WASTE MANAGEMENT: THE MISSING LINK

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ABSTRACT

A historical perspective of the management of radioactive waste is presented, with comments on the institutional and regulatory needs to permanently close the nuclear fuel cycle. The missing link is the lack of a sense of urgency on the part of top officials. The paper concludes that there has been no immediate threat to health or safety; that the increasing inventory of defense waste should be addressed regardless of the viability of a commercial nuclear economy; and that although technology for waste disposal has been available, institutional and budget constraints have encouraged the expediency of deferring action for decades, one year at a time. This expediency is costlier in the long run. It is essential that regulations be based on rational and technically defensible levels of protection rather than on the misapplication of the as low as reasonably achievable (ALARA) principle to specific nuclear activities. The prompt identification of minimum levels of contamination for regulatory concern is urged, as well as the perspective obtained by stating risks, benefits, and costs of implementation in relation to other national needs. The recommendations provided are generally applicable to management of all hazardous materials.

BACKGROUND AND HISTORICAL OVERVIEW

Since everyone's a radiation expert, especially people who don't know rads about it, someone is always dispensing some new conjecture, hypothesis, or hysteria. Now it is our turn to reflect personal philosophy, and institutional endorsement should not be assumed. In sequel, another paper presents the status and approach to management of transuranium (TRU) contaminated materials and the technological needs to properly close this part of the nuclear fuel cycle.[1]

The Department of Energy (DOE), Nuclear Regulatory Commission (NRC), and Environmental Protection Agency (EPA) operate under the basic premise of the Atomic Energy Act (as amended) that atomic energy activities should be conducted and regulated to protect public health and safety. The DOE operates defense facilities safely and effectively under this authority and is exempt from licensing, except for future high-level waste repositories that by law are subject to NRC regulation.

The question of how to manage nuclear waste in the safest and most cost-effective manner is frequently cast in terms of pronuclear versus antinuclear. This results in avoidance of effective approaches because of opposition to either armaments or proliferation or because of fear of nuclear power. This tendency is detrimental to the best interests of the majority. Nuclear wastes exist regardless of decisions on nuclear options and cannot be wished away.

DOE generates nuclear waste from atomic energy defense and from research, development, and demonstration activities. Medicine, industry, and energy have benefited from these programs. The Atomic Energy Commission (AEC) established interim practices for radioactive waste management, including definitions of waste types to differentiate what can be disposed of by shallow-land burial from waste stored awaiting future decisions.

A recent directive[2] (DOE Order 5820.1, Management of Transuranic Contaminated Materials), updated management practices and modified the traditional boundaries between low-level waste (LLW), TRU, and high-level waste (HLW). Alternate practices are considered, based on site-specific analyses of risk and cost.

First, A Little Perspective

To anyone who takes a long look at the history of waste management in this country, the most important missing link will readily emerge as lack of a sense of urgency on the part of top officials. Not that the people responsible for the introduction and early development of the atomic age failed to appreciate the seriousness and the hazardous nature of radioactivity, they did. Not that the atomic planners were casual, capricious, or cavalier about the handling of nuclear wastes, they were not. Still, until recently and in the context of other more compelling issues, not enough priority for plans and funding was given to waste management.

From 1947 to 1952, and until recently, urgency resided elsewhere. These were the years that span the origin of the AEC and its assumption under civilian control of total responsibility for all nuclear activities (including all the atomic weapons production and development activities from the Manhattan Project) up to the establishment of the Atoms for Peace Program by President Eisenhower. These were years of groping uncertainty about such profound and immediate questions as the international control of atomic energy and atomic weapons, and the extent to which atomic weapons would play a role in the defense of the free world. In relation, waste issues seemed small and remote. Then, as now, there were other controlling factors, other priorities, and, as always, there were the preeminent considerations of the budget. Then, as now, technical opinion that waste problems were solvable prevailed.

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To be more specific, let me cite some items from the early part of the 40-year-long history of Hanford waste in Richland. Recall that in the early 1940's, liquid waste containing TRU was discharged directly to the arid ground in trenches and underground cribs. This practice was preceded by extensive analyses of geology, seepage, and migration rates, which established that selective absorption took place in the soil. There was good scientific reason to believe that no radioactivity would reach underground water or the Columbia River. Disposal directly into the ground was recognized as a temporary expedient and underground tanks were soon introduced. The first tanks, constructed during the Manhattan Project, were designed to use half of their volume and were placed on concrete 40 feet underground. Plates of mild steel were welded together to form the inner floor and walls. Mild steel, that is commercial high carbon steel, was used because stainless steel was in very short supply and was required for other much higher priority items such as building reactors.

Vents were provided but no instrumentation was inserted either inside or outside the tanks. The grout underneath the tanks, used for leveling, turned out to be a source of trouble, and it happened this way: waste was put into the tanks and concentrated because there were not sufficient numbers of tanks and, therefore, the radioactive residues became very hot. This heat in turn was transmitted through the bottom of the tank to moisture in the grout and apparently formed pockets of steam which caused the bottom of a few tanks to buckle. During 1950, and for sometime thereafter, from time to time pressure inside the tanks would build-up and would burp or blowout through the vent tubes. This highly radioactive vapor was carried downwind and eventually deposited or crystallized on the ground or adhered to particles of soil, brush, or any available material. After burping incidents, the staff would go out with detectors and pick up by hand every last particle of material which gave any reading of radioactivity.

To prevent the sludge from burping or causing blowouts of radioactive steam, airlift circulators were installed in each of the tanks using the same principle as that in a common coffee percolator. A hollow tube with side vents was inserted to the bottom of the tank, and the heat induced internal circulation. The tanks were kept at about 205° F by adding water, which, in turn, diluted the waste and increased the volume. Therefore, they had to pump out some of the diluted waste, which was put through a condenser, and the concentrated material was returned to the tanks. And so the belching was cured, but now a new problem emerged, what to do with the very low activity condensate from the evaporators. As had been the previous practice, very low activity was put into a trench in the ground.

One trench, full of condensate discharge, overflowed and drained into Gable Lake. In the early 1950's, Canadian scientists discovered that migrating ducks would settle on the lake and feed on the vegetation around the edge. This vegetation had picked up very low-level activity. And so the solving of the burping problem led to an environmental problem, and Gable Lake was examined. Eventually treatment consisted of a well known crop duster whose name was Mr. Wheat (and therefore he was called Buck, Buck Wheat), flying his private plane over Gable Lake and dispersing large quantities of bentonite into the lake to seal the bottom. The bentonite destroyed the grasses all around the edge, and we were able to clean up the radioactivity there so that no further "duck" incidents were recorded.

In the early days it seemed that every problem's solution would lead to another problem, and that all efforts went to put out brushfires as they came up. It is also instructive because that's the way information is obtained. That is the way progress is made. That is the way it's found to do things in a better and more reliable fashion.

For example, we learned that better concrete was needed to prevent moisture from turning into steam that lead to tank buckling problems. The concrete used during early construction had heat-induced breakdown. To include better concrete, stainless steel, and so on, would have raised the cost of the tanks, and therefore not enough tanks could be built. The design of new tanks was constantly delayed one year at a time, and we had to make do with the older style tanks. I recall that even as late as 1974, we were still pushing for better and more advanced design.

I indicated that there was no instrumentation to detect leaks in the early days. The material inside the tanks was monitored and sampled to determine any change in volume. It was through this system that the small leak of 1952 was detected. In order to prevent undetected leaks, instruments were designed and a pneumatic system developed for monitoring outside and underneath the tanks. Hundreds of test wells around tanks, cribs, and trenches were monitored year after year, always finding no evidence of leaks. By 1966 more than 10 years had passed without any problems of leakage, and this probably lead to a certain amount of complacency. A leak was duly recorded and duly presented to the area supervisor but went unnoticed for some time. How strange that a similar situation should occur later in the big leak of 1973.

These and similar situations of the early learning years in waste management are a lesson to us all of the curious, interesting, tedious, and sometimes ludicrous way that science progresses. To understand now, in 1983, the tragic dilemma that the least of our worries of three decades ago, management of radioactive waste, now threatens to destroy the nuclear industry and poses severe problems for nuclear weaponry, requires that we appreciate the special urgencies and fears of the early years.

There is an interesting exception, however, to the general relegation of waste management problems to low priority. This was the outspoken opposition to developing nuclear power on the part of the two men most responsible for the successful production of plutonium at the wartime Hanford plant, Vanevar Bush, President Roosevelt's Scientific Counselor, and James B. Conant of Harvard. Both men feared the radiation hazards from atomic wastes.

In 1947, the AEC had little time for thoughts of the peaceful atom or radioactive waste. Soviet Russia, which at that time had not yet learned how to build atomic weapons, rejected the American/United Nations control plan and was busy trying to build atomic bombs of its own. We had just reported to President Truman that America's supposed shield of atomic bombs simply did not exist, we had no reservoir of atomic weapons. Under those circumstances, the overwhelming attention of the fledgling AEC was on weapons stockpile. Our sole preoccupation was to step up plutonium production for the fabrication of atomic weapons, and it was not long before we built a new plant. Disposal of spent fuel was considered a secondary matter, and the question of producing electricity from such reactors still lay far into the future. The sense of urgency was so overwhelming that I would like to quote from the memoirs of David Lillienthal,[3] first Chairman of the AEC, on this point:

> "In the late afternoon of April 3, 1947, I was in the oval room of the White House. As Head of the newly-created civilian Atomic Energy Commission, I had come to report to President Truman on the atomic energy establishment we had just taken over from the Army's wartime Manhattan District. At this time it was assumed by everyone, the President included, that America had a supply of atomic bombs. In fact, Winston Churchill was declaiming that it was our atomic stockpile that restrained the Soviet Union from moving in on the otherwise defenseless people of Europe. What we of the new AEC had just discovered in taking inventory of nuclear materials and devices inherited from the Army was that this defense did not exist. There was no stockpile. There was not a single operable atomic bomb in the vault at Los Alamos, nor could there be one for many months to come. This news was top secret, the biggest secret of that time; so secret that I did not commit it to paper, even as a part of AEC's secret archive. As I gave President Truman this shocking information, the impact of the news was evident in his expression, I wrote in my private journal that night without hinting at the nature of the subject concerned. He turned to me, a grim, grey look on his face, the lines from his nose to his mouth visibly deepened. At the end of the sobering meeting we shook hands as usual and made our goodbyes. I noted in my journal entry, the President was rather subdued and thoughtful looking, his customary joke on parting was missing, and then in that abrupt jerky way of talking he said, 'Come in to see me anytime, just anytime. I'll always be glad to see you. You have the most important thing there is. You must make a blessing of it or (and a half-grin as he pointed to a large globe in the corner of his office) we'll blow that all to smithereens.' President Truman's injunction to make a blessing of the atom rang in my ears from that day on. In that homely phrase he expressed the hope and purpose of all Americans, scientists and average citizens alike. This became our job, our mission, to find a way to convert the virtually unlimited power of nuclear fission into electric energy for the benefit of all mankind."

But it would be some time before the peaceful uses of atomic energy would become evident and the new Commission set up its priorities as follows: first, to increase the supply of uranium ore; second, to increase the supply of enriched uranium; third, to increase the production of plutonium; and fourth, to increase the fabrication and numbers of weapons themselves.

In 1949, Soviet Russia detonated its first atomic bomb. It is hard now in the context of today's debates about nonproliferation and freeze on nuclear weapons to recapture the shock of realization that the atomic secrets were no longer secret. The argument and acrimony about developing a super weapon, the so-called hydrogen bomb, ended on November 1, 1952, with the successful detonation of the first truly thermonuclear weapon, the Ivy Mike Test, which totally erased the island of Elugelab from the Eniwetok group. Waste management, never considered an unsurmountable hazard or a difficult technical problem, took a back seat.

By 1951, as recorded in the history of the AEC,[4] the demand for more and bigger weapons, showed every sign of becoming more intense. Within the AEC, Commissioner T. E. Murray deliberated over a Joint Committee request for information on the cost of increasing production capacity by 50%, 100%, or even 150%. He supported Commissioner T. K. Glennon's interest in improved reactors so long as the search for efficiency did not take precedent over the immediate need for more production. Mr. Murray was eager to find a new site and a contractor for more production reactors, and he explored with industry ways of increasing the flow of U^{235} from the gaseous diffusion plants. In July of 1951, Congressman McMahon, Chairman of the Joint Committee, and Congressman Mel Price met in the Pentagon with Secretary of State Marshall and Deputy Secretary Lovett. The conversation there reinforced Chairman McMahon's conviction that the nation needed thousands and thousands of atomic bombs, and of the tremendous impact large numbers of nuclear weapons would have on military strategy. Elated to find such a close meeting of minds, McMahon left the Pentagon more determined than ever to end what he considered the AEC's fumbling, half-hearted efforts to build the nuclear stockpile.

The enormous pressure that the AEC was put under by the Joint Committee is a crucial point in the curious history of waste management. The responsibility for lack of progress lies not with the people in the field, not at Hanford, Savannah River, Idaho, nor at the level of the contractors. In all instances, the people responsible for operations came up with ingenious proposals for proper long-term care, but they always became victims of higher priorities. In order to put anything into effect in the Federal Government, there have to be two preconditions, authorization and appropriation. Without them, little can happen.

In 1968, the General Accounting Office (GAO) recommended a vigorous long-term waste management program, including an office within the AEC for policymaking and oversight. In response, an AEC task force made a number of recommendations, including that:

- there should be no need for licensing nor for uniformity of practices at all sites;
- waste should be decontaminated to the extent practicable before being released ;
- HLW should be suitably contained;
- waste stored in tanks should be reduced to solids for long-term storage, or placed deep underground; and that
- we should not preclude the possibility of further recovery of actinides.

It also suggested the early identification and acquisition of future disposal sites and to keep the responsibility for waste management on those who produce the waste.

Partially in response to a 1971 GAO audit, the AEC came up with a plan for: Hanford to continue encapsulation of Cs and Sr and in-tank solidification, start construction of long-term facilities by 1978 and have them operable by 1986; Savannah River to concentrate on bedrock disposal, start construction of an exploratory shaft in 1973 and complete construction thereof in 1976, start facility construction in 1978 and begin placing waste in bedrock in 1981; and Idaho to complete the evaluation of calcine immobilization in 1973, determine safe bin storage life by 1978, and support a decision on immobilization or packaging for repository disposal by 1982.

The Lyons, Kansas, Mine

By 1954, the AEC was sufficiently concerned to ask the National Academy of Sciences to evaluate methods for burying waste. In late 1955, the Academy established a permanent Committee on the Geological Aspects of Radioactive Waste Disposal consisting of prominent earth scientists. The Committee's first report, issued in 1957, contributed a new idea favoring disposal in mined salt. It argued that salt flows plastically and can heal itself, affords radiation protection, has a high thermal conductivity, is usually found in seismically stable areas, and has had no contact with water for millions of year. Ultimately, the Carey mine at Lyons, Kansas, was chosen to test this concept. Beginning in 1965, the Lyons mine was instrumented for study of rock mechanics, heat flow, and radiation flux; and spent fuel elements, along with electric heaters, were installed to represent solidified waste. Thus began Project Salt Vault. Consultations were held with local citizens, and regular mine tours were conducted for the general public.

On March 24, 1970, AEC representatives met with Governor Robert Docking to propose that the abandoned Carey salt mine become a repository for high-level waste. The success of the earlier tests, seismic stability of central Kansas, availability of a 300-foot thick section of salt overlain by 800 feet of impermeable shales, the opportunity to use the abandoned Carey mine, and the hospitality of the people of Lyons were cited in support of the proposal. Governor Docking asked appropriate questions concerning safety of the site and received reassuring answers. His revived interest in safety may have been influenced by a fire at the AEC's weapons facility at Rocky Flats, Colorado. The transuranic debris from the fire had been sent to Idaho, but promise had been made to the Idaho congressional delegation that it would be moved by 1980 to a Federal repository, presumably at Lyons.

The minutes of the meeting reached the Kansas Geological Survey, and at a subsequent meeting, Governor Docking was convinced that the problem was not so simple, particularly with respect to the possibilities for groundwater access to the mine. He committed to a thorough technical evaluation of the proposal.

Meanwhile, a subcommittee of the Academy was completing a report on Disposal of Solid Radioactive Waste in Bedded Salt Deposits. Concerned by the hint of opposition to Lyons, now the focus of the report, the subcommittee invited the State Geologist of Kansas to serve on the committee. On June 16, 1970, the subcommittee met with Kansas representatives for further discussions. Simultaneously, John Erlewine, Assistant General Manager of the AEC, announced the tentative selection of Lyons as a repository. Nevertheless, the subcommittee issued its report in November 1970 and announced that bedded salt is satisfactory for waste disposal if the salt meets design and geological criteria, and that the Lyons site is satisfactory subject to development of additional confirming data and evaluation.

Then began a period of acrimonious and emotional debate. John Lear wrote a paper about "Radioactive Ashes in the Kansas Salt Cellar" in the Saturday Review. It used inflammatory terms such as "ashes of atomic furnaces," "atomic moonshine still," and "Welcome to Kansas, home of beautiful women and the National Nuclear Waste Dump. Please be careful." Emotions ran high as Kansas congressmen entered the debate in press releases, letters to the AEC, and at hearings before the Joint Committee. In August of 1970, the AEC agreed to fund a Kansas Geological Survey study of the Lyons. The final report, issued in March 1971, dealt with the inadequacies of experimental data and identified specific hydrologic problems. Subsequently, the American Salt Company reported that it had lost substantial amounts of water during a hydraulic mining operation in its nearby mine. One should recall that the National Environmental Policy Act, passed in 1969; and now an Environmental Impact Statement (EIS) was required for the site. The EIS received severe criticism, and by February 1972, the repository in Kansas was unofficially dead. A policy of engineered surface storage for HLW was announced in May 1972 but not implemented.

The management of TRU waste has followed a more recent but similarly tortuous path. The curie inventory of TRU is similar to that of HLW but is of much higher volume and lower concentration. It would be interesting to compile its history, including the ups and downs on policy and on consultation and cooperation.

CONTINUED OPERATIONS

TRU is defined as waste that at the end of institutional control periods is contaminated with alpha-emitting radionuclides of atomic number greater than 92 and half-lives greater than 20 years (primarily plutonium) in concentrations greater than 100 nanocuries per gram (nCi/g), and is destined for geologic repository disposal. It decays primarily through the emission of alpha particles, which have short range, generate little heat, and are readily stopped. Radioactive waste with less than 100 nCi/g of TRU is in effect LLW and disposed of in near-surface facilities as appropriate. TRU waste must meet rigorous acceptance criteria for transportation and repository disposal and may require processing before certification to meeting these criteria.

HLW is the highly radioactive mixture of fission products and TRU that results from reprocessing of spent nuclear fuel and that is in concentrations as to require permanent isolation. Decay heat produces elevated temperatures if not dissipated. HLW is of concern because of the simultaneous presence of heat and some TRU radionuclides of high toxicity and long half-lives. Heat from fission product decay diminishes rapidly with time after irradiation and dissipates easily at or near the surface of the ground. Depth generally increases thermal insulation and long-term isolation. After a few hundred years of decay, the heat generation of HLW is not of consequence to repository performance. Because of lower burnup, HLW from defense activities is of lower concentration of TRU and fission products than HLW from commercial reactors and, therefore, poses a lesser thermal impact to the repository. Defense HLW is stored in tanks pending immobilization.

Transuranic Waste

Before the 70's, TRU waste was disposed by shallow-land burial, and about 120,000 m^3 of the buried wastes are above 100 nCi/g. Of the estimated 70,000 m^3 of DOE wastes retrievably stored as TRU, 97% can be contact-handled, and 10% to 35% is virtually LLW. The projected generation rate of DOE TRU waste is 4200 m^3/yr. Stored and newly-generated TRU waste will be sorted and processed, as required, to meet repository acceptance criteria.

Recent developments in management of TRU waste include: a process for in situ vitrification of hard-to-retrieve waste; accurate assaying methods; design of a package transporter; and ongoing site preliminary design validation of the Waste Isolation Pilot Plant (WIPP).

Plans for disposal of most DOE/TRU waste revolve around the WIPP and the procedures for certification of meeting acceptance criteria for this facility. By law, the WIPP is an unlicensed research and development facility to demonstrate the safe disposal of radioactive waste from defense activities.

This segment of the defense nuclear fuel cycle will be closed by implementing updated practices for assaying and sorting, immobilization, and packaging, and by operating the WIPP at full capacity.

HAZARDS PHILOSOPHY

Strategy and regulation for managing hazardous substances should be based on the assessed risk to populations, individuals, and the environment and on a rational determination of what constitutes acceptable risk. A measure of acceptable risk from particular events can be obtained through comparison with the risks of exposure to natural background. It makes no sense to impose controls to minimize an incremental exposure which is immeasurable or otherwise trivial by comparison.

Risk assessment starts with the development of models to predict the mobility of radionuclides, and the identification of scenarios for exposure. This includes scenarios for tapping the water, ingestion, and identification of the size and location of the population.

Ideally one would like to assign uncertainties to each step and provide for confidence levels and realistic results, but due to the difficulties in validating models, decisionmakers have traditionally chosen conservative approaches. It is frequently assumed, for example, that leaching remains constant or increases with time; although the opposite has occurred. Since events outside human experience are considered, deterministic models are not credible unless they are augmented by models relative to observed events or by probabilistic models.

The inclusion of incredibly unlikely scenarios highlights the difficulties associated in estimating risk. A high value is placed on protecting postulated intruders who ignore institutional controls, penetrate natural and engineered barriers, choose to reside in waste and consume only contaminated substances. In some models the postulated persistent intruder generates significantly more health effects than the sum total from all other scenarios. For example, if the intruder is a geological artifact hunter, it makes more difference to the calculated number of health effects, in some models, whether his spouse is interested in geology enough to come with him or not, than the total difference between the various geologic sites being considered.

Responsible regulation requires a balance between the risk (monetary value of the associated detriment) and the cost of reduction or elimination of the risk. In promoting new ideas, the total benefit has to exceed the total cost. If the risk is slight, so should be the cost of compliance with the regulation addressing it.

The efficient use of limited resources requires analysis of comparative risks. The Federally chartered National Council for Radiation Protection and Measurements (NCRP) stated in their Review of Current State of Radiation Protection Philosophy:

> "...numerical estimates of radiation-related risks, even when realistic, are of little use in vacuum, i.e., without comparable numerical estimates of associate benefits, and of risks and benefits for alternative means to achieve the desired end."[5]

If the same safety goals that are applied to nuclear industry were applied to other sectors such as fossil fuel, transportation, chemicals, or even medicine, they would collapse and so could the economy.

To conclude, I'd like to mention a recent model that caught my attention since it grasps to provide the appearance of technical credibility in ascribing health effects where they just don't exist. The extrapolation to very low doses of a linear non-threshold relationship with health effects is standard practice since it establishes an upper limit of risk. Using such relationship, the model used the maximum dose to an individual (a very low dose) to calculate the risk to the most exposed individual, then it postulated large populations to have similar risk and integrated the risks over extremely long periods of time. The result was a couple of postulated health effects per century. The model actually ignored the dependence of risk to dose rate, used maximum individual dose rather than the appropriate average or per capita dose, and inherently assumed that dose is somehow accumulated and passed on through generations until individual health effects are caused. With no regard for cost, such models are used to establish regulations that require large expenditures for compliance.

As stated, standards and regulations must establish protection goals that are technically and economically defensible. The ALARA principle is useful in compliance with regulations but not when used as a generic excuse to rachet down safety limits, regardless of cost, only because of what is achievable.

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