RADIOACTIVE WASTE RECLASSIFICATION

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ABSTRACT

Domestic radioactive waste today is currently loosely classified according to the ten classification categories presented in the DOE's Integrated Data Base Program for Spent Fuel and Radioactive Waste Inventories and Projections. While this data base is fairly complete and helpful, several alternate systems are available including the widely adopted, useful, five-fold classification scheme developed by the International Atomic Energy Agency (IAEA).

In the United States, waste has been classified according to a scheme that has developed as a result of a number of historical and statutory reasons, and for arcane agency jurisdictional reasons. This system results in confusion, orphan waste, regulatory morass, and inequity.

This paper presents a broad review of the current classification system in the United States and proposes a new classification scheme based on the work of the IAEA.

INTRODUCTION

In the preceding five decades of the nuclear age we have developed a series of sophisticated nuclear weapon systems, a global nuclear power industry, nuclear diagnostic and therapeutic medical applications, and a host of other atomic and nuclear applications. What we have not done is solve the waste problems inherent in all these advances in which we take pride.

In part, in the beginning, it was ignorance. Gone are the days when the games of Las Vegas were interrupted to go outside with an atomic cocktail to watch the next test taking place. In the last 50 years we have learned that the benefits we obtain from nuclear energy come with a price - and a responsibility. The next 50 years of nuclear development will take us into the twenty-first century at which time we will have, hopefully, solved some of the waste problems.

We have a fair and improving knowledge of our nuclear waste streams of the past When we look to the future, we normally develop the predicted waste accumulation data on the basis of a no new nuclear power plant scenario (1,2). These data are being presented at the same time as we are reviewing new and innovative reactor designs (3,4,5). In order to effectively deal with future inventories, we will need to have some concept of what the operational waste stream and decommissioning scenarios of the new reactor designs will involve. Repositories receiving waste need to be custom designed for the radioactive waste that they will store. Classification describes the content of the waste and is, therefore, critical.

Classification should be based on such factors as: radioactivity levels, radionuclide half-lives (long or short), radiation type (alpha, beta, gamma), source of radiation (e.g., spent fuel), physical form (gas, liquid, or solid), repository designations, etc. In the United States, the *classification* scheme for radioactive waste as a whole has evolved not only on the basis of the factors listed above, but also on a series of laws and regulations developed by the Congress and governmental agencies (e.g. NRC, EPA, DOE, etc.). In other countries, waste classification is based on physical and radiological factors, but, in some cases, is also dependent on the same historical factors followed in the United States.

This paper looks at this system and suggests a new system based on a model established by the IAEA.

CURRENT WASTE CLASSIFICATION

The DOE Integrated Data Base Program for Spent Fuel and Radioactive Waste Inventories and Projections (IBD) (1,2,6) is an excellent reference to broadly document past accumulation, monitor current activity, and predict future trends in the radioactive waste inventory. In the United States, utilizing the major categories recognized by the IBD, nuclear waste is roughly divisible into ten categories. They are: spent fuel, high-level waste, transuranic (TRU) waste, miscellaneous radioactive materials, by-product material (uranium mill tailings), low-level waste, mixed waste, naturally occurring and accelerator produced radioactive material (NARM)), naturally occurring radioactive material (NORM), and below regulatory concern (BRC). The first five of the list may be roughly classified as high- and intermediate-level radioactive wastes. The last five with the exception of a portion of the mixed waste, may be considered to be low-level waste.

One can also roughly group the interest of the public and private sector bodies in the disposal of the different waste streams. The DOE high level radioactive waste program and operators of nuclear power plants are interested in the disposal of spent reactor fuel and, incidentally, in the disposal of greater than class C radioactive material. The commercial radioactive waste disposal companies, the interstate waste disposal compacts, and certain departments of the DOE are interested only in the low-level radioactive waste generated in relation to the commercial fuel cycle, the institutional and industrial uses of radioactive material, and in certain military applications. The DOE in its capacity as the keeper of the nation's weapons programs and through its related cleanup of DOE laboratories is concerned with yet another part of the low level radioactive waste stream. The DOE and certain commercial operations such as uranium miners concern themselves with the uranium mill tailings remedial action programs. Certain industrial operators, oil and gas production companies, and chemical manufacturing facilities have lately become more concerned about a class of waste originating from naturally occurring radioactive material, known more widely by its acronym "NORM." The DOE, as operator of the nations high energy accelerators, and some large university systems are also interested in the disposal of accelerator-produced radioactive waste.

From the regulatory viewpoint, the NRC is interested in the whole breadth of radioactive waste disposal, but only to the extent that it relates to the fuel cycle. The EPA is also interested in the disposal of fuel cycle waste, but only as a standards setting body. State health departments and, to some extent, the EPA are concerned with the disposal of naturally occurring and accelerator produced radioactive waste The clash between the NRC and the EPA in the setting of standards for the disposal of mixed waste is a well known and widely discussed controversy. The EPA also has some incidental regulatory authority over the operation of the DOE's Waste Isolation Pilot Plant, also widely known by its acronym, "WIPP."

From this brief review, one can see how widely fractured the regulation of radioactive waste is in the U.S. Not surprisingly, state and federal law and the resulting rules and regulations are a hodgepodge of conflicting standards drawn along agency jurisdictional lines.

A LOOK AT CURRENT AND FUTURE WASTE STREAMS

The following discussion looks at some of the current problems confounding waste disposal professionals, and projects some considerations that might emerge in the future. The review is based on a brainstorming exercise between the authors, one of whom is decidedly pro-nuclear and the other who has his doubts. It is not intended to be a comprehensive, or even coherent, discussion of radioactive waste.

High- and Intermediate-Level Wastes

These wastes need to be identified in reference to their position in the overall classification scheme. Spent fuel refers to permanently discharged fuel consisting primarily of uranium, mixed fission products and neutron activated cladding. High-level wastes are fission products developing a high degree of decay energy resulting in heat generation and penetrating radiation requiring the utilization of heavy shielding. High-level wastes which result from reprocessing of spent nuclear fuel present a number of problems in that they occur in a variety of physical forms (e.g., slurry, liquid, sludge, calcine, etc.). Miscellaneous radioactive materials (MRM) is somewhat of a general waste basket term for several high and intermediate nuclear wastes such as greater than class C (GTCC-LLW) low-level wastes that exceed the limits of 10 CFR 61.55, or can be special spent fuel categories, etc.

Transuranic (TRU) wastes are defined in 40 CFR 191 (1985) and DOE Order 5820.2a as being waste primarily developed from fuel reprocessing, from the fabrication of plutonium weapons, and plutonium-bearing reactor fuel. It is further subdivided into TRU waste requiring little or no shielding (Contact Handled (CH), 90% of the volume) and fission product contaminants with energetic gamma and neutron emissions requiring shielding and/or remote handling (RH, 10% of the volume). These TRU wastes contain more than 100 nCi/g of alpha emitting isotopes with an atomic number greater than 92 and have a half-life of less than 20 years. Fifty to sixty percent of TRU wastes are mixed wastes containing both hazardous constituents and radioactive wastes (2). The WIPP site TRU waste repository near Carlsbad, New Mexico will accept only retrievable, defense related TRU waste. TRU waste from commercial operations, remedial activities and decontamination and decommissioning (D/D) will be handled by the Office of Environmental Restoration, EM-40.

Uranium Mill Tailings

Uranium mill tailings are an important radioactive waste problem. Uranium mill tailings are normally more broadly referred to as by-product material type II (section 11.e(2) of the Atomic Energy Act of 1954 refers to the byproducts of uranium mining, as opposed to 11.e(1) which refers to the byproducts of fission). At the end of 1991 only a few operational uranium mining sites remained in the United States; but, a number of abandoned and decommissioned mines and mills still need to be stabilized and monitored.

Mixed Wastes

Mixed low-level waste is a category that has been developed to include a mixture of radioactive waste and hazardous chemicals. The components of the hazardous chemicals are identified within the federal statutes, namely the Resource Conservation and Recovery Act (RCRA). The radioactive components can be subjected to the jurisdiction of the NRC within the Atomic Energy Act or within the jurisdiction of the EPA through the Toxic Substances Control Act (TSCA). The cleanup of at least one abandoned Texas landfill contaminated with radium was determined to be within the mandate of the EPA under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA, also referred to as the "Superfund").

Typically mixed-LLW includes such diverse items as engine oils, medical and research scintillation counting fluids, water treatment chemicals etc. Mixed-LLW of concern is generated by industrial facilities, NRC licensed governmental facilities, medical facilities and nuclear utilities. Mixed-LLW may be further subdivided by hazardous category classification in descending degree of seriousness listed, such as ignitable, reactive, corrosive, or according to the toxicity-characteristic leaching procedure/extraction procedure (TCLP/EP).

The disposal of these wastes are problematic at best as they are typically not uniform blends of hazardous and radioactive waste. Additionally, these wastes may be mixed products of more than one process. A better comprehension of the waste streams that make up this category, as well as the development of standard treatment and preparation and codification for storage are desperately needed (7).

Low Level Radioactive Wastes

Low-level waste is waste that is not classified as spent fuel, high-level waste, TRU waste, or by-product material type II (uranium tailings). The radiation level may be high enough to require shielding for handling and transport.

The U.S. NRC recognizes four disposal classes in sequential order of more careful disposal specifications: A, B, C, and greater than class C (GTCC). The maximum concentration limits for LLW are established in 10 CFR Parts 20 and 61. In classes B and C, wastes may not be liquid or packaged in cardboard containers. Normally, they are packed in low-carbon steel drums. Class C wastes must be protected from inadvertent intrusion by humans and animals (9).

Waste with concentrations of radionuclides in excess of Class C limitations have been judged to be not generally suitable for near surface disposal. Nuclear power plants generate approximately 57% the volume of GTCC wastes. DOE will contribute an additional 33%, with the remaining 10% produced in other categories (1,2,8). A disposal facility for GTCC-LLW is not currently available.

Commercial low-level waste classed as A, B, and C account for nearly 80% of the waste volume shipped to commercial disposal sites. This waste is normally subjected to minimization by either incineration or compaction. Texas LLW shipped to commercial disposal sites in 1991 amounted to 1,503 cubic meters which contained 4,155 Curies (2).

The majority of the nuclear power plants in the United States are Pressurized Water Reactors (PWR)). The amounts of A, B, C, and GTCC waste stream generated by current boiling water reactors (BWRs) and PWRs while operational are becoming increasingly more predictable.

Decommissioning Radioactive Wastes

The current reactors in service are normally given a forty year life span after which they will forward to the process of decommissioning and decontamination which will be the next future challenge. The IDB has estimates to indicate what the cumulative wastes from these reactors will be for the entire system. Low-level decommissioning wastes fall into the general categories of neutron-activated wastes, surface contaminated wastes and miscellaneous.

Currently, civilian reactor fuel remaining at the end of life is directly disposed of. If there is an upturn in the nuclear fuel market, the utilization of the PUREX process to reprocess civilian fuel becomes a distinct possibility. If adopted, challenges would develop in the analysis of the consequent waste streams (11).

Recycling metals with significantly low radioactivity also is an excellent possibility during the decommissioning of a nuclear power plant (12). The major problem is the setting of a threshold value.

Several alternatives are available for decontamination and decommissioning. They are: DECON, SAFSTOR, and ENTOMB (2). DECON means that the nuclear plant site has been decontaminated to a level that permits the property to be used in an unrestricted manner (e.g., Pathfinder Atomic Plant, Sioux Falls, South Dakota, BWR). SAFESTOR and ENTOMB are delay options. SAFESTOR is a facility that can be maintained in such a condition that it can be safely decontaminated in the future to levels that allow unrestricted usage of the land (e.g., Indian Point Station, Unit 1, Buchanan, New York, PWR). ENTOMB refers to facilities that are encased in a structurally long-lived media such as cement or bitumen (e.g., Hallum Nuclear Power Facility, Hallum, Nebraska, sodium-cooled, graphite moderated reactor). The ENTOMB facility should be available for use in 100 years or less.

Decommissioning costs have been estimated to be on the order of $265 million in 1992 dollars for a 1200 megawatt nuclear plant based on earlier EPRI/NRC decommissioning studies (13). LLW from decommissioning has been estimated to be on the order of half million cubic feet per reactor unit.

NARM, NORM and BRC

Naturally occurring or accelerator-produced radioactive materials (NARM) are of current interest and will be of future concern to the nuclear community and others. The DOE must dispose of the low-level NARM produced from its accelerators such as the Superconduc-ting Super Collider (SSC) to be completed in Texas. Several estimates of the amount of NARM waste to be expected from new accelerators have been postulated with the best estimates developed from the Fermi National Accelerator Lab in Batavia, Illinois. Nuclear medicine represents another important contributor to the NARM waste stream (e.g., 57Co utilized for in vitro blood testing)(1,16).

Naturally occurring radioactive materials (NORM) are developed as the result of natural processes that deposit the material. NORM is observed in three decay series: uranium radium, and thorium. Examples of major areas impacted by NORM would be in extractive metallurgy (e.g., thorium tailings, phosphogypsum), geothermal power generation, water purification resin beds, oil and gas production (pipe scale). In the industrial sector and in other areas that have not been considered to be a problem before, NORM now may become a serious issue.

Below regulatory concern (BRC) is in a state of flux at the present time as there is no consistent and publicly acceptable level or safety limit. The problem is the determination of the radioactive base line that is not to be exceeded under normal circumstances. The principle of operation is to set this level as low as reasonably achievable (ALARA), This can be a problem frequently.

The medical profession in standard hospital and clinical practice has been using radionuclides with very short half-lives for some time in both diagnostic and therapeutic procedures. The waste is held to allow it to decay to such a level that it can later be disposed of as non-radioactive trash. The development of BRC levels, however, will be essential in establishing precise procedures for the reuse and recycling of the materials of decommissioning, especially with reference to metallurgical recycling (16,17).

Advanced Reactor Designs

The new and advanced reactor designs of the next generation of nuclear power plants holds both problems and promise. The primary emphasis has been on reactor safety and, secondarily, on greater simplicity in design and operation (3,4,5). It is also evident that greater international cooperation is now a feature as can be noted in the design of the advanced light-water reactors (ALWRs), pressurized heavy water reactors (PHWRs), and fast breeder reactors (FBRs) (4). Operational waste streams and ease of decommissioning should be considered along with the efficiency of the design. It is not clear as to whether this is taken as a priority aspect of reactor design. If not, it should be.

The resurgence of the nuclear power industry accompanied with the construction of a new generation of reactors will lead to new considerations of waste disposal. If fuel reprocessing were to re-emerge as a viable industry, new considerations for high and intermediate level waste repositories would be raised. The need for increased low level waste disposal capacity would occur. New reactor designs could present challenges in the disposal of reactor materials that are new or different in their chemical of physical form.

INTERNATIONAL ASPECTS

The relatively complex framework of waste classification utilized in the United States is a reflection of the system's growth during the last 50 years when there was a gradual shift from military weaponry to civilian application and utilization. This has been accompanied by a growing awareness of safety and the environment. At the beginning of 1992, there were 414 operational reactors units worldwide (238 PWRs, 88 BWRs, and 88 other types) and 59 reactors no longer in service. The U.S. had 111 reactors in service at that time with 15 reactor units no longer in service (3). International cooperation can provide a great deal of information in reference to waste management.

The exchange between countries would be useful as well. The problem is that in waste management, one is not always talking about the same wastes because nearly everyone classifies them differently. France, for example, classifies waste into three categories: A, or short-lived waste, B, or alpha waste (or transuranic), and C, or vitrified waste. Categories B and C are long-lived waste while Category A consists of short-lived low- and medium-level waste. Category A, among other requirements, must have a half-life of 30 years or less, must be safely encapsulated, and may not contain toxic chemicals or flammable materials. The classification is basically founded upon a half-life decay period and an initial radioactivity (19).

The International Atomic Energy Agency (IAEA). has been a prime mover in the effort to promote international cooperation since its inception in 1957. It has acted as a primary source for the exchange of information. With some 113 member states, it has become a major advisor in international problems involving nuclear waste disposal. The IAEA is developing international standards and criteria for radioactive waste management and disposal. It has a number of waste management applicable programs (e.g., RADWASS, radioactive waste safety standards) (20). International technical cooperation is being aggressively pursued in high-level waste by DOE's Office of Civilian Radioactive Waste Management. The same effort needs to be made with the lower risk, more diffuse low-level waste.

In 1981, the IAEA proposed a five-fold classification based on half-life (long or short-lived), type and intensity of radiation, and the general level of radiotoxicity (22). This codification is still useful and relatable to most national systems. It could be the basic framework for an international cooperative classification. If one knows what the class is, one can then evaluate the disposal sites from both an engineering and geological standpoint. One should also be able then to select sites for such specified problems as mixed wastes, GTCC wastes and MRMs on a regional basis. Geological site selection and subsequent engineering are much more logical when based on the character of the material being stored or disposed of.

A PROPOSED CLASSIFICATION SYSTEM

The authors of this paper propose that consideration be given to a new waste classification system for general use in the United States. The system would use the already widely-known categories of Below Regulatory Concern, Low-Level Waste, and High Level Waste. But a new category of "Intermediate Level Waste" would be used as well.

Below Regulatory Concern (BRC) radioactive waste would correspond generally to the IAEA's low-level, short-lived waste stream and the low-level, long-lived waste stream in very small concentrations. For a risk standard, perhaps < 0.1 mrem to the most exposed individual could be used. This waste stream would be unregulated with respect to its radioactivity.

Low-Level radioactive waste would include only low concentrations of intermediate-level, short-lived wastes, or low-level, long-lived wastes. A suggested dose limit to the most exposed individual would be in the range of 0.1 to 1 mrem. This waste would be appropriate for disposal in a standard municipal landfill that met the new EPA standards.

Texas has promulgated a BRC rule that allows certain radioactive materials to be deposited in a municipal landfill. Using the 1 mrem standard and restricting disposal to only the most well-designed and operated landfills, the rule has provided an economical and safe method for the disposal of limited types of radioactive material that could be roughly compared the IAEA's low-level, short-lived category of disposal.

Also taken into consideration in formulating this proposal is the fact that the EPA's new standards for municipal landfills closely follow the NRC's view of a proper landfill for Class A low-level radioactive waste. If intermediate-level radioactive waste with a significant radiotoxicity (roughly class B and C wastes) was separated from conventional low-level waste and deposited in a more secure repository with engineered barriers, similar to the NRC's intrusion barriers required by 10 CFR 61, the new generation of municipal landfills seem to be adequate for disposal of the remaining material (i.e., class A waste).

An intermediate-level radioactive waste repository would be built to contain radioactive waste identified as high concentrations of intermediate-level, short-lived, or intermediate-level, long-lived radioactive waste. The proposed range of dose limitation would be 1 mrem, but not exceeding the current interim limit of 25 mrem. An intermediate level radioactive waste repository would look very much like the new generation of low-level radioactive waste disposal sites that are being built in the United States today. That is, they would incorporate engineered barriers such as concrete canisters, vaults, or other appropriate combination of barriers.

High-level radioactive waste would not change. It would continue to be as defined by the IAEA as high-level, long-lived radioactive waste.

WHY THIS PROPOSAL?

The authors make this proposal in light of the changes that have taken place in radioactive waste management since the promulgation of 10 CFR 61 in 1981. Public opposition to new "low-level" radioactive waste sites has prevented the construction of the classic landfills that were envisioned by the NRC at that time This same opposition has brought any consideration of a "BRC" or "deminimus" rule for disposal of radioactive waste to a halt. In response to this same public opposition, new low-level radioactive waste disposal sites will incorporate some form of engineered barrier in their design.

This use of engineered barriers to provide greater confinement of wastes is at the heart of this proposal. These barriers will allow new sites to far exceed the performance standards established by the NRC in Part 61. To use such expensive facilities to contain low-level, short-lived radioactive material (class A waste) seems to be a misapplication of resources. This is especially true in light of the EPA's new restrictive standards for municipal landfills.

Future waste streams have also been considered in the formulation of this proposal. The new generation of reactors coupled with fossil fuel shortages will surely cause a resurgence in the operation of nuclear reactors. Disposal of NORM will become a more pressing issue after the promulgation of rules by the EPA for the safe handling and disposal of this waste.

New treatment technologies now widely in use such as supercompaction and incineration, as well as processing methods that are sure to be developed by the DOE as part of their environmental restoration research, has changed and will continue to change, the character of radioactive waste. These potentially new waste characteristics should be taken into consideration in the evaluation of waste disposal practices in the not so distant future.

CONCLUSIONS

In conclusion, the authors are suggesting a three part approach. First, the classification of radioactive waste should be restructured along the lines of that adopted by the IAEA in 1981. Artificial classifications based on historical considerations (e.g., pre-Manhattan Project waste vs. post-Manhattan Project waste), source considerations (reactor produced isotopes vs. accelerator produced isotopes), and bureaucratic considerations (e.g., the mixed waste controversy) would be ignored.

Second, what is now considered "higher activity low-level radioactive waste" would be shifted to a new waste category called "intermediate level radioactive waste." Disposal of this waste would require engineered barriers. In conjunction with this, short-lived low activity radioactive waste would be disposed of in municipal landfills.

Third, the authors believe that this new structure could cause a rethinking of waste disposal practices in the United States. This would result in consolidation of resources, better economics, and more safety for the general public.

Finally, the authors suggest that the move toward a rationale classification system should be considered on an international basis. By using one common system worldwide, data on radioactive waste and preferred disposal systems can be compared on an international basis. A system comparable to the DOE's Integrated Data Base Program (1,2) compiled under the auspices of the International Atomic Energy Agency might be desirable.

The authors invite critical commentary on this proposal.

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