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Soil Cleanup at Los Alamos National Laboratory

BY BRICE SMITH

Between 1944 and 1964, liquid radioactive waste was released into the South Fork of Acid Canyon from the Los Alamos National Laboratory, located in northern New Mexico. The lab performed a remediation of Acid Canyon in 2001. IEER published an analysis of the lab's cleanup in November 2005. Our study is summarized here.[1]

We chose to examine the cleanup of Acid Canyon because:

- it is a site that is accessible to the general public (today, Acid Canyon is located within 1,000 feet of a residential neighborhood and less than a mile from a local high school — see map on page 4);
- it already has had remediation efforts undertaken based, in part, on analyses conducted by the U.S. Department of Energy (DOE) for site-specific scenarios; and,
- it illustrates some of the general concerns that will arise at Los Alamos and other DOE sites which have actinide contamination as the main driver of risk.

The selection was made in cooperation with Concerned Citizens for Nuclear Safety and Nuclear Watch of New Mexico, grassroots groups based in Santa Fe. To perform the analysis, IEER evaluated the *Interim Report on Sediment Contamination in the South Fork of Acid Canyon* (hereafter, the *Interim Report*) prepared in April 2000 by Los Alamos National Laboratory (hereafter LANL or Los Alamos), on which the soil cleanup was based.[2]

LANL's *Interim Report*

The *Interim Report* guides the cleanup of Acid Canyon and describes LANL's technical basis for it. The plan is based on estimated doses to people given certain assumptions. The *Interim Report* considered

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Cleanup worker in Acid Canyon, Los Alamos National Laboratory, November 2001.

TRIP REPORT

Chernobyl: Two Decades Later

BY CATHIE SULLIVAN[1]

In the Spring of 2004, I traveled to Chernobyl, site of the world's most infamous nuclear power plant accident.

The trip, organized by Friends of Chernobyl Centers United States (FOCCUS) based in Madison, Wisconsin, started in the capital of the Ukraine, Kiev, 60 miles south of the Chernobyl site. It then took us to Slavutich, a town of 27,000 residents including Chernobyl's current 4,000-person workforce and their families. Some of these people were evacuated in 1986 from Pripiat, Chernobyl's original worker city, which remains uninhabitable due to contamination from the accident.

According to city officials, Slavutich has been struggling since the year 2000 to develop a new role as a national center for nuclear expertise, especially in decommissioning RBMK reactors like the Chernobyl units. They said the town's future depends on the continuing work at Chernobyl, where the last of the four reactors closed down in 2000 in response to pressure from several Western governments.

Our tour group rode the worker train to the Chernobyl plant from Slavutich. During the hour-long ride we crossed briefly into Belarus,

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only the external gamma, soil ingestion, and soil inhalation pathways because of the lack of edible plants in the canyon and because no hunting or fishing is allowed there.

In light of the proximity of residential areas to the canyon, the *Interim Report* assumed that children could use the canyon as an extension of their backyards and that adults could use the hiking/jogging trails in the canyons. Except for tritium, which is not a major concern in Acid Canyon, the so-called "extended backyard scenario" was the most restrictive scenario evaluated by Los Alamos.

Of the nine radionuclides considered in the *Interim Report*, plutonium-239 and plutonium-240 were by far the primary drivers of risk. This is shown in Table 1, which shows the radionuclide soil guidelines set by LANL for an extended backyard scenario and the measurements of contamination in Acid Canyon both before and after cleanup.

As shown in Table 1, the level of residual plutonium that is left in Acid Canyon following the 2001 cleanup is below the remediation goal set according to the extended backyard scenario. However, this Los Alamos cleanup guideline does not yet take into account the effect of the residual plutonium contamination on surface water. LANL has stated it will do an analysis of surface water. This is necessary because Acid Canyon regularly floods during rain storms.

IEER's principal finding is that significant additional remediation of Acid Canyon will likely be required when the assessment of surface water impacts is made. Our analysis indicates that the average plutonium concentrations in the canyon soil are significantly larger than the values which could lead to surface water concentrations above 0.15 picocuries per liter (pCi/L). This concentration is the current statewide surface water limit for Colorado and the level recommended by IEER and other groups for adoption by the U.S. Environmental Protection Agency (EPA) as the federal drinking water limit.[3] *While we have not made specific recommendations for the final remediation guidelines for Acid Canyon in this report, we have concluded that the present level of residual contamination is likely too high by at least a factor of ten based on surface water protection.*

The present level of residual contamination is likely too high by at least a factor of ten.

Generally protective assumptions of the *Interim Report*

Parts of the *Interim Report* are generally protective of public health. First, and most important, is the adoption of a 15 millirem per year (mrem/yr) dose limit to the maximally exposed individual. The use of a 15 mrem/yr dose limit is a more conservative than 25 or 100 mrem/yr, which are sometimes used. However, its use should be in conjunction with (a) suitably conservative scenarios, such as soil ingestion by children and local farming on contaminated land, and (b) a separate sub-limit of 4 mrem/yr to the maximally exposed organ from the drinking water pathway. We did not evaluate the drinking water pathway as part of this review because Los Alamos had not yet done its remedial investigation for surface water and groundwater in Acid Canyon.

Second, Los Alamos chose to use "upper-bound values" for the exposure factors which is appropriate for this type of screening

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Credits for This Issue

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TABLE 1: RADIONUCLIDE SOIL GUIDELINES AND MEASUREMENTS FOR SURFACE SOIL CONTAMINATION IN ACID CANYON (picocuries per gram)

Radionuclide	Extended backyard scenario soil guideline	Maximum detected value before cleanup	Canyon average concentration before cleanup	Canyon average concentration after cleanup
Tritium	38,000	1.86	0.53	0.2
Strontium-90+D	5,500	80	6.86	1.9
Cesium-137+D	210	148	7.50	3.5
Uranium-234	3,000	21.5	2.92	3.6
Uranium-235+D	710	2	0.25	0.2
Uranium-238+D	2,000	16.6	1.92	1.9
Plutonium-238	310	37.3	0.97	0.6
Plutonium-239/240	**280**	**7,780**	**211**	**112**
Americium-241	270	278	13.8	5.4

Note: "+D" means "plus daughters."
Sources: LANL's *Interim Report*, April 2000, pp. 12-13; LANL's *Interim Action Completion Report for the South Fork of Acid Canyon*, September 2002, p. 17.

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analysis. While we do not believe that appropriate upper-bound values were used for the amount of time children may spend playing in Acid Canyon or for the amount of soil that they may ingest, other pathways such as inhalation did make use of appropriately conservative assumptions.

Assumptions not adequately protective of public health

A number of assumptions of the *Interim Report* are not adequately protective of public health, including some relating to children's doses, exposure duration, soil ingestion, and transported soil.

Doses to children

Despite the focus of the extended backyard scenario on children, the *Interim Report* uses dose conversion factors for a 154-pound adult male.[4] Los Alamos justified this choice "[b]ecause dose conversion factors for populations other than adult workers have not been published by DOE" and that "[t]here are no data to estimate the dose conversion factors for children." When the *Interim Action Completion Report* was published in September 2002, the conversion factors for the adult male were still used to evaluate doses to children.[5]

At the time the *Interim Report* was published in April 2000, it is true that the Department of Energy had not issued its own collection of age-specific dose conversion factors. However, the International Commission on Radiological Protection (ICRP) had already published widely accepted age-specific dose models. Plutonium, the main contaminant of concern in Acid Canyon, was discussed in four of the five ICRP reports on age-specific dose models issued prior to the *Interim Report*.

The claim made by the *Interim Report* that there were "no data to estimate the dose conversion factors for children" is incorrect. These dose conversion factors were available at the time of the preparation of the report, and indeed had been officially published by the EPA in 2002.[6] There are only two possible explanations for this statement, neither of them very reassuring. Either the Los Alamos scientists and remediation officials who were the authors were unaware of basic health protection data officially published by the EPA, or they knew about it and chose to ignore it.

Per unit of ingestion, a young child will always receive a higher estimated dose than an adult.

Surprisingly, in the particular case of plutonium, the use of the age-specific dose conversion factors would tend to decrease the child dose relative to LANL's estimate. Per unit of ingestion, a young child will always receive a higher estimated dose than an adult. However, due to new scientific understandings about tissue weighting factors and the behavior of plutonium in the body as well as refinements in the model used to represent the respiratory system, the estimated dose to all age groups except infants has gone down relative to the Reference Man estimates used in the *Interim Report*. While this means that the LANL estimates for plutonium were, in fact, conservative with respect to the size of the dose conversion factor used, they were not based on the latest available scientific information. For

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many other radionuclides, the dose conversion factors for children would be far higher. In all future assessments, the DOE should make use of the latest available dose conversion factors.

Exposure duration

The *Interim Report* claims to have used "upper-bound values" for the exposure factors. However, Los Alamos's choice of the length of time future children would play in the canyon was not adequately conservative. The *Interim Report* assumes that a child would spend 200 hours per year in the canyon, which would amount to approximately one hour per day for seven months of the year. It claims that this assumption is "based on professional judgement, incorporating input from NMED [the New Mexico Environment Department]."[7] However, EPA estimates that, on average, children spend 2.2 hours outdoors at home and an additional 1.9 hours per day outdoors at parks, etc.

Soil ingestion is by far the most important exposure pathway.

A screening calculation is meant to provide a conservative basis upon which to base cleanup efforts; hence, it is important to make consistent use of "upper-bound values" for all parameters, including exposure duration. The choice of an adequately conservative estimate should be made with input from the local residential population. Based on the studies underlying the EPA recommendations, it would be likely that an exposure of 300 to 400 hours per year would be a more appropriate screening level even if we retain the Los Alamos assumption that children will only spend 200 days per year in the canyon. Higher screening values could be possible if input from area residents challenges this assumption as well.

Soil ingestion

Soil ingestion is by far the most important exposure pathway in the extended backyard scenario, accounting for more than 90 percent of LANL's total estimated dose. Given its dominant role, it is particularly important that the soil ingestion pathway be handled accurately and appropriately. The *Interim Report* starts with the EPA's recommended 95th percentile figure of 400 milligrams per day of total soil ingestion and estimates that a child

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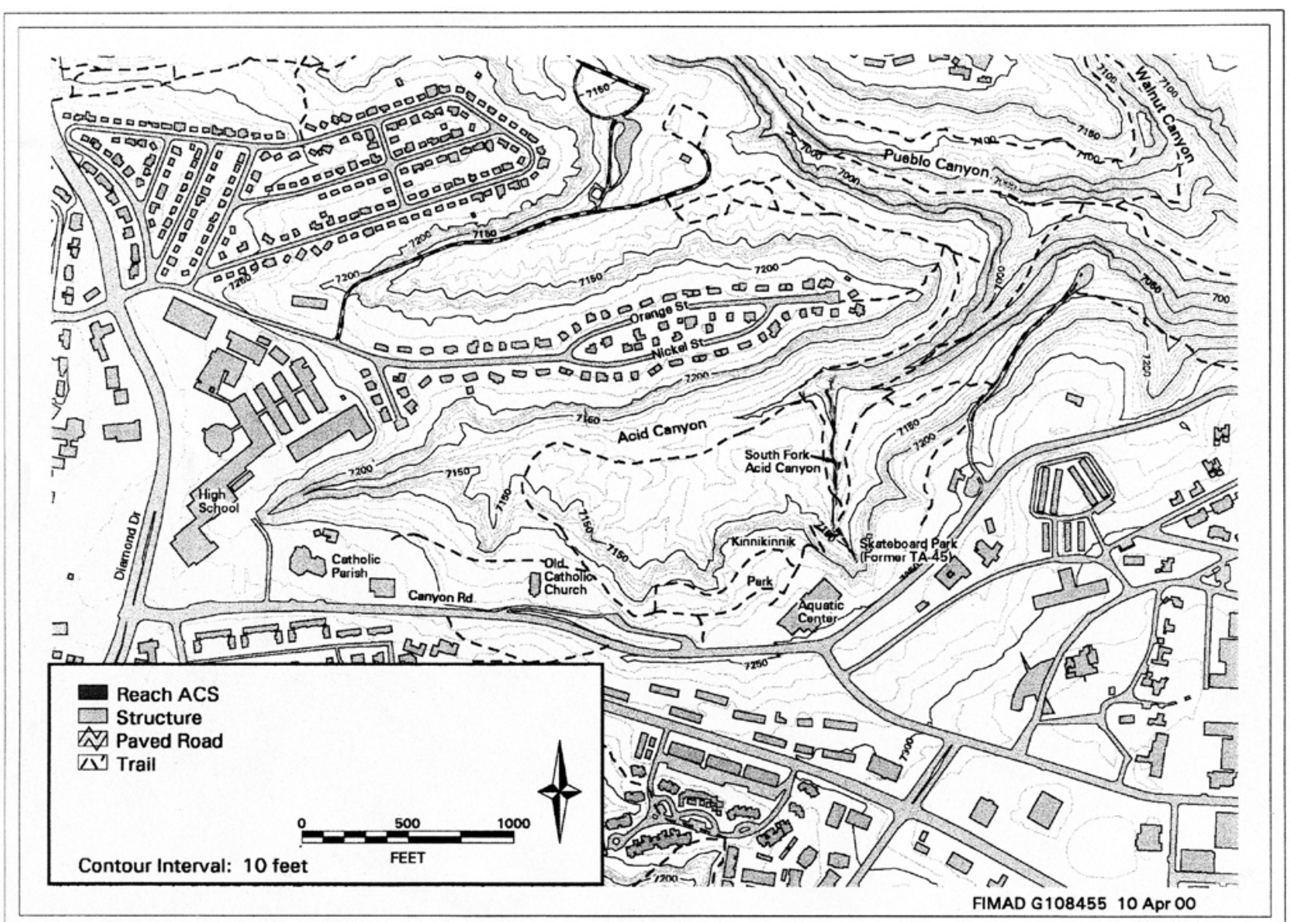

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Acid Canyon Area of Los Alamos National Laboratory.

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in the extended backyard scenario will unintentionally consume 14.3 grams of contaminated soil over the course of a year. (For comparison, this amount of dirt would fill a box nearly one inch on each side.) However, significant uncertainties remain about the long-term rate of unintentional soil ingestion and about the variability of soil ingestion between individuals and groups.

Even more important than the uncertainties in routine, unintentional soil ingestion is the issue of intentional soil ingestion. Geophagia, the intentional consumption of large quantities of soil, also called soil pica, is a behavior that has been documented for centuries. It has been found to occur across geographic, ethnic and cultural boundaries. In its 1985 Superfund Guidance, the EPA acknowledged that short term soil ingestion well above 400 milligrams per day is possible and recommended that risk assessments consider potential acute exposures of 5 grams per day. In 1997, the EPA concluded that "it can be assumed that the incidence rate of deliberate soil ingestion behavior in the general population is low." However, the EPA went on to note that "the prevalence of pica behavior is not known" and that due to the short time period over which children have so far been studied, "[i]t is plausible that many children may exhibit some pica behavior if studied for longer periods of time."[8]

Accurately estimating the amount of soil ingestion requires familiarity with the culture and habits of the people who may be doing the ingesting. That a pica child will consume between 5 and 10 grams of soil per day is consistent with the assumptions used by the EPA, the Centers for Disease Control, and the Agency for Toxic Substances and Disease Registry (ATSDR). The current EPA recommendation is to use 10 grams per day as the ingestion rate for a pica child. However, smaller estimates (one to five grams per day) and larger estimates (26 to 85 grams per day) have been suggested by other sources. For the purposes of screening calculations in which soil ingestion is a major pathway, like at Acid Canyon, acute exposures from the consumption of at least 30 to 40 grams of soil per year should be considered in addition to the chronic exposure from routine soil ingestion.

Finally, given that intentional soil ingestion events are most likely to be short-term, the inhomogeneous distribution of contamination should be considered in estimating the potential impact of pica events. This is particularly true for transuranic elements which are known to result in highly inhomogeneous contamination patterns. In the case of Acid Canyon, for example, prior to the cleanup there were hot spots with a combined area of 50 square meters (about 55 square yards) which had an average plutonium-239 concentration of 2,740 picocuries per gram (pCi/g). A single pica event in which a child consumed 10 grams of soil from these hot spots

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Workers vacuuming sediment out of Acid Canyon, Los Alamos National Laboratory, November 2001.

would have alone resulted in a dose greater than 25 millirem, which is greater than the yearly limit adopted by the *Interim Report*. Although no mention was made of the potential for such acute doses, these two areas of contamination were subsequently removed during the summer and fall of 2001 as part of attempts to maintain doses as low as reasonably achievable. After this cleanup effort was completed there were no longer any hot spots reported that would pose a significant concern with respect to single pica events.

Transported soil

The extended backyard scenario does not consider the possibility that children may track contaminated soil back to their homes. This pathway has been noted by the EPA and ATSDR in cases for exposure to chemical toxicants and heavy metals. This pathway creates the possibility that infants and other people at home could be exposed despite never traveling to the canyon.

Typical household dust is made up of a mixture of soil from outdoors, paint, plaster, biological material, and other materials. What fraction of household dust is dirt from outside is highly variable and depends on a variety of site-specific factors. For example, three different studies estimated the fraction of soil in household dust to be 14 to 15 percent, 30 to 40 percent, and 75 to 100 percent. Significant variations have been found from one contaminant to another and from one house to the next.

A number of factors may act to enhance the concentration of contaminants in dust: (i) There are fewer ways for contaminants on household dust to degrade or be transported away. (ii) Carpets can act to store dust over long times. (iii) Some dust is derived from biological material such as molds or fungi that can bioconcentrate certain contaminants. Studies of these effects, however, have shown significant variability. Measurements in and around local residences would be required to determine

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if this pathway is of importance in Acid Canyon.

Surface water assessment

The *Interim Report* explicitly excluded an analysis of surface water related exposure pathways due to "the lack of surface water data from Acid Canyon," but the report states that the analysis is pending. When this assessment is carried out, it will be important that it consider the most up-to-date science on plutonium health risks.

As detailed in the IEER report, *Bad to the Bone*, the science underlying the current drinking water limit for gross alpha-activity (which would include plutonium activity) is not a satisfactory basis for the protection of public health and not in accord with the intent of drinking water rules when they were promulgated in 1976. IEER has recommended reducing the concentration limit for plutonium and other long-lived alpha emitting transuranic elements from its current value of 15 pCi/L to 0.15 pCi/L which is consistent with the surface water standard for plutonium in the State of Colorado. In addition, New Mexico governor Bill Richardson has written to the EPA and encouraged them to lower the plutonium limit along the lines recommended by IEER.[9]

The potential impact on the surface and ground water of residual plutonium in the soil at the Los Alamos site must be carefully addressed.

To illustrate the potential significance of the impacts from the surface water contamination in Acid Canyon, we considered the typical levels of plutonium in stream sediment that would lead to an equilibrium concentration of 0.15 pCi/L in the surface water. Table 2 summarizes our results using typical values of the partition coefficient. (The partition coefficient describes how mobile radionuclides are in a given environment.)

Given that the average concentration of plutonium-239 after the 2001 remediation efforts was 112 pCi/g, it is clear that the potential exists for this contamination to adversely affect the surface water. As shown in table 2, this figure is well above that which could produce a plutonium water concentration of 0.15 pCi/L, the level recommended by IEER because it is more consistent with the health protection goals of federal drinking water regulations.

The potential impact on the surface and ground water of residual plutonium in the soil at the Los Alamos site must be carefully addressed. No remediation guideline should be accepted that would not maintain the concentration of all long-lived alpha emitting transuranic elements below 0.15 pCi/L. In the specific case of Acid Canyon, the requirement to protect the surface water will almost certainly be a more restrictive criterion than the extended backyard scenario.

Conclusion

Both for the assumed exposure duration and for intentional soil ingestion, the *Interim Report* is not adequately conservative. With respect to the extended backyard scenario, we found that, despite the significant underestimation of certain exposure factors, the average soil cleanup guidelines derived by Los Alamos would be reduced by only about 20 percent if our recommendations for exposure time and soil ingestion were followed. This is due to the approximate canceling of these underestimations by the overestimation of the dose conversion factor for plutonium in LANL's analysis.

Also, the estimated impact of plutonium contamination of surface water in Acid Canyon, while not addressed by the *Interim Report*, is likely to lead to a far more restrictive average cleanup criteria than the extended backyard scenario. The levels of plutonium remaining in the soil at Acid Canyon are likely to be too high by at least a factor of ten. While we have not proposed specific remediation guidelines for Acid Canyon pending further assessment by the DOE of the water pathway, we note that IEER has previously recommended setting a cleanup goal at Rocky Flats of between 1 and 10 pCi/g for transuranic elements.10 While the specifics of soil transport and water contamination would be different at Los Alamos compared to Rocky Flats, the range is consistent with our expectations for the level of residual contamination that may be required at Acid Canyon to protect surface water to a standard of 0.15 pCi/L.

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TABLE 2: CONCENTRATIONS ALLOWABLE IN STREAMBED SEDIMENT FOR DIFFERENT SOIL TYPES IN ORDER TO MAINTAIN THE EQUILIBRIUM CONCENTRATION OF THE SURFACE WATER AT 0.15 PICOCURIES PER LITER

Partition Coefficient – K_d (liters per kilogram)	Plutonium concentration in water (pCi/L)	Plutonium concentration in sediment (pCi/g)
550 (geometric mean value for sand)	0.15	0.083
2,000 (ResRad default value)	0.15	0.30
5,100 (geometric mean value for clay)	0.15	0.77

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1 This article is based on the IEER study by Brice Smith, *Soil Cleanup at Los Alamos National Laboratory: Sediment Contamination in the South Fork of Acid Canyon,* November 29, 2005. The study was undertaken as part of a Citizens' Monitoring and Technical Assessment Fund Grant, administered by RESOLVE, Inc. References can be found in the report, which can be found online at www.ieer.org/reports/lanl/cleanup.pdf.

2 Steven Reneau, Randall Ryti, Ralph Perona, Mark Tardiff, Danny Katzman. *Interim Report on Sediment Contamination in the South Fork of Acid Canyon*. LA-UR-00-1903. Los Alamos, NM: Canyons Focus Area, Environmental Restoration Project, Los Alamos National Laboratories, April 27, 2000.

3 Arjun Makhijani, *Bad to the Bone: Analysis of the Federal Maximum Contaminant Levels for Plutonium-239 and Other Alpha-Emitting Transuranic Radionuclides in Drinking Water*. Takoma Park, MD: Institute for Energy and Environmental Research, August 2005. On the Web at www.ieer.org/reports/badtothebone/.

4 Dose conversion factors are used to convert an amount of radioactivity (e.g, in Curies or Becquerels) into a dose (e.g., in rems or sieverts). The Reference Man model used to develop the dose conversion factors for adult workers was described by the International Commission on Radiological Protection as follows: "Reference man is defined as being between 20-30 years of age, weighing 70 kg [154 pounds], is 170 cm [5 feet 7 inches] in height, and lives in a climate with an average temperature of from 10° to 20° C. He is a Caucasian and is Western European or North American in habitat and custom." (ICRP 23, 1975, p. 4)

5 Steven Reneau, Tom Benson, Randall Ryti. *Interim Action Completion Report for the South Fork of Acid Canyon*. LA-UR-02-5785; ER2002-0544. "Environmental Restoration Project" Los Alamos, NM: Los Alamos National Laboratories, September 2002.

6 U.S. Environmental Protection Agency. *Cancer Risk Coefficients for Environmental Exposure to Radionuclides: CD Supplement*. Federal Guidance Report No. 13. EPA-402-C-R-99-001, Rev. 1, 2002.

7 *Interim Report*, p. 7.

8 U.S. Environmental Protection Agency. *Exposure Factors Handbook*. Volume I: General Factors. EPA/600/P-95/002Fa. Washington, DC: EPA Office of Research and Development, August 1997, pp. 4-18 and 4-20.

9 Bill Richardson, Governor of State of New Mexico, to Stephen L. Johnson, Administrator, U.S. Environmental Protection Agency. Letter dated November 2, 2005. On the Web at www.ieer.org/reports/badtothebone/richardsonltr.pdf.

10 Arjun Makhijani and Sriram Gopal. *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.* Takoma Park, MD: Institute for Energy and Environmental Research. December 2001. On the Web at www.ieer.org/reports/rocky/toc.html.

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which received the lion's share of Chernobyl's fallout.[2] As the plant came into view through morning fog above the marshy landscape, we turned our video cameras to film the icon of 20th century technology gone awry: the gray concrete "sarcophagus" that covers the destroyed reactor. (Instead of wealthy dead Greeks entombed in stone, Chernobyl's sarcophagus entombs an expensive dead nuclear reactor.) Workers riding with us immediately cautioned us to turn off our cameras. Security is tight at Chernobyl due to concerns over terrorism.

Once at the plant, we gave up our passports and pocket knives, emptied our backpacks and purses for inspection, and had our names checked off against a list supplied before our arrival. From our next stop in the observation room we could see the huge sarcophagus as well as radiation monitors on opposing walls of the 30 foot wide room indicating how rapidly the radiation level increases in the direction of the sarcophagus.

The accident and sarcophagus

The 1986 explosion flipped the reactor's massive cap like a coin and left it wedged and hanging askew inside the ruined reactor. The reactor's core caught fire, leading to the largest single nonmilitary radiation release in history, estimated at 100 to 200 million curies of fission products.[3]

The concrete sarcophagus was built over the ruined reactor in about six months by an estimated 250,000 workers working in high radiation conditions. Twenty years of seasonal temperature extremes plus gaps existing in the original structure have produced voids today equaling the area of about 13 American football fields.[4] Birds and animals come and go, radiation leaks out and snow and rain accumulate inside.

Construction of an immense new enclosure completely enclosing the present sarcophagus and adjoining turbine hall is planned. The new structure, with an estimated cost of over $1 billion, will lessen the fear that collapse of the aging sarcophagus could liberate the estimated 10 metric tons of accumulated radioactive dust in the ruin. Other radioactive materials present there include approximately 180 metric tons of fuel or fuel-containing materials, 64,000 cubic meters of building materials, 10,000 metric tons of metal structural materials, and 800–1,000 cubic meters of radioactive water.[5] Following a January 2006 meeting in Kiev, the European Bank for Reconstruction and Development, co-manager with Ukraine of the Chernobyl Shelter Fund, said award of the new shelter construction contract is expected in 2006 with major construction to be completed in 2008. The Chernobyl Shelter Fund is a consortium including the G8 countries, the European Union, Ukraine, Czech Republic, Finland, Ireland, the Netherlands, Norway, Poland, South Korea, Sweden, and Switzerland.[6]

> The 1986 Chernobyl explosion led to the largest single nonmilitary radiation release in history.

The conceptual design of the "New Safe Confinement" shelter was developed by a consortium including U.S. building giant Bechtel Corporation, Battelle Memorial Institute, Electricité De France, and a

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consortium of Ukrainian contractors. The new shelter will be an arch-shaped structure with a maximum height of 92.5 meters (about 300 feet), a length of 150 meters (about 500 feet), and an interior span of 245 meters (about 800 feet). It is big enough to fit three Titanic-sized ships inside.[7] The structure is designed to carry heavy snow loads, withstand earthquakes and high winds, and support four overhead cranes each able to lift 50 tons. While not radiation proof, it will provide a weatherproof enclosure for several generations of workers and the remote-control cranes and metal cutting machines designed to work in high-radiation environments.[8]

To protect workers from the high radiation levels, the new shelter will be assembled about 600 feet away from the sarcophagus. Before construction can begin, the assembly area itself must be stripped of radiologically contaminated soil, including approximately 800 dumps that were hastily dug in 1986 and 1987 to bury radioactive debris from the explosion.[9] One former cleanup worker told me that the dump locations are poorly known, so finding them and removing the contents safely will not be easy.

The town of Chernobyl

The Chernobyl power plant is about 12 miles from the 800 year old town of Chernobyl from which about 18,000 people were evacuated after the accident. Today, the streets are abandoned, weeds have erased people's gardens, house windows are smashed, and rotting apples dot rusty farm machinery. Chernobyl was emptied by a technical disaster its residents hardly understood; like other communities obliterated by the accident, it is a sad place.

But the town is not entirely empty, even though it is against the law to reside there. A few old timers have returned and a few younger families occupy contaminated but rent-free houses. For them, the health risks are outweighed by the free housing. It's a gamble; maybe radiation will never make them sick or not very sick and maybe not for many years. For the elderly, radiation is less a worry. They will die before many cancers can develop. For them, permanent exile from their home is a worse fate.

"Why did they build a nuclear power plant 12 miles from a town of 18,000 people?"

One of the older couples with whom we had the honor to talk, Anastasia and Nikolai, lived through famine in the 1930s under Joseph Stalin's brutal dictatorship and through the Chernobyl accident a dozen miles from their backyard. Anastasia, her smile revealing metal teeth above and plastic ones below, spoke as rapidly as our skilled translator could interpret, while her husband merely smiled and kept his gaze on the ground.

Anastasia was 8 years old when Joseph Stalin, punishing Ukrainian resistance to farm collectivization, sent soldiers through the Ukraine to commandeer the grain harvests of 1932 and 1933. As many as 7,000,000 Ukrainians starved to death in these years.[10] Anastasia described the malnourished, swollen bellies of that time — her own being one of them. Under the Soviets she and Nikolai worked on a collective farm: he drove a tractor and she worked as a school janitor and field hand. She gave her opinion on the Chernobyl accident in the form of a question: "Why did they build a nuclear power plant 12 miles from a town of 18,000 people?"

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QUICK FACTS ON THE CHERNOBYL ACCIDENT

- Early in the morning hours of April 26, 1986, Unit Number 4 of the Chernobyl nuclear power plant exploded during a safety test. Only one and a half minutes elapsed between the time the operators received a computer warning to shut down the reactor and the explosion.
- The fire in the reactor core burned for ten days and contributed to the release of 80 million curies of radioactivity during that time. Relatively smaller releases of radioactivity continued for months afterwards.
- The Ukraine, Belarus and Russia received the most radioactive fallout from the accident, but some fallout reached every country in the northern hemisphere. Hot spots of radiation 1,000 times above background levels were discovered up to 300 kilometers (186 miles) from the plant.
- After some delays, authorities evacuated 130,000 people from the "exclusion zone," a circular area radiating 30 kilometers (about 19 miles) from the plant. Farming and commerce were prohibited in this area. In June 1986, 113 villages outside the exclusion zone were also evacuated.
- Assessments of health impacts vary widely. The official number of immediate deaths (i.e., clean-up workers who received lethal radiation doses) is 31, but this ignores people who became sick in the months and years after the accident. Estimates of additional cancer deaths caused by the accident range from 200 to 600 in the former Soviet Union to 280,000 worldwide, not including the most severely exposed group, the Chernobyl clean-up workers and soldiers, who died as a result of their exposure.

Source: Arjun Makhijani and Scott Saleska, The Nuclear Power Deception: U.S. nuclear mythology from electricity "too cheap to meter" to "inherently safe" reactors. A Report of the Institute for Energy and Environmental Research (Apex Press, New York, 1999), pp. 153–164.

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Anastasia said the authorities told the people nothing at the time of the accident and gave no advice on how to protect themselves from radiation.

While we spoke to Anastasia and Nikolai, my friend Natalia Manzurova listened. Natalia, a radiation biologist and on the national Russian register of those diagnosed with Chernobyl-related illnesses, was one of more than 700,000 Soviet soldiers and citizens sent as "liquidators" to clean up after the accident. She served there for 4½ years and joined our group to provide a first-hand account of the Chernobyl "clean-up." Like many others, Natalia wears a "Chernobyl necklace," the lower throat scar from surgery for thyroid damage from exposure to radioactive iodine. Several times a year Natalia is visited by what she calls "the ambassador from Chernobyl," a metaphor for the frequent colds and lack of energy related to poor immune system function caused by past radiation exposure.

Pripiat

We also visited the city of Pripiat, the original home of Chernobyl's workers and their families. Under the chaotic conditions of April 1986, about 45,000 people were evacuated from Pripiat three days after the accident in 1,000 buses commandeered from Kiev.[12] Told to leave everything but documents, a change of clothes, and a little food for the bus ride, residents were told they would be home in a few days. It was the last time most of Pripiat's residents saw their homes and possessions.

It took some time to appreciate that this entire city was made uninhabitable by an invisible, tasteless, and odorless contaminant. As our bus pushed its way down weedy streets and past low-hanging branches of trees growing out of pavement cracks, I couldn't help but wonder if in a few decades Pripiat would be covered like an ancient Mayan city in the Yucatan jungle.

CATHIE SULLIVAN

Chernobyl nuclear power plant, summer 2004.

Some believe that the Chernobyl accident contributed significantly to the fall of the Soviet system.

These days, Natalia explained, guards and fences control access to Pripiat, but the looting of the town began soon after its people left in 1986. Some of the contaminated goods are now in the possession of unsuspecting people who are being irradiated in their homes by appliances and other items stolen from Pripiat.

Despite the looting and the mountains of contaminated furniture, appliances, and possessions hauled away for burial by the military, signs of bygone lives remain in Pripiat. In an old warehouse, we discovered six-foot tall banners of Soviet leaders still waiting for Pripiat's 1986 May Day parade to begin. Among them I recognized the portrait of longtime Soviet ambassador to the United States, Andrei Gromyko. A ballot box with remnants of red ribbons and an aluminum casting of the Soviet hammer and sickle lay nearby, a reminder of Soviet-style elections in which unopposed Communist candidates "won" 99% majorities. Some believe that the Chernobyl accident contributed significantly to the fall of the Soviet system. Gorbachev's glasnost (openness) policy revealed much repugnant history to Soviet citizens; Chernobyl was viewed as the last straw.

Not far from the warehouse, we found an old carnival with children's rides, a Ferris wheel, and a jumble of dented bumper cars. I imagined kids, now in their mid-20s, riding on their fathers' shoulders and eating cotton candy here 20 years ago. One patch of grass close to the bumper cars measured 1,259 microroentgens/hour of radiation, the highest radiation level we encountered the whole trip, even slightly higher than our highest reading at the plant.

In vandalized rooms of a large kindergarten school we found a toy Soviet tank, wrecked desks, and books lying face down on the floor amid dust and broken glass. The children of Chernobyl's employees were privileged because their parents worked in a nuclear facility. Among the benefits were modern buses, reliable telephone service, and more theaters, libraries, schools, and sports complexes than most Soviet workers enjoyed.

In one corner of the school, I came across a stack of silk screen prints. For 29 years I had been a silk screen printer and owned a print shop in Santa Fe, New Mexico, so these prints were of great interest. Each illustrated a different trade. There were men and women plastering walls, operating earth moving equipment, laying bricks, pouring concrete, and building apartment buildings. I considered taking one with me but the contaminated dust made it too risky a souvenir.

SEE **CHERNOBYL** ON PAGE 10, ENDNOTES ON PAGE 11

CHERNOBYL

FROM PAGE 9

Our last stop in Pripiat was the roof of an apartment building. The year after the accident, Natalia explained, soldiers had removed everything from this building, from TV sets to diapers. Before their work began, other teams visited Pripiat's thousands of apartments to list and package valuables like jewelry and icons for return to their owners. Natalia told us she was on one of these inventory teams. Some items could be cleaned, others could not. To prevent looting, contaminated items like crystal glassware were smashed and fur coats and fabrics were slashed. The value of everything left in Pripiat's apartments was divided by the number of apartments to find an average value. The Soviet government gave each resident the same amount — a good deal for some, a loss for others.

Chernobyl remains a warning for us today.

Soldiers then bundled everything into bed sheets and tossed them out the windows to the street to be hauled to burial sites outside of town. Natalia and her co-workers lived in the town of Chernobyl during this time and rode to and from work in Pripiat in buses that became known as the "crying buses." Occasionally a rider, catching sight of her own possessions being tossed from windows or lying in the streets, would begin to cry. When this happened, conversation on the bus stopped.

SEE **CHERNOBYL** ON PAGE 11

CHERNOBYL'S HEALTH IMPACTS

Much has been written on the health impacts of Chernobyl, from initial reports that only just over 30 people who were emergency workers had died from the accident to estimates of fatal cancers many orders of magnitude greater than that.

While the Institute for Energy and Environmental Research (IEER) has not done an independent evaluation of the data, the following appear to be reasonably sound statements on the health impacts of radiation exposure due to the 1986 Chernobyl accident, based on available and reliable information, the latest science on low-level radiation (the 2005 BEIR VII report of the National Academy of Sciences), and common sense.

A limited United Nations study* indicated the following:

- About 4,000 cases of thyroid cancer, mostly among children in the most exposed populations;
- 59 deaths, including 9 children who died of thyroid cancer and 50 emergency worker deaths;
- An estimated 3,940 fatal cancers among emergency workers and people in the most affected areas.

However, the UN study did not consider the effects on the vast majority of exposed people. In effect, it ignored the linear no-threshold hypothesis—that every increment of radiation causes an increased risk of cancer. Total fatal cancers are likely to be far larger than 4,000 when BEIR VII cancer risk coefficients are used and when exposed populations worldwide are accounted for, including the workers who built the first sarcophagus and those who will build the new containment structure and attend to the damaged reactor for the indefinite future. Total cancer incidence will be roughly about twice the number of cancer fatalities.

Potential developmental deformities are also possible, due to the thyroid glands of children being irradiated, in utero irradiation of fetuses, and lack of adequate medical care for large numbers of people. Damage to the environment, including plants and animals in the affected zone, has also occurred and will likely continue.

It must also be noted that the number of cancers are likely underestimated due to the collapse of the health care system after the breakup of the Society Union, not only in Ukraine and Belarus but also in Russia.

—Arjun Makhijani, IEER

*Chernobyl Forum, Chernobyl's Legacy: Health, Environmental and Socio-Economic Impacts, September 2005. On the web at www.iaea.org/NewsCenter/Focus/Chernobyl/. The Chernobyl Forum is made up of eight United Nations agencies and the governments of Belarus, Russia, and Ukraine. The UN agencies are the International Atomic Energy Agency (IAEA), World Health Organization (WHO), United Nations Development Programme (UNDP), Food and Agriculture Organization (FAO), United Nations Environment Programme (UNEP), United Nations Office for the Coordination of Humanitarian Affairs (UN-OCHA), United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR), and the World Bank.

MORE INFORMATION ABOUT CHERNOBYL

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Swetlana Alexievich, Keith Gessen (translator), *Voices from Chernobyl* (Dalkey Archive Press, 2005)

International Chernobyl Research and Information Network: www.chernobyl.info

Fact sheet of the U.S. Nuclear Regulatory Commission: www.nrc.gov/reading-rm/doc-collections/fact-sheets/fschernobyl.html

CHERNOBYL

FROM PAGE 10

To reach the roof of the apartment building, we climbed 16 flights of stairs littered with shattered glass, furniture and deep with contaminated dust. Going up the stairs, Natalia covered her mouth and nose with a handkerchief. I did the same, but our companions seemed not to appreciate the possible danger of breathing dust contaminated with radioactivity. The sight from the rooftop was worth the climb. Two kilometers away, surrounded by marshes, were the reactor buildings and the sarcophagus. At our feet in all directions was an urban landscape of deserted squares, high-rise apartment houses, and streets being invaded by trees. Painted on a high building wall was the famous profile of Vladimir Lenin encouraging Pripiat to help build the bright Socialist future, while all around us was evidence of the failure that befell that goal.

There are viable alternatives to nuclear power.

Chernobyl remains a warning for us today. The site of a nuclear accident cannot be fenced and abandoned, nor can it be returned to its original condition. Once blighted, contamination will remain for centuries. The health and economic costs are staggering. There are viable alternatives to nuclear power and we must work to see that these alternatives become the accepted technologies for how the world generates electricity.

1. Cathie Sullivan serves on the Steering Committee for Nuclear Watch of New Mexico, a group working on Los Alamos National Laboratory issues. With her colleague, Natalia Manzurova, who served at Chernobyl, she has traveled in Russia and Ukraine speaking with groups of liquidators about radiation health issues. This travelogue represents her views.
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3. Decay corrected to 10 days after the start of the accident. Zhores Medvedev. *The Legacy of Chernobyl*. New York, W.W. Norton, 1990, reprinted 1992. Table 3.1, p. 78.
4. Nuclear Energy Institute, *Source Book: Soviet-Designed Nuclear Power Plants in Russia, Ukraine, Lithuania, Armenia, the Czech Republic, the Slovak Republic, Hungary and Bulgaria*, 5th edition. Washington, D.C.: NEI, 1997. P. 208. On the web at www.insc.anl.gov/neisb/neisb5/. Viewed March 12, 2006.
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12. Medvedev, p. 138.

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