

Science Compromised in the Cleanup of Rocky Flats

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“Science-based cleanup of Rocky Flats,” an article published in *Physics Today* in September 2006, describes the work of a team of scientists who spent several years researching how and to what extent plutonium and other radionuclides migrate in the Rocky Flats environment. Their study, the Actinide Migration Evaluation (AME), produced information used in setting the cleanup levels for the badly contaminated Rocky Flats site. Accordingly, David L. Clark and his co-authors claim for themselves and their colleagues on the AME team a big share of the credit for the cleanup of the defunct Rocky Flats nuclear bomb plant that was completed in 2005.¹ Their claim is apt, but the “science-based cleanup” they celebrate is, as this article demonstrates, an instance of science compromised.

The article by Clark et al. describes the methods and results of the AME project. It is a story familiar to me, because I co-chaired a panel that provided citizen oversight of the AME work. The story as they tell it contains omissions and problems, starting with the scandal with which the AME project began.

A momentous finding

The AME work was preceded by the totally unexpected detection in the exceedingly wet spring of 1995 of substantial movement of plutonium in the near surface soil (vadose zone) at Rocky Flats. This surprising find was made with real-time remotely controlled monitoring instruments set up in the soil on the site by environmental engineer M. Iggy Litaor. An adjunct professor at the University of Colorado, Litaor had for some years worked as a senior soil scientist at Rocky Flats studying actinides in the environment. Over the years he had published more than a dozen articles reporting his findings in leading technical journals.

Litaor estimated that on May 17, 1995, the wettest day of that very wet spring, a quantity of plutonium ranging from 10 millionths of a curie to one-half of a curie² was “remobilized overland” and traveled more than 100 meters down slope. This finding, he said, “challenges the framework of the suggested accelerated cleanup,” because the plutonium migration he detected “was not envisioned under any environmental condition or hydrogeochemical modeling scenarios considered for Rocky Flats.” Indeed, his finding countered

¹ David L. Clark, David R. Janecky, and Leonard J. Lane, “Science-based cleanup of Rocky Flats,” *Physics Today* (September 2006), pp. 34-40.

² One curie is the quantity of any radioactive material that emits 37 billion bursts of radiation per second.

the dogma heard often by the public from Rocky Flats officials, namely, that once in the environment plutonium stays in place. Litaor himself had previously supported this concept, until, as he admitted in a public forum, “Mother Nature” proved him wrong.³

Scandal

When Kaiser-Hill took over as cleanup contractor at Rocky Flats on July 1, 1995, barely five weeks after Litaor’s surprising finding, one of the company’s first acts was to terminate him. Asked at the October 1995 Rocky Flats Citizens Advisory Board meeting if Litaor had been dismissed, Kaiser-Hill official Christine S. Dayton said, “No.” At its next meeting the board learned that she had not told the truth. In response to public outcry over Litaor’s dismissal, Kaiser-Hill retained his services for a brief period, but by this time his research team of graduate students had been dispersed and his field instruments dismantled. Meanwhile, Ms. Dayton was named director of the Actinide Migration Evaluation, a post she would hold for the nearly ten years of the project’s existence.

The foregoing was only the most visible part of the scandal surrounding Litaor and the creation of the AME. Behind the scenes during its first weeks as the new cleanup contractor Kaiser-Hill commissioned a review of Litaor’s work by five scientists, among them Bruce D. Honeyman of the Colorado School of Mines and David L. Clark from DOE’s Los Alamos Lab (lead author of “science-based cleanup” article). Their 33-page critique of Litaor’s work faulted him most pointedly for failing “to address the question of the chemical form, i.e., speciation, of plutonium in the environment.” Speciation is the study of the range of chemical forms an element like plutonium may take under varied conditions (e.g., whether liquid, solid or gas). Clark and Honeyman, who are speciation specialists, in effect were criticizing Litaor for not being themselves. Both, not incidentally, were soon identified as members of the new AME group.⁴

Litaor learned about this dismissive review of his work, which was never made available to the public, only after it was completed. In a written response he said that the main objectives of his work had been “characterization and quantification of the physical processes that control plutonium mobilization.” It was with a “real-time in-situ remotely controlled monitoring system” that he observed the “unexpected phenomenon” of

³ M. Iggy Litaor, *The Hydrogeochemistry of Pu in Soils of Rocky Flats, Colorado: Summary*, Public Presentation, Denver, May 15, 1996; and Litaor, “Open Letter to the U.S. Fish & Wildlife Service concerning its draft plan for the Rocky Flats National Wildlife Refuge,” March 10, 2004.

⁴ “Technical and Peer Review” of M. Iggy Litaor’s work by Bruce D. Honeyman et al. (Subcontract No. KH 353044ED3), September 22, 1995.

plutonium migration under exceptional meteorological conditions, something that would never have been achieved with speciation analyses that in his view “merely study the beaker environment.”⁵

Over a period of at least two years after termination of his Rocky Flats contract, Professor Litaor, having returned to his native Israel to assume an academic post, sought crucial geological data needed to complete a detailed account of his plutonium-migration findings. Neither Kaiser-Hill nor the DOE would provide him with what he sought. I and others petitioned the site on his behalf, to no effect. A full report on Litaor’s important finding thus has never been published. The very wet spring of 1995, when Litaor detected plutonium migration, has been called the equivalent of a hundred-year storm. This means that, on average, the conditions he encountered are likely to be repeated once each century. Due to Litaor’s dismissal, how it happened and how he was subsequently treated, the AME work celebrated by Clark et al. began under a cloud. For some in the engaged public this cloud never lifted.

The question of plutonium solubility

As the AME team began their work, they faced a barrage of questions about plutonium migration at Rocky Flats. Clark et al. say in their article that “researchers hypothesized” that migration happened because plutonium “was soluble in surface and groundwater,” but “the initial models of contaminant transport – ones based on soluble forms of plutonium – were flawed and indefensible.” They never, however, identify the “researchers” or the “models” to which they refer. Litaor, in his numerous public presentations regarding his finding of plutonium migration, never spoke of solubility.

In the context of the AME work, the only person to claim that plutonium moved in the Rocky Flats environment because it became soluble was AME team member Bruce Honeyman of the Colorado School of Mines. At a public meeting on August 20, 1997, he said he had concluded from his speciation studies that up to 90% of the plutonium in the environment at Rocky Flats could become soluble. Asked if this meant it would eventually migrate off the site, he said, “Yes, but additional work is needed to determine the rate of movement.”⁶ He never spoke this way again, and efforts to get him to explain what he had said were brushed aside by those involved with the AME project. Had his exact words not been recorded in minutes of that particular meeting, they might be forgotten by all but a few people with very acute hearing. Honeyman soon stopped attending AME public meetings.⁷

⁵ M. Iggy Litaor to Bruce D. Honeyman, November 1, 1995.

⁶ Record of Meeting Notes, Actinide Migration Status Report, August 20, 1997.

⁷ This author once sent a letter to Mr. Honeyman seeking documentation of misleading remarks he had made in an AME public meeting. A reply came not from him but from John Rampe, a DOE official, saying that in the future any concerns regarding things said by AME

Bioturbation

In an unprecedented 1996 study, ecologist Shawn Smallwood revealed how burrowing animals redistribute contaminants left in the soil at Rocky Flats. He identified 18 species of burrowing creatures at Rocky Flats, all constantly moving soil and any adhering contaminants. They take surface material down and bring buried material up. Major diggers, like pocket gophers, harvester ants, and prairie dogs, burrow to depths of 10 to 16 feet and disturb very large areas on the surface, while coyotes, badgers, rabbits, and other animals move additional soil. Plants loosen soil and create passages animals can use. Smallwood estimated that burrowing animals disturb 11 to 12% of surface soil at Rocky Flats in any given year. Undisturbed soils do not exist at this site. The plutonium, which at Rocky Flats is only partially remediated down to a depth of 6 feet and is not remediated at all below that level, is being constantly re-circulated in the environment. What is now buried is likely some day to be brought to the surface for wider dispersal by wind, water, fires or other means.⁸ In his research Smallwood, who is located in Davis, CA, went onto the Rocky Flats site on three separate occasions in the summer and fall of 1996, each time accompanied by Rocky Flats personnel. He finished his report before the end of that year and two years later published results in a technical journal.⁹ But his findings were totally ignored by the AME scientists. Their final report issued in 2004 states that data on highly mobile species that might transport actinides “are not available and would be difficult and in some cases logistically nearly impossible to obtain.”¹⁰ Smallwood’s study had been completed eight years earlier.

Uptake of plutonium in grass and other plants

An eleven-year study done at DOE’s Savannah River Site in South Carolina demonstrates that plutonium in subsurface sediments at that site moved upward from the buried source material. The authors of this study conclude “that the upward movement was largely the result of invading grasses taking up the plutonium and translocating it upward,” producing a

team members should be addressed not to them but to Mr. Rampe or to Christine Dayton, the AME supervisor at Kaiser-Hill. The documentation I sought was thus never provided, and Mr. Honeyman was allowed to duck his responsibility to be forthcoming with the public.

⁸ Shawn Smallwood, “Soil Bioturbation and Wind Affect Fate of Hazardous Materials that Were Released at the Rocky Flats Plant, Colorado” (November 23, 1996). Report submitted for plaintiff’s counsel in *Cook v. Rockwell International*, United States District Court, District of Colorado, No. 90-CV-00181; see also the transcript of Smallwood’s appearance in court in this case, pp. 3912-4130.

⁹ Smallwood et al., “Animal Burrowing Attributes Affecting Hazardous Waste Management,” *Environmental Management*, vol. 22, no. 6, 1998, pp. 831–847.

¹⁰ Kaiser-Hill Co., *Actinide Migration Evaluation Pathway Analysis Summary Report*, ER-108 (April 2004), p. 23.

“measurable accumulation of plutonium on the ground surface.”¹¹ By contrast, the AME study at Rocky Flats concluded that “uptake into plant . . . tissues is minor.”¹² The Rocky Flats site consists for the most part of prairie grassland. If grass at the Savannah River Site brings plutonium up to the surface, should we not expect something similar to happen at Rocky Flats? Very likely the grasses at Rocky Flats have roots that run deeper into the soil than those at Savannah River, due to the comparably drier climate at Rocky Flats. The question whether the grass at Rocky Flats brings plutonium to the surface presents an uncertainty worth detailed exploration.

The question of plutonium uptake by plants other than grass was much studied in the 1970s and summarized in a report issued by the EPA in March 1979.¹³

The AME conclusion: Plutonium “relatively immobile”

Despite the never explained interlude with Honeyman about plutonium solubility, the AME researchers concluded in their final report that virtually all plutonium in the Rocky Flats environment is in the form of non-soluble plutonium-oxide particles that can be moved by wind or water, that is, by the physical processes of erosion and sediment transport. This conclusion, based mainly on computer modeling, is very close to what Litaor had said a decade earlier. But the AME researchers differed strongly from Litaor as well as the from the findings of Smallwood and the grass research at the Savannah River Site in concluding that plutonium and americium left behind at Rocky Flats “are relatively immobile in the soil and groundwater because of their low solubility and tendency to sorb [attach] onto soil.”¹⁴

¹¹ D. I. Kaplan et al., “Upward Movement of Plutonium to Surface Sediments During an 11-Year Field Study, SRNL-STI-2010-00029, January 25, 2010. <http://sti.srs.gov/fulltext/SRNL-STI-2010-00029.pdf>

¹² Kaiser-Hill Co., *AME Pathway Analysis Summary Report*, ER-108 (April 2004), p. 28; see p. 24.

¹³ EPA, Ecological Research Series, *Plutonium-239 and Americium-2541 Uptake by Plants From Soil*. See at <https://nepis.epa.gov/Exe/ZyNET.exe/9101AEK6.TXT?ZyActionD=ZyDocument&Client=EPA&Index=1976+Thru+1980&Docs=&Query=&Time=&EndTime=&SearchMethod=1&TocRestrict=n&Toc=&TocEntry=&QField=&QFieldYear=&QFieldMonth=&QFieldDay=&IntQFieldOp=0&ExtQFieldOp=0&XmlQuery=&File=D%3A%5Czyfiles%5CIndex%20Data%5C76thru80%5CTxt%5C00000026%5C9101AEK6.txt&User=ANONYMOUS&Password=anonymous&SortMethod=h%7C-&MaximumDocuments=1&FuzzyDegree=0&ImageQuality=r75g8/r75g8/x150y150g16/i425&Display=hpfr&DefSeekPage=x&SearchBack=ZyActionL&Back=ZyActionS&BackDesc=Results%20page&MaximumPages=1&ZyEntry=1&SeekPage=x&ZyPURL>

¹⁴ *Ibid.*, p. 28.

On the basis of this conclusion, Clark and his colleagues can rightly claim that the AME contributed substantively to the final legally binding Rocky Flats Cleanup Agreement (RFCA) adopted in June 2003. RFCA requires cleanup of concentrations of plutonium and americium in the top three feet of soil in excess of 50 picocuries per gram (a picocurie is one trillionth of a curie). But it allows concentrations of 1,000 to 7,000 picocuries per gram at levels 3 to 6 feet below the surface, and puts no limit on the quantity allowed below 6 feet. In adopting these standards for cleanup, DOE and the regulators relied on the AME conclusion that plutonium left in soil at Rocky Flats would remain “relatively immobile” and thus posed no significant public-health risk.¹⁵

But plutonium at Rocky Flats does move

The AME team’s conclusion of inconsequential plutonium migration at Rocky Flats flies in the face of one of their own reports. This report maintains that cleanup of plutonium in the soil at Rocky Flats even to citizen-recommended 10 picocuries per gram,¹⁶ rather than the 50+ actually adopted, would result in conditions of either a 10-year or a 100-year storm in failure at certain downstream areas to meet the Colorado State standard for plutonium in surface water of 0.15 picocuries per liter. He said further that nothing can be done to prevent this problem, because it is not possible to find the source of the plutonium.¹⁷ This contradictory report, though it was part of the AME work, is not even cited in the final summary report of the AME project.¹⁸

Twice in 1997, before this wayward report was written, the quantity of plutonium in Walnut Creek at the downstream boundary of the Rocky Flats site exceeded the state standard.¹⁹ This occurred on several subsequent occasions. The exact source of this plutonium was never identified. The

¹⁵ For a critique of the cleanup including the risk calculation on which it is based, see my “Rocky Flats: The bait and switch cleanup,” *Bulletin of the Atomic Scientists* (January/February 2005), pp. 50-57. <http://www.rockyflatsnuclearguardianship.org/leroy-moores-blog/papers-by-leroy-moore-phd-2/>

¹⁶ Establishing the cleanup level for plutonium in soil at 10 picocuries per gram or less was recommended in a report prepared for the Rocky Mountain Peace and Justice Center by 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 for Rocky Flats* (Takoma Park, MD: Institute for Energy and Environmental Research, December, 2001). <http://www.ieer.org/reports/rocky/toc.html>

¹⁷ Kaiser-Hill Co., T. E. Hakonson, *Report on Soil Erosion and Surface Water Sediment Transport Modeling for the Actinide Migration Evaluation at the Rocky Flats Environmental Technology Site*, 00-RF-01823/DOE-00-93258 (August 2000), p. 51.

¹⁸ Kaiser-Hill, *AME Pathway Analysis Summary Report*, ER-108 (April 2004).

¹⁹ J. E. Law, Rocky Mountain Remediation Services, L.L.C., Memo to D. C. Shelton, K-H. Environmental Compliance, dated August 18, 1997, Re: Recent elevated plutonium and americium in water at RFCA point of compliance, Walnut Creek at Indiana Street.

problem is being handled with engineered controls that divert and dilute the water. Can maintenance of such controls be expected to outlast the plutonium?

Research done elsewhere counters the AME “relatively immobile” conclusion

The AME conclusion that migration of plutonium oxide at Rocky Flats would be insignificant is countered by findings at other locations. A report on plutonium transport at the site of the then-proposed Yucca Mountain nuclear waste repository asserts that plutonium “in oxidized form . . . can be quite mobile.”²⁰ Important recent research has focused on the propensity of minuscule plutonium oxide particles to attach to submicrometer-size colloids consisting of organic or inorganic compounds. Such colloids can transport the plutonium considerable distances in groundwater. Annie B. Kersting et al. reported that plutonium released from an underground bomb test at the Nevada Test Site moved at least 1.3 kilometers (0.8 mile) in 30 years, with “colloidal groundwater migration” the likely means of transport.²¹ A recent study concludes that colloidal transport accounts for the migration of plutonium more than 4 kilometers (2.5 miles) in about 55 years in the subsurface environment at the Mayak facility in Russia. Other studies show similar long-distance plutonium transport in the subsurface environment at DOE’s Los Alamos and Savannah River sites.²² Kersting says regarding the Mayak findings, “we need to get away from this idea that plutonium doesn’t move, because it does.”²³

Mayak and Savannah River are very wet environments, the Nevada Test Site and Los Alamos very dry ones. Rocky Flats resembles the latter two more than the former. If plutonium attached to colloids can move long distances quickly at all these locations, cannot the same thing happen at Rocky Flats? The AME team thinks not, because, in Honeyman’s words, “the very properties that make some compounds good candidates for colloidal

²⁰ Yucca Mountain Site Description, TDR-CRW-G5-000001, Rev 01 ICN 01 – 10. Factors Affecting Radionuclide Transport (http://www.ymp.gov/documents/m2nu_a/sect10/sect10-01.htm).

²¹ A. B. Kersting et al., “Migration of plutonium in ground water at the Nevada Test Site,” *Nature*, vol. 397, no. 7 (7 January 1999).

²² Alexander P. Novikov et al., “Colloid Transport of Plutonium in the Far-Field of the Mayak Production Association, Russia,” *SCIENCE*, vol. 314 (27 October 2006); notes 6 and 8 of this article reference reports of similar long-distance plutonium migration at DOE’s Los Alamos and Savannah River sites; note 10 suggests greatly increased public health risk from such migration at Yucca Mountain.

²³ Kersting is quoted in David Biello, “Colloids in Russia: Have Plutonium, Will Travel,” *Scientific American.Com*, November 10, 2006.

transport – low solubility and high particle reactivity – limit the amount of contaminants that can be transported.”²⁴

Another location where plutonium may be migrating rapidly is at DOE’s Idaho National Laboratory. From 1954 until 1988 large volumes of waste highly contaminated with plutonium were sent from Rocky Flats to the Idaho facility where the waste was dumped in shallow pits on the assumption that many millennia would elapse before the plutonium could percolate down the 600 feet to the Snake River Plain aquifer, the principal water source for large agricultural areas in Idaho. However, a graph published in a National Academy of Sciences report shows dramatic changes in estimates of how long it will take for the plutonium to reach the aquifer, from an estimate of 80,000 years in 1965 to one of 30 years in 1997.²⁵ Asked about this, the AME researchers said two things: First, they assert but don’t demonstrate that the National Academy’s graph “was developed to refer to contaminants in general, and not plutonium in particular.” The burden of proof rests with them. Second, they say that knowledge about actinide migration at INL is deficient because that site has not had the benefit of the kind of work done at Rocky Flats by the AME project.²⁶

The AME group’s claim at being at the cutting edge of science is refuted by the ongoing work of Annie B. Kersting, whose finding of rapid transport of plutonium in groundwater at the Nevada Test Site was mentioned above. Since reporting that finding in 1999, Kersting, a geochemist at DOE’s Lawrence Livermore Laboratory, has intensified her research on actinide migration because of its significance at various sites worldwide, including Rocky Flats. According to a recent article about her work, it is driven by the recognition that, despite very low concentrations of actinides transported from the original source, their “long half-lives combined with their high toxicity make them of particular concern.” Thanks to her team’s research on plutonium, “the most perplexing element on the periodic table is slowly losing some of its mystery about how it travels underground faster and further than anyone at first expected.”²⁷

What about the long-term?

²⁴ Bruce D. Honeyman, “Colloidal culprits in contamination,” *Nature*, vol. 397, no. 7 (7 January 1999), quoted in Christine S. Dayton, Kaiser-Hill, to LeRoy Moore, March 13, 2003 (03-RF-00441), with attachment from AME Advisory Group (CSD-004-03).

²⁵ For the graph and discussion, see Michelle Boyd and Arjun Makhijani, “Poison in the Vadose Zone: Threats to the Snake River Plain Aquifer from Migrating Nuclear Waste” http://www.ieer.org/sdfiles/vol_10/10-1/poison.html.

²⁶ Christine S. Dayton, Kaiser-Hill, to LeRoy Moore (03-RF-00441), March 13, 2003, with attachment (CSD-004-03).

²⁷ Arnie Heller, “Plutonium Hitches a Ride on Subsurface Particles,” *Science & Technology Review*, Lawrence Livermore National Laboratory, October/November 2011, pp. 16-18.

Given the 24,110 year half life of plutonium-239 and the danger it poses if minuscule particles are taken into the body, the cleanup at Rocky Flats, based as it is on the work of the AME team and done with their imprimatur, looks like a short-term solution to a long-term problem. The AME researchers, with all their confidence in modeling, made no effort to predict conditions at Rocky Flats 500 years from now, much less 10,000 or 100,000 years from now.

Conclusion

The most persistent criticism of the AME work is that the researchers relied mainly on computer modeling to reach their conclusion that plutonium left in the environment at Rocky Flats will be relatively immobile. Future sampling could show whether the modeling was correct or flawed. But adequate future sampling is not likely. The affected public thus may never know the validity or invalidity of the AME work. The consequences are not minor, since the government intends to allow public recreation on the Rocky Flats site.²⁸

The authors of “Science-based cleanup of Rocky Flats” write with certitude about realms of knowing that are replete with uncertainties. People of the future, whether near or distant, are not well served by the kind of cleanup done at Rocky Flats, even if it is “science-based.” In a situation like that at Rocky Flats, what is the measure of good science? What would responsible science look like? One doesn’t have to be a certified scientist to venture an answer to this question.

²⁸ After completion of the Rocky Flats cleanup, about seven square miles (roughly three quarters of the site) were transferred from the DOE to the U.S. Fish & Wildlife Service to manage as a wildlife refuge. FWS intends eventually to open the refuge for public recreation. For details on why this should not happen, see my “Plutonium and People Don’t Mix” at <http://www.rockyflatsnuclearguardianship.org/#!eroy-moore/c1m5x> . The four parts of chapter 8 deal with the Rocky Flats National Wildlife Refuge.