards for cleanup at its Rocky Flats nuclear weapons plant near Denver, Colorado that could result in unprecedented levels of plutonium being left at the site. The DOE's approach could affect people in the future in a variety of ways, for instance by inhaling resuspended plutonium or other radioactive particles during windstorms, or by using contaminated water, which can become polluted both by runoff into surface water and transport of contaminants into groundwater as rainwater percolates down.

The Institute for Energy and Environmental Research (IEER) was commissioned to provide technical assistance to the Rocky Mountain Peace and Justice Center of Boulder, Colorado, in that group's effort to secure more protective cleanup levels at Rocky Flats. As part of that work IEER prepared the report, *Setting Cleanup Standards to Protect Future Generations: The Scientific Basis of Subsistence Farmer Scenario and Its Application to the Estimation of Radionuclide Soil Action Levels (RSALs) for Rocky Flats* (December 2001).[1] This article is based on that report. References can be found in the report, which is available in its entirety on IEER's web site at www.ieer.org/reports/rocky/toc.html.

The subsistence farmer approach

The approach to protecting people far into the future must be based on the assumption that any institutional controls put in place today will lapse with time, that institutional memory will not endure as long as the hazardous lifetimes of some of the contaminants, and that people may live on the land, farm it and use the water on it not knowing that it was contaminated. If a cleanup or waste management program can be devised to protect self-sufficient farmers, it is reasonable to conclude that the rest of the population will also be protected. This is the basis of the "subsistence farmer" approach to setting radiation cleanup standards.

This general approach was developed by scientific advisory bodies, notably the International Commission on Radiological Protection, as well as by governmental authorities, such as the U.S. Atomic Energy Commission and its successor agency, the U.S. Department of Energy. The DOE used this approach in the 1980s to evaluate options for the management high-level wastes at its Hanford site.

Using the subsistence farmer approach for setting standards makes scientific sense because it minimizes a large number of the uncertainties (though not all of them) that are associated with estimating the impact of contamination on people's health far into the future. More information on the development, use and scientific basis of the subsistence farmer approach is on page 8-9.

In addition to being a reasonable scenario in general, the subsistence farmer approach is reasonable for setting cleanup standards at the Rocky Flats site. Because the Denver-Boulder corridor is one of the fastest growing areas in the country, there is a great deal of pressure to develop open spaces. Also, farms, businesses and homes are located at the boundary of the site. The sound scientific basis of the subsistence farmer scenario is independent of any interim uses for which specific sites may be designated.

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Editor: Lisa Ledwidge

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Some current official proposals for radioactive waste management and cleanup of contaminated sites are discarding the subsistence farmer scenario. They argue that if public access to the contaminated site is prevented, then there will be no need to establish conservative cleanup standards because no one will be exposed. But it is not realistic to assume that institutional control and public memory will exist long enough to prevent unnecessary exposure to the future public. Some of the contaminants in question have half-lives of thousands of years.

Rocky Flats' radionuclide soil action levels[2]

From 1952 until 1989 the Rocky Flats plant produced plutonium pits for U.S. nuclear weapons. Routine operation plus accidents contaminated surrounding water and soil with plutonium, americium and other radionuclides, as well as with nonradioactive toxic substances. Now, Rocky Flats is a "flagship" site in DOE's attempt to clean and close some nuclear weapons production sites. Rocky Flats is slated for closure in 2006.

Plutonium (along with the associated americium-241) is the contaminant of principal concern at Rocky Flats. To deal with plutonium in the soil, DOE and the regulators set radionuclide soil action levels (RSALs) for the site. An RSAL indicates how much radioactive material may remain in the soil. When the amount of radioactive material in the soil exceeds the RSAL, action must be taken to remove or contain the material. Contaminant concentrations below the RSAL require no remedial action. No single decision regarding Rocky Flats cleanup is likely to have greater long-term effect on human health and the environment than the one establishing how much plutonium can remain in soil.

In 1996, federal and state government agencies proposed an RSAL for plutonium at Rocky Flats of 651 picocuries per gram of soil (pCi/g), a level higher than the action level adopted at any other plutonium-contaminated site anywhere. In addition there would be associated radionuclides, mainly americium-241. (See the table on page 5 for examples of the differing levels of residual radioactivity in soil assumed or measured at DOE and other sites, and the resultant doses estimated using a variety of scenarios.)

This RSAL was met with public opposition and the DOE eventually agreed to fund an independent scientific review of the matter, which was done by the Risk Assessment Corporation (RAC). The RAC report is available online at www.racteam.com/Experience/Projects/RSALS.htm.

The RAC team recommended an RSAL of about 35 pCi/g plutonium, plus the associated americium-241 in a specified ratio. RAC used a subsistence rancher scenario as a reasonable local variant of the subsistence farmer scenario in assessing Rocky Flats RSALs. A 15 millirem (mrem) annual dose limit (whole body effective dose equivalent) was used in RAC's calculations.

The RAC analysis admittedly did not consider the issue of groundwater doses in detail. Yet contamination in the soil acts as a reservoir for potential contamination of water that may eventually be used for drinking or irrigation. Thus if site conditions evolve to allow much faster plutonium migration than assumed in the RAC study, which is plausible given the results of recent government research on plutonium mobility in soil, the analysis may underestimate doses by the groundwater pathway.[3]

The agencies responsible for Rocky Flats cleanup never formally responded to this recommendation but conducted their own review instead. This raised the possibility that the findings of the independent review would be rejected implicitly or explicitly and that lax RSALs might be proposed again, especially in view of the target date for completion of December 15, 2006 to declare the site cleaned up.

> If cleanup can be devised to protect self-sufficient farmers, it is reasonable to conclude that the rest of the population will also be protected.

A "target fee" of about $340 million to the contractor, Kaiser-Hill, is at stake in meeting this deadline. This amount decreases, to a set minimum, for each day the project goes beyond the target date. By contrast, it increases if the project is completed early and below target cost, reaching a maximum of $460 million.[4] Since the RSALs were not defined at the start, there is a built-in incentive for the contractor to want more lax rules.

Protecting water resources

An analysis of the water pathway dose indicates the crucial importance of using the subsistence farmer scenario as the basis for protection of future populations.

The current contamination of groundwater at Rocky Flats with americium-241 and plutonium-239/240, alpha-emitting radionuclides, is generally regarded as minimal because it is far below the current U.S. Environmental Protection Agency (EPA) standard for transuranic radionuclides[5] of 15 picocuries per liter. However, that does not take into account the fact that the EPA standards for transuranic radionuclides are far more lax than the health risk based limit of 4 mrem per year to the critical organ that applies to most beta emitters.

Safe drinking water limits for transuranic radionu-

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RADIONUCLIDES IN WATER: POSSIBLE FUTURE CHANGES IN REGULATIONS

Federal safe drinking water regulations contain glaring inconsistencies as regards radionuclides. Stipulated in 40 CFR 141†, the regulations allow total contamination by alpha-emitting transuranic radionuclides, like plutonium-238, plutonium-239 and americium-241, of up to 15 picocuries per liter (pCi/liter).

At the same time, the regulations limit doses for most beta-emitting radionuclides, for instance cesium-137 and iodine-129, to 4 millirem (mrem) per year to the critical organ. The allowable concentrations are not specified but must be derived from prevalent dose conversion factors.

It turns out that if the currently applicable dose conversion factors‡ are applied to alpha-emitting transuranics, the dose to the critical organ of an adult male who regularly drinks water contaminated with 15 pCi/liter of plutonium-239/240 or americium-241 would be about 180 times greater than the 4 mrem per year allowed for most beta emitters. (The critical organ for plutonium and americium is the bone surface.) Contamination of water to just a fraction of a picocurie of plutonium-239/240 is sufficient to yield a drinking water dose of 4 mrem per year. In the case of neptunium-237, the dose corresponding to a 15 pCi/liter contamination would be almost 280 times higher than 4 mrem per year to the bone surface.

The State of Colorado has a state standard for plutonium in surface water of 0.15 pCi/liter. At Rocky Flats the standard is enforced at the downstream boundary of the site where 30-day moving average is calculated from streams exiting the site. For two separate 30-day periods in 1997, averages for one of the streams, Walnut Creek, exceeded the standard.

The DOE has suggested changing the Colorado standard by changing the averaging period from one month to longer periods. At the same time, a multi-year study, done by the site contractor Kaiser-Hill and funded by DOE, concluded that cleanup to an RSAL of 10 pCi/g would not meet the 0.15 pCi/liter limit for the most contaminated areas downstream from the 903 Pad (the most contaminated part of the Rocky Flats facility). On the other hand, a standard that is enforced for a thirty day period would produce an annual average that, in most cases, would be less than 0.15 pCi/liter.

In the case of plutonium-239/240, the Colorado limit would result in a dose to the bone surface of about 7 mrem per year compared to the 4 mrem per year federal drinking water dose limit that applies to most beta emitters. If the standard were set for a maximum 4 mrem per year to the bone surface for americium-241 or plutonium-239/240, the annual average maximum allowable concentration would be about 0.08 pCi/liter (rounded to one significant figure). The concentration limit for each radionuclide would be lower if there is more than one contaminant present.

Federal safe drinking water standards in effect today are a hundred times less strict in regard to plutonium concentration than the State of Colorado's standards for surface water purity. There is no rational reason for the federal transuranic radionuclide limit to be as high as it is and at such variance with maximum allowable doses from most radionuclides.

† U.S. Environmental Protection Agency, *Code of Federal Regulations,* Title 40, Part 141, 7-1-00 Edition. Online at www.epa.gov/safewater/regs.html

‡ In Federal Guidance Report No. 11 (see footnote 8 on page 6 for full citation)

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clides, most of which are alpha emitters, are not currently defined the same way as those for most beta-emitting radionuclides. EPA limits for alpha-emitting transuranics are set according to dose estimation procedures that are 40 years old. For the purposes of long-term planning, it is reasonable to assume that limits for transuranic radionuclides will eventually be brought into line with the current dose estimation procedures.[6] (For further discussion of the inconsistencies in safe drinking water regulations as regards radionuclides, see the box above.)

At Rocky Flats, the reported contamination level in groundwater in the fall of 2000 for americium-241 was 0.0354 picocuries per liter (pCi/liter). This sample also contained 0.00624 pCi/liter of plutonium-239/240. When added together, these amount to only about 0.3 percent of the current safe drinking water limit. But if someone drank water with these concentrations all year, the dose would be about 2.1 mrem per year to the bone surface (the critical organ[7] for these radionuclides) using the dose conversion factors that the EPA now normally requires for risk dose estimation.[8]

For the 35 pCi/g suggested as the plutonium RSAL by RAC, the estimated water pathway dose would be about 6 mrem per year whole body effective dose equivalent. The corresponding bone surface dose would be about 110 mrem per year. The RSAL corresponding to a 4 mrem per year dose limit to the bone surface alone would be about 1.2 pCi/g, or about 30 times lower than that recommended by the RAC team.

The radioactive wildlife refuge

In the early 1990s, the DOE embarked on a cooperative process with the Environmental Protection Agency to develop national cleanup standards, but the DOE pulled out of the process abruptly in the mid-1990s without any plans for its resumption. Since then, the DOE has proceeded on a site-by-site basis. This has

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led to a welter of proposals for cleanup using various scenarios, with the wildlife refuge having emerged as one of the favorites of the DOE and its contractors.

Five sites out of the more than 130 sites in the nuclear weapons complex are expected to account for the majority of cleanup costs: Oak Ridge in Tennessee, Hanford in Washington State, Savannah River Site in South Carolina bordering on Georgia, the Idaho National Engineering Laboratory, and Rocky Flats. These same sites are now being proposed as wildlife refuges.

In December 2001 President Bush signed into law the bill designating Rocky Flats as a National Wildlife Refuge.[9] It stipulates that the site will be transferred from DOE to the Department of the Interior following cleanup (as defined by the Rocky Flats Cleanup Agreement) and closure.

SOIL ACTION LEVELS AND RESULTANT DOSES FOR DIFFERENT SITES AND VARYING SCENARIOS

		Soil Action Level (pCi/g)		Dose from SAL (mrem/year)	
SITE	**SCENARIO**	Pu-239/240	Am-241	Pu-239/240	Am-241
Rocky Flats	Open Space	9906	1283	15	15
	Office Worker	1088	209	15	15
	Future Resident	252	38	15	15
	Future Resident	1429	215	85	85
Hanford	Rural Residential	34	31	15	15
	Industrial Worker	245	210	15	15
Nevada Test Site*	Rural Residential	162	13.2	10.7	1
	Rancher	162	13.2	42.6	3.56
	Farmer	162	13.2	20.1	1.84
	Child Rancher	162	13.2	16.7	1.61
	Industrial Worker	162	13.2	3.97	0.42
Johnson Atoll	Residential (inhalation)	17	N/A	20	N/A
Maralinga	Residential (inhalation)	280	N/A	500	N/A
Palomares	Residential (inhalation)	1230	N/A	100	N/A

* At Nevada Test Site the doses were calculated from assumed soil concentrations. They are not true Soil Action Levels.

Source: *Final Report: Task 1: Cleanup Levels at Other Sites.* Radionuclide Soil Action Level Oversight Panel. (RAC Report No. 6-RSALOP-RFSAL-1999-Final), Risk Assessment Corporation, April 1999.

Note: The IEER recommended range for Radionuclide Soil Action Levels at Rocky Flats is 1 to 10 pCi/gram, with the lower end of the range recommended when water use considerations are taken into account.

The DOE, EPA, and the Colorado Department of Public Health and Environment plan to use the wildlife refuge designation to set RSALs at Rocky Flats. Specifically, the agencies intend to calculate the RSALs to protect a wildlife refuge worker, a less protective scenario than the subsistence farmer scenario. They expect to propose RSALs in May 2002. Following a 60-day comment period, they will make a final decision.

Proponents argue that a wildlife refuge would minimize actual risk to off-site human populations by restricting access to the site. They also argue that the DOE cleanup program has been very expensive, ineffective, inefficient, and the costs will only increase, while declaring them wildlife refuges would exempt the DOE from major cleanup and would also serve to protect the natural ecosystems that have flourished. They argue that because nuclear weapons sites have been off limits to the public for so long, they have become havens to endemic species that would otherwise have been at risk due to sprawl and human intervention. (See, for example, *From Waste To Wilderness.*[10]) They also argue that technology for long-term cleanup to high levels is not available at present and it will require technological advances to accomplish such cleanup. We have assessed these arguments, at least as regards Rocky Flats, and conclude that they do not stand up to scrutiny.

Whether a site is designated a wildlife refuge in order to preserve open space and reduce the access of people to contaminated areas in years to come is an issue that is quite distinct from how doses to people far into the future should be assessed. Institutional memory tends to be short compared to the time frames we are considering. Laws change as do patterns of land use. Rocky Flats is already a part of the rapidly growing Denver-Boulder urban corridor, and there can be no *a priori* assurance that this open space will not fall prey to development pressures as has happened elsewhere. Thus, the wildlife refuge designation should not be used to assess how the site may be used centuries from now.

Further, the proposals for making contaminated sites into wildlife refuges have not taken into account the long-term evolutionary impacts on wildlife, the increases in organic matter on site that may cause more rapid radionuclide migration, and complex pathways to humans due to the interaction of wildlife and people in a densely populated area. Finally, the problem of non-availability of technology is at least in part a spurious one in regard to RSALs. There is no reason why highly

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contaminated soil cannot be removed and stored retrievably as radioactive waste.

The protection of public health by restricting site access can only be a temporary expedient, at best. It cannot be justified on the grounds of public health protection over a period of many decades, much less hundreds or even thousands of years. Therefore the Rocky Flats' wildlife refuge designation should not be used to set RSALs.

Institutional and cost considerations

The Department of Energy has done quite a bit to characterize the nature of the environmental problem in the weapons complex since the end of the Cold War. However, the actual process of cleanup has been limited by the fact that DOE has been unable to develop a coherent set of priorities. Much of the waste of money is not due to the difficulty of cleanup but the poor management that has plagued DOE projects. Poor institutional culture is at the core of the problem, as IEER has shown in a previous detailed study of the subject.[11]

Cost is often cited as a factor in setting more lax standards. But the DOE has historically chosen to use waste management methods that have been expedient in the short-term but turn into far more costly and difficult problems of cleanup in the long-term. Not doing the job of cleanup right in the first place allows contamination to spread both through the forces of weather and, it is becoming increasingly apparent, by fauna that pass through the site but do not stay on it. Expedient solutions may appear cheaper now but they have been a central part of the reason that the United States is faced with immense cleanup costs in its nuclear weapons complex today.

While even a well managed and coherent cleanup program would be expensive, one must look at these costs in context. The DOE estimate for partial environmental restoration, waste management and disposal is $227 billion over 75 years. This is about 4 percent of the total of 5.5 trillion dollars that the United States spent between 1940 and 1996 to construct and deploy nuclear weapons.[12] Moreover, most of this expenditure is actually for materials management and safeguards, site security, and the like, which would have to be spent anyway. Actual cleanup costs may be on the order of a couple percent of the total Cold War nuclear weapons expenditure even if it is done to exacting standards, presuming the money will be well spent.

Cost internalization of environmental problems is an important principle that the government tries to impose when it creates regulations for private industry. Setting and meeting strict cleanup standards is a part of cost internalization for nuclear weapons. It is essential that the government set for itself the high standards it expects of the private sector and that it do so based on long-term public health protection criteria.

Recommendations

IEER's recommendations for setting cleanup standards to protect future generations are summarized on the back page.

1 The work was supported in part by a grant to the Rocky Mountain Peace and Justice Center from the Citizens' Monitoring and Technical Assistance Fund.

2 Some information presented in this section draws from the statement of LeRoy Moore of the Rocky Mountain Peace and Justice Center at the IEER press conference on the report *Setting Cleanup Standards to Protect Future Generations* on December 11, 2001, online at www.ieer.org/reports/rocky/lerstmt.html.

3 See p. 25 of the IEER report for more information about plutonium migration.

4 Email correspondence with Tod Anderson, DOE-Rocky Flats, March 22, 2002, and Kaiser-Hill Contract No. DE-AC34-00RF01904, Feb. 1, 2000 to Site Closure (Dec. 15, 2006), viewed online March 22, 2002 via www.rfets.gov.

5 The term transuranic refers to elements with an atomic number greater than 92 (the atomic number of uranium), which are essentially man-made elements. (A few transuranic radionuclides occur in nature in extremely tiny concentrations.)

6 Reg. Guide 13 of the EPA incorporates more recent scientific methods but the methods are not directly comparable. On an approximate basis, an RSAL based on these methods would be about 3 picocuries of plutonium per gram of soil. [Full citation for Reg. Guide 13 is: Eckerman, et al. *Cancer Risk Coefficients for Environmental Exposure to Radionuclides*, (Federal Guidance Report No. 13) (EPA Report Number EPA-402-R-99-001) Oak Ridge, TN: Oak Ridge National Laboratory; Washington DC: U.S. Environmental Protection Agency, Office of Radiation and Indoor Air, 1999.]

7 The critical organ is that which is most affected by a radionuclide due to its chemistry. For instance, the critical organ for plutonium-239/240 and americium-241 is the bone surface. The dose to the critical organ is only one part of the dose received due to inhalation or ingestion of a radionuclide. Limiting doses to the critical organ to a certain number is more protective than the same dose to the whole body. In other words, the level of contamination required to produce a whole body effective dose equivalent of 4 millirem is considerably greater in most cases (including plutonium and americium) than that which produces the same dose to the critical organ.

8 Federal Guidance Report No. 11: Eckerman et al., *Limiting Values of Radionuclide Intake and Air Concentration and Dose Conversion Factors for Inhalation, Submersion, and Ingestion* (Spine title: *ALIs, DACs & Dose Conversion Factors*), EPA 520/1-88-020, Oak Ridge, TN: Oak Ridge National Laboratory; Washington, DC: U.S. Environmental Protection Agency, Office of Radiation Programs, September 1988. Online via www.epa.gov/radiation/assessment/pubs.html.

9 The Rocky Flats National Wildlife Refuge Act of 2001, Title XXXI, Subtitle F of the National Defense Authorization Act for Fiscal Year 2002 (Public Law No. 107-107).

10 Robert H. Nelson, *From Waste To Wilderness: Maintaining Biodiversity on Nuclear-Bomb-Building Sites.* Washington, DC: Competitive Enterprise Institute, 2001.

11 Marc Fioravanti and Arjun Makhijani, *Containing the Cold War Mess: Restructuring the Environmental Management of the U.S. Nuclear Weapons Complex*, Takoma Park, MD: Institute for Energy and Environmental Research, 1997.

12 Stephen I. Schwartz, (ed.), *Atomic Audit: The Costs and Consequences of U.S. Nuclear Weapons Since 1940*. Washington, DC: Brookings Institution Press, 1998.

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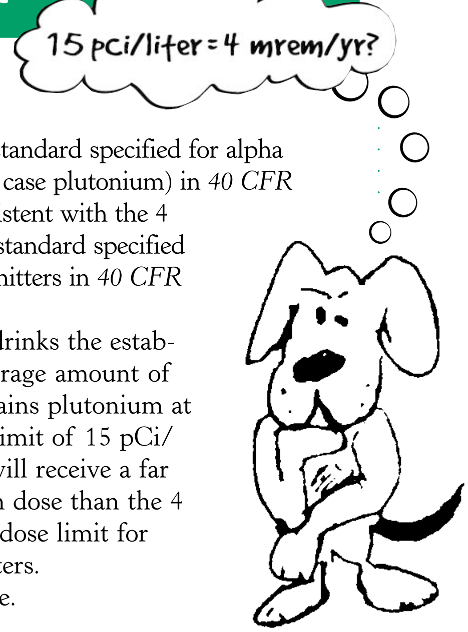

Gamma Digs Up Inconsistencies

Dr. Egghead's dog Gamma did some sniffing around and found that there are some inconsistencies in the regulatory limits for plutonium in drinking water. Plutonium is an alpha emitter. The U.S. Code of Federal Regulations, specifically *40 CFR 141.15*, sets the maximum contaminant level (MCL) for gross alpha particle activity in drinking water at 15 picocuries per liter (pCi/liter). The next section, *40 CFR 141.16*, sets a dose limit of 4 millirem (mrem) per year from the drinking water pathway for most beta-emitting radionuclides. The concentrations of these radionuclides that would lead to a 4 mrem dose limit are based on dose conversion factors that were originally published in 1963 by the National Bureau of Standards.[1] The dose conversion factors were updated in a 1988 Environmental Protection Agency document referred to as Reg. Guide 11[2], but the drinking water gross alpha particle activity MCL (15 pCi/liter) is still based on the old dose conversion factors. While keeping this in mind, do the following problem.

1. a. In Reg. Guide 11, the dose conversion factor for adults for plutonium-239 to the bone surface, in this case the critical organ, is 1.76 x 10^{-5} Sieverts per Becquerel (Sv/Bq). What is the dose conversion factor in millirem per picocurie (mrem/pCi) given that, 1 Sv=10^5 mrem, and 1 Bq=27 pCi.
   b. If a drinking well were at the regulatory of limit of 15 pCi/liter, what dose would one receive per liter of water?
   c. The regulatory limits assume that the average adult drinks exactly two liters of water per day. If someone were to drink this much, what dose would s/he receive after one year of 365 days?
   d. By what factor does this exceed the 4 mrem per year limit described in 40 CFR 141.16?
   e. What would the maximum contaminant level for plutonium have to be in order to meet the 4 mrem per year dose limit for most beta emitters? (Hint: Use the answer to part d)
   f. What can be concluded from this exercise?
      i. The current practice of using the 15 pCi/liter drinking water standard specified for alpha emitters (in this case plutonium) in *40 CFR 141.15* is inconsistent with the 4 mrem per year standard specified for most beta emitters in *40 CFR 141.16*.
      ii. An adult who drinks the established daily average amount of water that contains plutonium at the regulatory limit of 15 pCi/liter probably will receive a far higher radiation dose than the 4 mrem per year dose limit for most beta emitters.
      iii. All of the above.

2. True or False: Regulatory practice assumes that alpha radiation is 20 times more damaging per unit of energy deposited in the body than beta radiation. *(Bonus question.)*

3. Which of the following is the most conservative model for estimating doses to future populations, all other things being equal?
   a. Wildlife Refuge Worker Scenario
   b. Office Worker Scenario
   c. Subsistence Farmer Scenario
   d. Young Adult Scenario

4. True or False: The hypothetical maximally exposed individual is not considered part of the critical group.

Notes:

1 *Maximum Permissible Body Burdens and Maximum Permissible Concentration of Radionuclides in Air or Water for Occupational Exposure,* (Handbook 69), National Bureau of Standards, 1963.

2 Federal Guidance Report No. 11: Eckerman et al., *Limiting Values of Radionuclide Intake and Air Concentration and Dose Conversion Factors for Inhalation, Submersion, and Ingestion* (Spine title: *ALIs, DACs & Dose Conversion Factors*), EPA 520/1-88-020, Oak Ridge, TN: Oak Ridge National Laboratory; Washington, DC: U.S. Environmental Protection Agency, Office of Radiation Programs, September 1988. Online via www.epa.gov/radiation/assessment/pubs.html.

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The Subsistence Farmer Scenario

Its Development, Use and Scientific Basis

The principal scientific basis for radiation protection has been, and continues to be, to set limits on the maximum allowable exposures to individuals at greatest risk from man-made radiation sources. Historically, radiation standards were set in the context of worker protection, such as medical X-ray workers, radium-dial painters, and Manhattan Project personnel. Worker exposures are measured or inferred through the use of film badges, urine monitoring, and other methods. (See *Science for Democratic Action* vol. 9. no. 1, December 2000, for a summary of worker dose regulations.)

The general public outside of nuclear facilities does not have the same protective monitoring. As a result, conservative approaches to estimating doses have been developed to protect people off-site, which also serve to limit population dose in most cases. In the late 1950s and early 1960s, the Atomic Energy Commission, a predecessor of the U.S. Department of Energy (DOE), established the first regulations designed to protect off-site populations. Over time, it has become established practice to limit the maximum allowable concentrations of radionuclides at the site boundary so that a hypothetical maximally exposed individual is not exposed to more than a specified radiation dose. For long-term dose calculations, the concept of "critical group" has also been established.

The **maximally exposed individual** is a hypothetical off-site person, usually located at or near the site boundary, who would receive the maximum dose from a facility's operations. The maximally exposed individual concept was implicit in U.S. regulations as early as the late 1960s and is now at the heart of current radiation protection regulations for present populations.

The **critical group** is a small, homogenous subset of the general population with characteristics such as lifestyle or diets that would cause them to have higher exposures than the rest of the population. In practice, the maximally exposed individual is a member of the critical group whose exposures are the highest of the group, and therefore of the entire general population.

The critical group and the maximally exposed individual are necessarily statistical concepts and do not cover all possible contingencies, but they are tools which prevent, with a high degree of probability, the general population from getting higher radiation doses than the limits specified in regulations. (See the box on page 9 for further discussion of these concepts.)

The **subsistence farmer scenario** was developed as an extension of the maximally exposed individual in situations where contamination or waste disposal activities may put future generations at risk of cancer or other disease outcomes. When the main route of exposure over long time periods is uncertain, it is the general practice to use the subsistence farmer scenario for calculating risk or the level of permissible exposure to radiation. If the predicted dose and risk of the subsistence farmer is estimated to be less than allowable limits with a high degree of confidence, then it is reasonable to assume the rest of the public is protected as well.

> The subsistence farmer approach assumes that some people would unknowingly use contaminated water for drinking and growing all of their own food.

The choice of a framework for cleanup cannot resolve all the uncertainties — future lifestyles, diet, population settlement patterns, land-use regulations, climate, environmental protection standards, future assessments of the risk of pollution or contamination, future utility of specific resources — but it can address them in a manner as to make the cleanup standards relatively robust to changes that might occur. Correspondingly, the subsistence farmer approach assumes that institutional memory of contamination will be lost and that some people would unknowingly use contaminated water for drinking and growing all of their own food. Further, it assumes that such exposure would last a lifetime, and not just a few years. It is conservative in that there are few assumptions about future lifestyles that will result in much greater exposures. The remaining uncertainties are then in the parameters chosen for modeling future doses, such as those related to climate and hydrology and those related to mobility of contaminants through the environment.

It is not at all implausible that there may be significant numbers of people in the future who would choose to be self-sufficient farmers or something close to it, even in the context of rapid urbanization of populations. Indeed, it is quite possible to imagine economic, social, and technological arrangements under which a large proportion of the population of the future would grow most of their own food or obtain it very locally.

The assumption that the risk to all individuals within a population will be below that of the hypothetical

The maximally exposed individual joins the critical group

For the purposes of calculating future radiation dose and setting cleanup standards (or repository performance standards), a small homogeneous group of individuals is used to define a **critical group.** The International Commission on Radiological Protection (ICRP) Publication 46 (1985) defines the critical group in the following manner:

> When an actual group cannot be defined, a hypothetical group or representative individual should be considered who, due to location and time, would receive the greatest dose. The habits and characteristics of the group should be based upon present knowledge using cautious, but reasonable assumptions. For example, the critical group could be the group of people who might live in an area near a repository and whose water would be obtained from a nearby groundwater aquifer. Because the actual doses in the entire population will constitute a distribution for which the critical group represents the extreme, this procedure is intended to ensure that no individual doses are unacceptably high.

ICRP recommends that critical groups be small so that they are homogenous with the upper limit to size usually being "up to a few tens of persons." They could be as small as only one person. In this specific instance, the congruence of the critical group with a **hypothetical maximally exposed individual** is complete.

> In an extreme case it may be convenient to define the critical group in terms of a *single hypothetical individual*, for example when dealing with conditions well in the future which cannot be characterized in detail. (emphasis added) (ICRP Publication 43, 1984)

subsistence farmer is an estimate that, with some unknown but small likelihood, may turn out to be wrong. For instance, the subsistence farmer approach assumes that the diets as well as food and water intake of future populations will be similar to those of today. It is common to exclude extreme diets consisting only of the most contaminated foods. While such diets cannot be ruled out, they may reasonably be considered as improbable, unless there is some evidence to the contrary.

Use of the subsistence farmer scenario has a strong precedent. DOE analyses of allowable residual contamination levels have used a subsistence-farmer-like model since the 1980s. The Yucca Mountain Project, in the past, estimated future doses based on subsistence farmers. The U.S. Nuclear Regulatory Commission and projects at the Waste Isolation Pilot Plant and Sandia National Laboratories also have used the subsistence farmer scenario or variants thereof. In regulatory terms, the U.S. Environmental Protection Agency in establishing Superfund regulations used the subsistence farmer scenario. There is also considerable international consensus supporting the subsistence farmer approach: it has been used in Britain, Sweden, Finland, Norway, Switzerland and other countries, and is consistent with recommendations of the International Commission on Radiological Protection. (See the IEER report for quotes and references from international sources.)

Use of the subsistence farmer scenario has a strong precedent.

One argument that has been used against the subsistence farmer scenario is that it is too stringent for proposed geologic disposal sites such as Yucca Mountain or nuclear facilities such as Rocky Flats. However, this argument is weak. In relation to Yucca Mountain, it has been shown that the repository design adopted by the DOE would in future time fail established performance limits. It could not meet currently established safe drinking water limits near the repository footprint. This does not mean that the subsistence farmer scenario is too stringent but rather that the repository location and design are poor.

In sum, the subsistence farmer scenario is a conservative, stringent, and practically bounding approach to calculating future regulatory dose limits. It provides a reasonable, scientifically and historically defensible framework that is robust to a large variety of future uncertainties.

This centerfold draws from the IEER report, *Setting Cleanup Standards to Protect Future Generations: The Scientific Basis of Subsistence Farmer Scenario and Its Application to the Estimation of Radionuclide Soil Action Levels (RSALs) for Rocky Flats* (December 2001). References can be found in the report, which is available on IEER's web site at www.ieer.org/reports/rocky/toc.html.

COGEMA

FROM PAGE 1

the contract for the design of the processing plant to a consortium in which COGEMA Inc. is the only company with experience in plutonium fuel processing. The fuel would be a mixture of uranium and plutonium oxide (from weapon-grade plutonium) and goes by the technical name of mixed oxide fuel or MOX.

COGEMA Inc.'s experience is restricted to making MOX fuel from plutonium derived from commercial reactor spent fuel. (No company has ever made weapon-grade plutonium into fuel on an industrial scale.) However, its qualifications for the DOE job come from its parent corporation in France, COGEMA (Compagnie Générale des Matières Nucléaires). COGEMA is the largest commercial nuclear reprocessing and commercial MOX fuel fabrication company in the world.

Because the experience and expertise of the French parent company of COGEMA Inc. are the basis for the U.S. subsidiary's participation in the consortium, IEER believes the record of the parent company in all its aspects is relevant to the conduct of its subsidiary. The position of the U.S. Nuclear Regulatory Commission (NRC) is that the U.S. subsidiary will have to obey U.S. laws, abide by DOE contracting procedures, and be regulated by NRC.[3] However, this may be cold comfort.[4]

The health, environmental, and regulatory compliance record is relevant to U.S. operations for the same reason that the expertise of the French parent company is relevant to awarding the contract to the U.S. subsidiary. If the conduct of the parent company in regard to compliance with French law and regulations is lax, and if it chooses to deny the scientific basis of internationally recognized radiation protection rules, what is the basis for assuming the subsidiary will not have the same culture? The matter is at least worthy of inquiry, especially since matters in France have gone so far that Christian Bataille – a leading French parliamentarian, supporter of the French nuclear industry, and author of France's nuclear waste law – has come to conclude that COGEMA has set itself above the spirit of the law he authored.

We are not alone in our concerns. They are shared by many other groups, and by South Carolina Senator Phil Leventis, who voiced his concern in a letter addressed to U.S. Senator Strom Thurmond:

> Do we want a company operating in our state whose culture includes defying the law? Do we want a company operating in our state that stalls on meeting its commitments to a judge for so long that he had to go to the company's headquarters with a police escort? I know that I don't.[5]

COGEMA's reprocessing operations in France

As part of its commercial reprocessing operations to extract plutonium from French and foreign spent fuel, COGEMA discharges hundreds of millions of liters of radioactive liquid waste into the English Channel each year. Specifically, in 1996, 500 million liters were discharged into the sea, containing a total radioactivity of 285,000 curies.[6] COGEMA's commercial reprocessing plant (which has two large units) is located at La Hague on the Normandy Peninsula.

> COGEMA discharges hundreds of millions of liters of radioactive liquid waste into the English Channel each year.

The average radioactivity concentration of the liquid discharge is about 570 microcuries per gram and clearly fits the definition of low-level radioactive waste. According to the regulations of the U.S. Department of Transportation, if this liquid waste were put into a container, a special permit for its transportation as radioactive waste would be required because it far exceeds the limit of two nanocuries per gram defining such waste.[7]

Were this liquid waste coming out of the pipe put into a container and then dumped into the open ocean, this action would violate the 1992 OSPAR (Oslo-Paris) convention in which the "dumping [into the oceans] of low and intermediate level radioactive substances, including wastes, is prohibited."[8] But France and Britain, both signatories to the OSPAR convention, were at the time of its signing provided

SEE **COGEMA** ON PAGE 11
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OSPAR

The Convention for the Protection of the Marine Environment of the North-East Atlantic (more commonly known as the OSPAR Convention, short for Oslo-Paris) was opened for signature on 22 September 1992. The Convention entered into force on 25 March 1998. There are 16 Contracting Parties to the OSPAR Convention (i.e. Parties that have signed and ratified it):

Belgium	Iceland	Spain
Denmark	Ireland	Sweden
European Union	Luxembourg	Switzerland
Finland	Netherlands	United Kingdom
France	Norway	
Germany	Portugal	

Source: www.ospar.org, viewed 27 March 2002.

COGEMA

FROM PAGE 10

with a temporary loophole to continue to discharge radioactive wastes into the sea.

This loophole has allowed COGEMA and its British counterpart, BNFL (British Nuclear Fuels Limited), to rely on a legal fiction that liquid wastes discharged through a pipe are not low-level radioactive wastes. This legal magic, of course, does not change the physical and ecological reality in the seas of Europe, and it is that reality that has become the basis of a protracted struggle between the majority of the parties to OSPAR on the one hand and COGEMA, BNFL, and their French and British governmental champions on the other. (BNFL is 100 percent owned by the British government. COGEMA is part of a new giant conglomerate, AREVA, which has wide-ranging interests in nuclear power, communications, and other businesses, and is more than 85 percent owned by various French government entities.)

In July 1998 OSPAR took up the question of liquid waste discharges with greater urgency. The commission adopted the following strategy at that time:

> We shall ensure that discharges, emissions and losses of radioactive substances are reduced by the year 2020 to levels where the additional concentrations in the marine environment above historic levels, resulting from such discharges, emissions and losses are close to zero.[9]

This still left a small loophole. With evidence mounting that radioactivity from the reprocessing operations of COGEMA and BNFL was spreading far into the oceans all the way to the Arctic, OSPAR eliminated loopholes at its meeting in 2000. In June of that year:

> …a binding decision on the reduction and elimination of radioactive discharges, emissions and losses, especially from nuclear reprocessing, was adopted by 12 states. This requires the urgent review of current authorisations for discharges and releases of radioactive substances from nuclear reprocessing plants, with a view to implementing the non-reprocessing option for spent nuclear fuel management at appropriate facilities, and taking preventive measures against pollution from accidents. France and the United Kingdom abstained, and are not therefore bound.[10]

The decisions of OSPAR are only binding on those countries that vote in favor of the resolutions. Since the French and British governments abstained, they were not bound by the decisions. But in order to assuage the strong demand by the 12 European governments without actually eliminating waste discharges, COGEMA has adopted a policy of "zero impact" on the environment, rather than a policy of zero release. This would by itself not have set COGEMA above the law, since the French government's abstention has left the company free to continue to pollute European waters. But COGEMA has gone much farther. It has taken the science on which radiation protection is based into its own hands and thereby overruled all established radiation protection regulatory bodies.

COGEMA becomes an arbiter of science and law

In deciding to respond to the OSPAR demand for zero discharges by saying that it would aim for "zero impact," COGEMA made the following declaration:

> COGEMA has made a commitment that impacts from COGEMA-La Hague operations, regardless of the processing campaign involved or the type of material processed, will never exceed the threshold dose of 30 microsieverts per year to reference members of the public. Experts consider this dose level to be synonymous with "*zero impact*", and it is the working translation of the zero release concept.[11]

By this statement COGEMA asserts flatly that radiation doses have no impact below a threshold of 3 millirem (30 microsieverts) per year. It cites unnamed "experts" as its basis. However, U.S. and international scientific advisory bodies and regulatory authorities have repeatedly rejected the idea of a threshold for radiation damage. The basis for radiation protection in the United States, as in Europe, has been and continues to be that every increment of radiation dose produces a proportional increment of cancer risk. This is known as the linear no-threshold hypothesis. There are those in industry and academia who disagree with these scientific bodies and regulations, since there is considerable uncertainty, and controversy, about the exact magnitude of the risk. But every scientific examination by well-established bodies has come to the same conclusion – that the accepted hypothesis of dose and risk being proportional is the best, both on scientific and regulatory grounds.

The latest conclusion to that effect is from the U.S. Center for Disease Control and Prevention (CDC). In an August 2001 report, the CDC concluded that based on "conclusions and summaries derived by these national and international expert groups […] The data do not suggest the existence of a threshold below which there is no excess risk." It even added that "*Some think that there may be a threshold*, that is a dose below which there is no risk, though as noted previously, *this hypothesis is not supported by current available data*." [12] (Emphasis added.) The CDC report has been submitted to the National Academy of Sciences for review.

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COGEMA
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A dose of 30 microsieverts (3 millirem) would certainly not be regarded as zero impact under current U.S. regulations. For instance, U.S. safe drinking water regulations limit the dose to the critical organ from exposure to various radionuclides as a result of drinking contaminated water. The rule for most beta-emitting radionuclides, such as iodine-129, is that concentration in drinking water should not exceed a level that would cause a dose of more than 4 millirem per year to the critical organ. For many or most radionuclides, this would translate into a dose of less than 3 millirem per year whole body dose equivalent, but that is not uniformly the case.

For instance, consider the case of iodine-129, for which the critical organ is the thyroid. The weighting factor for thyroid is 3%. Thus a dose of 4 millirem per year to the thyroid corresponds to a whole body effective dose of about 0.12 millirem per year. If U.S. drinking water were contaminated with I-129 to a level that would produce a whole body dose of 3 millirem, COGEMA's own level of "zero impact," the water would exceed allowable contamination levels by a factor of 25. Hence, what for COGEMA would be "zero impact" for I-129 pollution of the water would be in gross violation of U.S. regulations for safe drinking water. (See the box on page 4 for information about inconsistencies in the radionuclide provisions of U.S. safe drinking water regulations.)

Because European regulations are similar to those in the United States, COGEMA's assertion of "zero impact" for 30 microsieverts radiation dose flies in the face of established regulations both in the European Union as well as in the United States. And while it has not named the experts it relies on, there is evidence that COGEMA has simply used an opinion of a single scientist, who happens to be the chair of the ICRP (International Commission on Radiological Protection). Yet the ICRP has not accepted this hypothesis. To have taken the opinion of one scientist, shared no doubt by others in industry and academia, when an established regulatory and advisory scientific body has taken the contrary view means that COGEMA has taken both the science and regulation of radiation protection into its own hands.

In sum, an industrial company – in defiance of the stated goals of a large majority of European governments, of established science, and of long-established regulatory schemes – has simply decreed that a 3 millirem dose is zero impact. The arrogation of authority in the absence of any democratic or open scientific process should at least give the U.S. government some pause before it allows the company's subsidiary, COGEMA Inc., to work with weapon-grade plutonium inside a U.S. nuclear weapons plant.

An inquiry should long ago have been initiated by the NRC, given the express concern of a number of people, including State Senator Leventis. Instead, the NRC has cavalierly stated that what the parent company does in Europe is not a concern here (see quote by Ms. Galloway on page 1). The U.S. government is relying on COGEMA's expertise in Europe to enable the company to meet its license conditions in the United States. If the expertise is relevant, why not the management culture or record of compliance?

Storage of foreign nuclear waste in France

Article 3 of the 1991 French law on the management of nuclear waste makes it illegal to store nuclear wastes of foreign origin on French soil beyond a certain period once these wastes have been reprocessed.[13] Implicit in this language is that the storage of imported nuclear spent fuel is illegal if reprocessing is not intended or if the authorization to reprocess has not been sought or issued. A number of lawsuits and objections contend that COGEMA is in violation of the spirit and letter of the law by accepting spent fuel without proper reprocessing contracts and by being very slow in returning nuclear waste. (Information about these lawsuits was presented in *Science for Democratic Action* vol. 9 no. 3, May 2001, online at www.ieer.org/sdafiles/vol_9/9-3/crilan.html.)

Parliamentarian Christian Bataille said of the investigation that ensued during one of the lawsuits against COGEMA:

> I take my hat off to this young judge who has the guts to insist that the law should be obeyed. At that time [during passage of the law] all sorts of

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ANSWERS TO ATOMIC PUZZLER

from SDA vol. 10 no. 2, February 2002

1. a. 24 million barrels
   b. 30 million barrels
   c. 36 million barrels
2. a. 100 billion dollars per quadrillion Btu
   b. 87 billion dollars per quadrillion Btu
   c. 117 billion dollars per quadrillion Btu
3. 25 percent
4. Iran
5. True
6. Algeria, Indonesia, Iran, Iraq, Kuwait, Libya, Nigeria, Qatar, Saudi Arabia, United Arab Emirates, and Venezuela

pressures were put on me so that Article 3 would not be voted on. It interferes with many commercial contracts and COGEMA is a business enterprise. Today its enforcement comes into conflict with a technocratic structure that considers itself above the law.[14]

* Linda Gunter is Communications Director at Safe Energy Communication Council, www.safeenergy.org.

1 Matthieu Ecoiffier, La mise en examen de la Cogema, Un juge dans l'antre du nucléaire, *Libération,* July 13, 1999. Article 3 makes it illegal to store nuclear wastes of foreign origin on French soil beyond a certain period once these wastes have been reprocessed.

2 Brandon Haddock, "Mox plan scrutinized by residents", *Augusta Chronicle,* July 14, 2000, at www.augustachronicle.com/stories/071400/met_051-5368.000.shtml.

3 Ibid.

4 See various materials on IEER's web site as regards DOE management of clean up, www.ieer.org/webindex.html#waste. See also the web site of the Union of Concerned Scientists (www.ucsusa.org) for information about laxness in NRC regulation of the commercial nuclear industry. For instance, see Testimony of David Lochbaum, Nuclear Safety Engineer for the Union of Concerned Scientists before the Clean Air, Wetlands, Private Property, and Nuclear Safety Subcommittee, United States Senate Committee on Environment and Public Works, May 8, 2001, and before the Subcommittee on Energy and Power, United States House of Representatives Committee on Commerce, June 8, 2000. Also see Mr. Lochbaum's article, "Nuclear Plant Risk Studies: Dismal Quality," in *Science for Democratic Action* vol. 9 no. 1, December 2000, online at www.ieer.org/sdafiles/vol_9/9-1/nrcrisk.html.

5 Letter from Senator Phil P. Leventis to U.S. Senator Strom Thurmond. November 4, 1999.

6 Michèle Rivasi, Rapport sur les conséquences des installations de stockage des déchets nucléaires sur la santé publique et l'environnement, Paris: Office Parlementaire d'Evaluation des Choix scientifiques et techniques, Paris : *Assemblée Nationale No 2257, Sénat No 272*, March 2000, p.104.

7 U.S. Department of Transportation, *Code of Federal Regulations,* Title 49, Part 173, Subpart I, "Radioactive Materials," 1992, p. 600.

8 1992 OSPAR Convention, *Annex II - On the Prevention and Elimination of Pollution by Dumping or Incineration,* at www.ospar.org/eng/html/convention/ospar_conv3.htm.

9 Ibid.

10 OSPAR press notice, "Further Protection for the North-East Atlantic," Friday 30 June 2000, at www.ospar.org/eng/html/final_OSPAR_2000pressrelease.htm.

11 *COGEMA's commitment at La Hague: zero impact on the environment* (undated), at www.cogemalahague.fr/LaHague/InstitutionUK.nsf/Environnement/Engagement?OpenDocument, viewed March 21, 2002.

12 *A Feasibility Study of the Health and Consequences to the American Population from Nuclear Weapons Tests Conducted by the United States and Other Nations, Volume 1 Technical Report, Predecisional Draft,* prepared for the U.S. Congress by the Department of Health and Human Services, Center for Disease Control & Prevention and the National Cancer Institute, August 2001, pages 131, 133, and 148.

13 *Loi no 91-1381 du 30 décembre 1991 relative aux recherches sur la gestion des déchets.*

14 See note 1.

This article is based on a longer report of the same title jointly prepared by IEER and SECC (Safe Energy Communication Council).

DEAR ARJUN

Dear Arjun,

Is radium a substance to be concerned about in uranium mining? If so why? What are the current largest uses of radium?

Curious Carl in Colorado

Dear Curious Carl,

In Roman times, radium was a bright, long-lasting candle used to illuminate stadiums hosting particularly grueling gladiatorial contests. But in modern times, the term radium has been taken over by the nuclear establishment (like so much else).

Radium, specifically the radium isotope known as radium-226, is a serious concern related to uranium mining and milling. Radium-226 is part of the decay chain of uranium-238 (which can be found on IEER's web site at www.ieer.org/fctsheet/uranium.html), and so is always present in uranium ore. Here is a partial view of that decay chain, using standard symbols for the elements, starting with uranium-238:

> U-238 → Th-234 plus alpha particle → Pa-234m plus beta particle → U-234 plus beta particle → Th-230 plus alpha particle → Ra-226 plus alpha particle → Rn-222 plus alpha particle (etc.)

Being like calcium chemically, radium-226 gets incorporated into bones if it gets into the body. It is long-lived (half-life 1,600 years). As you can see from the above diagram, radium-226 decays by emitting an alpha particle (which is the nucleus of a helium-4 atom) and becomes radon-222, which is a gas. Hence, where there is radium-226 there is radon (including uranium mines, mills, and in the soil generally). Seepage of radon gas into basements is responsible for considerable radiation doses to the general population in certain areas of the world (including certain parts of Colorado).

Alpha particles are dangerous only if emitted inside the body, since they cannot penetrate the dead layer of the skin. But radium-226 also emits gamma radiation, which is high frequency electromagnetic radiation (like X-rays). Such radiation penetrates into the body. Hence radium contamination poses threats both from incorporation of radium (by ingestion or inhalation or through cuts) or simply from being near it, due to the external gamma radiation. Besides bone cancer, radium also causes diseases like anemia, since it affects the bone marrow.

> Radium contamination poses threats both from incorporation of radium or simply from being near it.

Mines

At the mine sites there is often overburden of low-grade unusable ore left scattered about. The radium, uranium and thorium-230 (also a decay product of uranium-238) are all problems. There are many contaminated mine sites in the western United States, notably on or near Native American reservations. There are no regulations covering the cleanup of mines or protecting the people who live near them. The U.S. Environmental Protection Agency (EPA) started a standard setting process that would have governed such contamination, but the process was abandoned, mainly under pressure from the U.S. Department of Energy (DOE sites would also have been covered under the cleanup regulations).

Mills

At the uranium mill sites, uranium is separated from the non-radioactive and other radioactive materials in the ore. (Typically uranium is less than one percent of the ore though there are richer ores, for instance in Canada). The residual materials are sent to a "tailings pond." The radium-226 ends up there, along with the thorium-230. If the tailings pond is dry, then there is a risk of radium-226 and thorium-230 becoming airborne. Rain also mobilizes the radium, some of which then pollutes the groundwater. There is some naturally occurring radium in groundwater, but in milling areas, the water can become quite contaminated.

Dry tailings ponds also emit radon gas to the air, and this can deliver significant doses to nearby populations. In order to prevent radon emissions, tailings piles are usually kept underwater. This of course causes greater mobilization of radium into the groundwater. Remediation standards for mill tailings require the creation of lined ponds (plastic liners) and the transfer of the tailing piles into such lined ponds. But it is unlikely that this kind of remediation will endure for

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DEAR ARJUN

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the period of the danger, which corresponds to a several times the half life of thorium-230, which is about 75,000 years.

Finally, the soil around uranium mills tends to get contaminated with radium. There are cleanup standards for this, limiting radium contamination to a maximum of 5 picocuries per gram near the surface and 15 picocuries per gram more than 6 inches down. Common levels of radium-226 in soil that occur naturally are in the range of 1 to 3 picocuries per gram of soil.

Cleanup problems also exist from the radium industry in the early part of the twentieth century. They kept surfacing throughout the rest of that century. Some radium waste was sent to municipal landfills, and then housing projects were built on or near these places. There was also quite a bit of contamination of some private properties near some radium-using factories. There are also radium-226 contaminated areas near many oil wells that have been subjected to secondary recovery of oil.

Uses of radium

In the first part of the twentieth century, especially in the 1920s, radium-226 was used to paint dials of watches and instruments (like dials on aircraft) to make them luminous. The radium-dial painters, who were young women, used to lick the brushes to make them pointy to be able to paint more precisely. They got huge doses of radiation and many died from bone cancer. It led to the demise of the radium-dial painting industry and the first standards limiting internal doses of radiation.

Today radium is used to produce neutron sources (it is mixed with beryllium for this purpose). It is used to a limited extent in cancer therapy. Radiation cancer therapy is now mainly done with other isotopes, like cobalt-60 and increasingly, for some cancers, with powerful electron accelerators that do not require radioactive materials.

Sincerely,
Dr. Egghead

CLEANUP

FROM PAGE 6

IEER RECOMMENDATIONS

for setting cleanup standards to protect future generations

- The U.S. Department of Energy (DOE) should abandon its attempt to use the wildlife refuge designation as the basis for setting RSALs. It should adopt the subsistence farmer scenario as the basis for the cleanup program throughout its nuclear weapons complex. It is the scientifically sound approach and it is far less likely to result in future damage of a kind that could cause future suffering, loss of trust and expenditure should problems crop up.
- The subsistence farmer or subsistence rancher scenario should be used as the basis for setting a residual soil action level at Rocky Flats, regardless of the site's designation as a wildlife refuge.
- The designation of Rocky Flats as a wildlife refuge should not serve as a precedent for other sites or for reducing cleanup expenditures at other major DOE nuclear weapons sites.
- Careful investigations of the effect of high residual contamination on wildlife should be undertaken. Investigations of the potential for the wildlife refuge designation to enhance the mobility of plutonium into the accessible environment, including groundwater, should also be undertaken.
- A residual soil action level (RSAL) between 1 and 10 picocuries of plutonium per gram of soil should be considered as the basis for the cleanup program at Rocky Flats, regardless of the site's wildlife refuge designation. Our evaluation indicates that, if groundwater pathway doses are taken into account, a choice in the 1 to 3 picocuries per gram range would be more appropriate. Such an RSAL would also be compatible with the dose implications of the current State of Colorado surface water standard of 0.15 picocuries per liter of plutonium, should it be extended to groundwater in the future. Soil action levels deriving from scenarios related to designation of the site as a wildlife refuge should be rejected.
- The steps towards the achievement of the ultimate RSAL, and the institutional arrangements in the interim, are beyond the scope of the IEER report. But any cleanup plan should specify how a standard based on the subsistence farmer or rancher scenario would be achieved, and how any interim steps would relate to this goal.

For the full set of recommendations, see the report, *Setting Cleanup Standards to Protect Future Generations*, www.ieer.org/reports/rocky/toc.html.

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