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Why We Can Not "Solve" The Radioactive Waste "Problem" With the Current Science, Technology, Regulations and Societal Demands-10085

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ABSTRACT

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The main obstacle to resolving the nuclear waste "problem" is that no one can believe a Department that promises to control the impacts from radioactive waste disposal over the next 1 million years. Further, DOE requires, that one must assume that the human condition, where one lives, what one eats and drinks, what medical treatments are available, what science and technology exist, etc, are the same as they are today. No one can accurately predict the future so one should try for a solution that provides for adequate disposal during the next 100 years without endangering future generations and repeat the process after the 100 years. To make nuclear power an attractive option, we need to reduce the concerns about radioactive waste disposal, proliferation of nuclear weapons and availability of uranium. If one can extract uranium from the oceans, 4.5 million tons, at a commercial scale at an attractive price, no reprocessing would be needed. Disposal of the spent fuel into the sub-seabed sediments where the fissile material would be safe from terrorists and the impact on the oceans and humans would be slight as no one drinks sea water and the chemical and physical dilution is great.

INTRODUCTION-WHAT IS WRONG WITH THE PRESENT SYSTEM?

False Assumptions- Predicting the Future

We can not "solve" the radioactive waste "problem" because the proposed solutions are based upon false pretenses that any literate person can easily recognize and destroy. The major false pretense is that we can predict with a reasonable degree of certainty what will happen in 100 years, 1,000 years, 10,000 years and 1,000, 000 years as required by USA laws [1] and regulations [2] and endorsed by the scientific elites. [3] We can not "solve" the radioactive waste "problem" because the proposed solutions are based on false scientific, technical, philosophical, economic and social assumptions. We only need to look at every day occurrences to realize that accurate predictions for these time periods are patently impossible. If we continue to attempt to meet such requirements even at sites other than Yucca Mountain, we are doomed to failure. First, we must admit that such predictions are meaningless and then move on to objectives that are achievable and are as protective of public health and the environment to the extent possible in an uncertain future.

Of course, philosophers have wrestled with the problem of what do we owe future generations for many years. This is not a philosophical treatise so I shall limit the discussion to a few well known examples. Approximately 2500 years ago, Lao Tsu had the definitive word on predictions, "Those who have knowledge don't predict. Those who predict don't have knowledge." [4] John Rawls wrote that we need "put aside in each period of time a suitable amount of real capital accumulation" so that future generations are at least as well off as this generation.[5] Edith Brown Weiss extended this work to conclude "that each generation leave to its successor a planet in at least as good a condition as that generation received it." [6] In the seminal work on sustainability, the Brundtland report stated "What is needed now is a new area of economic growth – growth that is forceful and at the same time socially and environmentally sustainable." [7]

Professor Milton Russell has articulated operationally how we should approach these problems. [8] For the "near term, say from tomorrow to a few decades from now, I assert that as individuals and in social decision makers for this period, we pretty conclusively prefer near term satisfactions to that which is delayed." However, for times that stretch far into the future Russell points out that the decision about what we owe the future is "far more about how we feel about ourselves when we make one choice or the other". The same views were articulated earlier about the remediation of the Wyoming uranium mining and milling sites "where hundreds of millions of dollars have been spent to protect a population that might be there from 200 to up to 1000 years in the future from statistical deaths." (emphasis added) "Does it make sense to spend those amounts of money now to protect these future generations while allowing so many local members of the population to live below the poverty level?" [9]

False Assumptions- Unrealistic Assumptions About Future Conditions

These false assumptions are further exemplified in one of the latest reports from the Department of Energy, October 2008, and shown as Figure 1, where the radiotoxicity of the wastes are indicated out to 1 million years. Further, radiotoxicity assumes that we eat, drink and inhale the waste for these long time periods with the same diet and physiological responses that we have today, and that is clearly impossible.

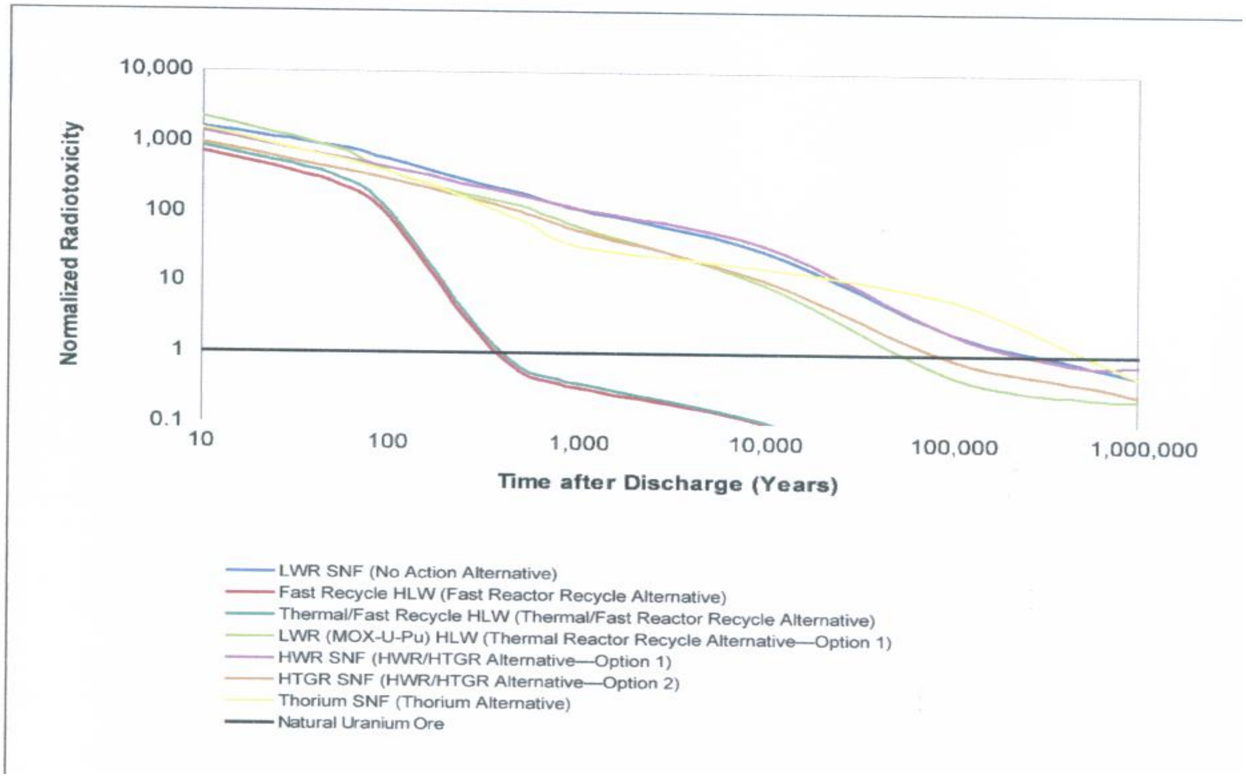

Fig. 1. Radiotoxicity of Spent Nuclear Fuel and/or High-Level Radioactive Waste [10]

False Assumptions- About the State of the Science

Even the physical, chemical and biologic knowledge of movement of wastes in soils and groundwater are incomplete. For example one of our most knowledgeable hydrogeologists predicted in 1961, as shown in Figure 2, adapted from “Research Needs in Subsurface Science”, that radioactive wastes discharged to the earth’s surface at the Idaho National Engineering Laboratory site (now Idaho National Laboratory) would never reach the groundwater table because the annual evapotranspiration so far exceeded the annual precipitation. The ground water table ranges from 200 to 900 feet below the surface with a depth under the most contaminated area of the Laboratory of about 590 feet. However, in less than 40 years, contaminants had flowed that distance and new models had to be created to reflect that fact.

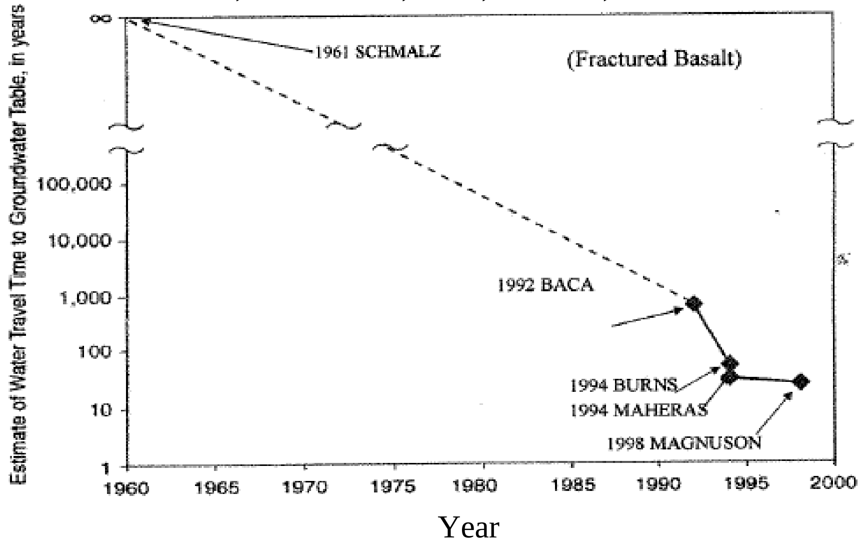

Fig. 2. Estimated time for contaminated water at the surface at INEL to reach the groundwater table. [11]

False Assumptions- Unrealistic Assumptions About the Adequacy of the Data Base

It should also be noted as we extrapolate to the future, we rely upon a very short term data base, a little over 200 years for carbon dioxide concentrations in the atmosphere and a little less than 5,000 years of written records. [12]

Failure of the Present System for Deep Geological Disposal

The history of the attempts to establish deep geological disposal of high-level nuclear waste is long and tragic. The National Academy of Sciences first recommended Deep Geological Disposal for High Level Waste (HLW) at their meeting in 1955 and published the report of that meeting in 1957. [13] The major conclusions for this historical reconstruction were1, "The Committee has considered the complex and varied problems of waste disposal on land and can express **considered opinions** on various of the problems and the research needed to deal with the problems." (emphasis added) and 2. "The most promising method of disposal of high level waste at the present time seems to be in salt deposits."

Scientific Conference on the Disposal of Radioactive Wastes, Monaco, November 1959

Five technologies for vitrification of HLW and the first field tests of the disposal of HLW in salt deposits were described at First International Conference on Waste Disposal in 1959. [14] Five U.S. laboratories reported on successful laboratory scale studies of vitrification of high level waste**.** (Conversion) A. ICPP (Idaho)—Fluidized Bed Calciner Pilot Plant; B. BNL—Fixed on Clay @ 1700°F Pilot Plant; C. ORNL—Pot Calciner @ 600-800°C Developing; D. Hanford Atomic Products Operation—Calcination of PUREX Pilot Plant being Designed; and E. ANL—Calcination of Purex Bench Scale studies. [15] Results of field scale experiments of simulated radioactive waste disposal in bedded salt formations were presented in Disposal of Radioactive Wastes in Natural Salt [16].)

Project Salt Vault

The Nuclear Waste Policy Act established National Policy on HLW disposal in 1982. Congress amended the Nuclear Waste Policy Act and directed U.S. Department of Energy to study only Yucca Mountain in 1987. The U.S. Senate cast the final vote for the development of a repository at Yucca Mountain in 2002. DOE submitted to the Nuclear Regulatory Commission a license application for construction of the repository on June 3, 2008. Secretary Chu announced the abandonment of Yucca Mountain as a waste depository on March 11, 2009. [17]

The experiments with simulated waste were followed by experiments in the Lyons, Kansas Carey Salt Mine with spent fuel from the Materials Testing Reactor at the National Reactor Testing Station, Idaho By 1968, Project Salt Vault had successfully demonstrated field scale disposal of spent nuclear fuel at the temperatures and radiation doses that would be reached in a full scale repository in salt. [18]

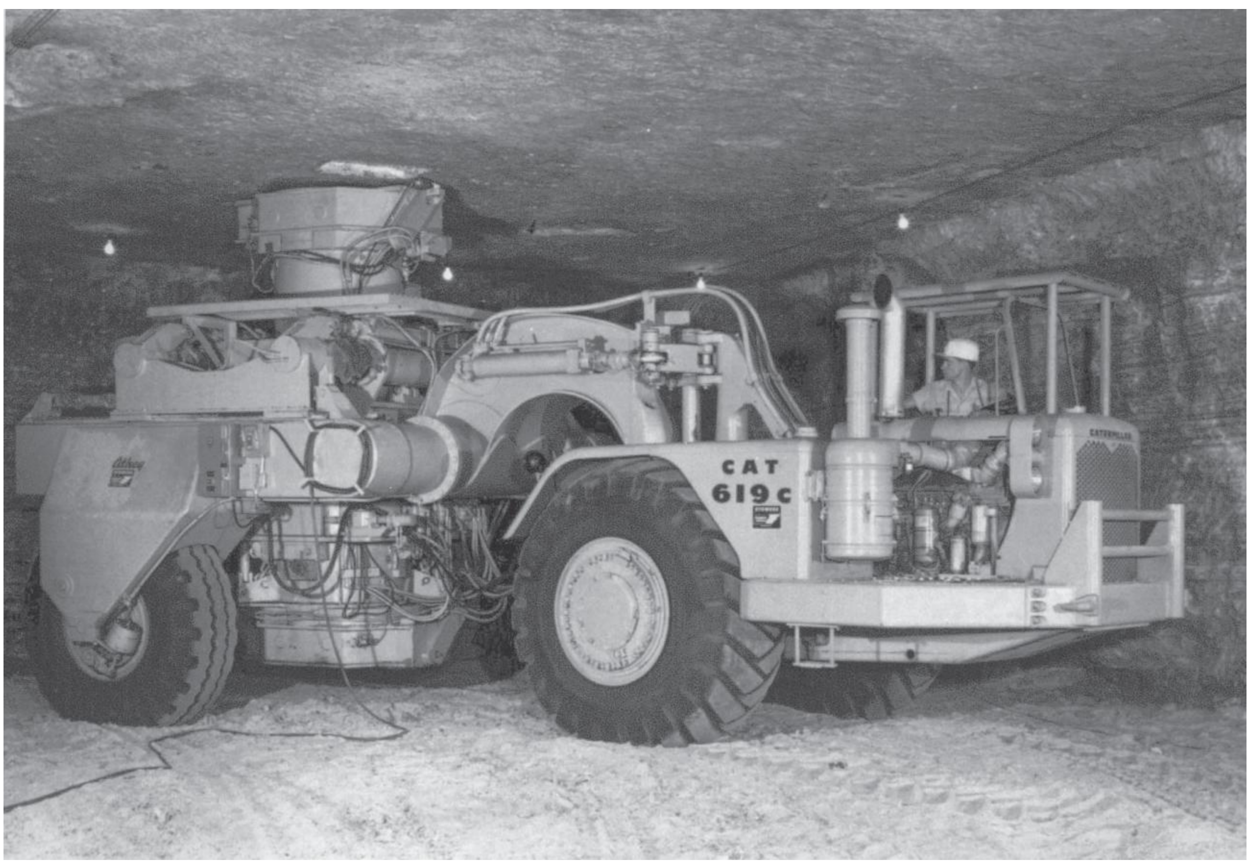

Fig. 3 Underground Spent Fuel Transporter

Following the successful completion of these tests**,** AEC announced in June 1970 a "tentative plan" to make the Project Salt Vault site the first repository at a total cost of $28.5 million for a turnkey facility and to be in operation by 1975.[18]

Failure of the System-High level waste

Where are we now in 2010? There is no vitrification at Hanford, the site with most of the high level waste. No high level waste or spent fuel has been disposed in geologic formations anywhere in the world. DOE's best current estimate to complete Yucca Mountain with a 2017 opening date is about $23 billion (FY 2006 dollars) [19] In addition, GAO also estimated the total costs including closure but used present value costs so that the 2 costs are not comparable. [20] Of course, Yucca Mountain has been abandoned. [17] For comparative purposes, the direct US costs for Iraqi War are approximately $600 Billion Dollars to date and estimates of total costs areas high as $5 Trillion to 2017 [21]

What have we gotten for this? Very little. Right now, some helpful technical information but nothing that would be very useful in the search for a new repository site since it is highly unlikely that the new site will be in the unsaturated zone nor in welded tuff. How many statistical lives have we saved? None.

Failure of the System-Remediation of Contaminated Sites

Though not the purpose of this paper, it is useful to know that in the remediation of the DoE sites, the Environmental Waste Management (EM) Office's regular budget, 2009, is $6 Billion (Milliard) plus $6 Milliard from the stimulus budget. EM's estimated present value costs for cleanup of DOE's sites from 1997 to completion, 2008 data, are $274 to $330 Billion. [22] These costs do not include money spent prior to 1997 nor other costs that EM will incur as other facilities are transferred to them.

Failure of the System-Burial of Low Level Wastes

Further, for the burial of low level waste, Congress passed the Low-Level Radioactive Waste Policy Act December 22, 1980 [23] and further amended it in 1986 [24] to allow states to form compacts to open low-level waste disposal facilities. Since that time no such compact has opened and operated a new low-level waste disposal facility though such a compact is on the verge of opening in Texas. A more detailed discussion of these problems and potential solutions was published in 2004. [9]

Failure of the System-Non-Proliferation

Non-proliferation is a problem that is outside the scope of this discussion but has to be considered as one makes a decision on what fuel to use for energy production. It is a problem that must be considered even if we freeze all energy production from nuclear fission energy today.

Table 1 Stockpiles of Fissile Materials for Weapons (International Panel) [25]

	HIGHLY ENRICHED URANIUM, MT	SEPARATED PLUTONIUM, MT
WORLD WIDE	1400-2000	500 (CIVILIAN 250 MT)
AMOUNT RETAINED FOR WEAPONS	600-1200	
SUFFICIENT FOR NUMBER OF WEAPONS	25,000-50,000	
AMOUNT NEEDED FOR A NUCLEAR WEAPON		"REACTOR GRADE" 8 Kg/SIMPLE WEAPON

According to Wikipedia, the critical mass for 85% highly enriched uranium is about 50 kilograms (110 lb), which at normal density would be a sphere about 17 centimeters (6.7 in) in diameter. Clearly, there still remain many tons of fissile Pu 239 and of highly enriched uranium available to be used in nuclear weapons and not all of it satisfactorily secured. (Wikipedia is quoted as the actual numbers may be classified)

RATIONALE FOR A "SOLUTION"

It is a new economic era. Money is scarce and should be used for enterprises with a future. Do these remediation and disposal measures do this? Obviously not as they only deal with already generated high level waste and contaminated sites though there will be increasing need for spent fuel disposal.. This certainly will not create any new industries with growth potential.

So where does that leave us? To decide that nuclear energy is part of the desired energy mix, we need to take into account both proliferation and nuclear waste disposal concerns. Most other concerns can rather easily be disposed of in any comparison test. On the positive side, again taking into account the entire nuclear fuel cycle, the major advantage is the lack of green house gases production throughout the fuel cycle if the energy used in mining, transporting and transforming the fuel is derived from nuclear energy. Most of the other pollutants are relatively easily handled. Second, the amount of waste is very small in comparison to fossil fuels, the amount of uranium is infinite, depending upon the price one is one willing to pay if one takes into account the uranium in the oceans and very large, more than 1,000 years at the present rate of consumption, if one utilizes breeder reactors so that the U-238-is almost fully used as fuel.

High Level Waste

So now to high level radioactive waste, the waste remaining after dissolving spent nuclear fuel and removing most of the plutonium and uranium it contains. This waste is more than 95 percent of the volume of the initial dissolved material. Admitting that our claims of satisfactory control of nuclear waste for more than 100 years are false will not be easy. The legislative and judicial bodies that demanded such certainty and the scientific and technical elites who guaranteed such control would have to admit that they were wrong.That would cause further loss of trust in such institutions and give greater credence to those who are trying to undermine those institutions. Once we have done our mea culpas, one must propose a solution that is transparently believable and that “resolves” the nuclear waste “problem” as a “solution” in the dictionary sense of the word and that is not possible. Some of the radioactive waste will still be emitting alpha, beta and gamma radiation for thousands and millions of years. As can be seen in Figure 4, the radiation emitted decreases exponentially so that from 1 hour after removal from the reactor to10 years later, only 0.025 percent of the initial radiation emitted is left. The amount of heat continues to decrease with time. However, that is an aggregated amount and does not consider the mobility of the radionuclides in the environment, the bioavailability of the material, their residence time and bioaccumulation in the body and the interaction with tissue, organs and bones.

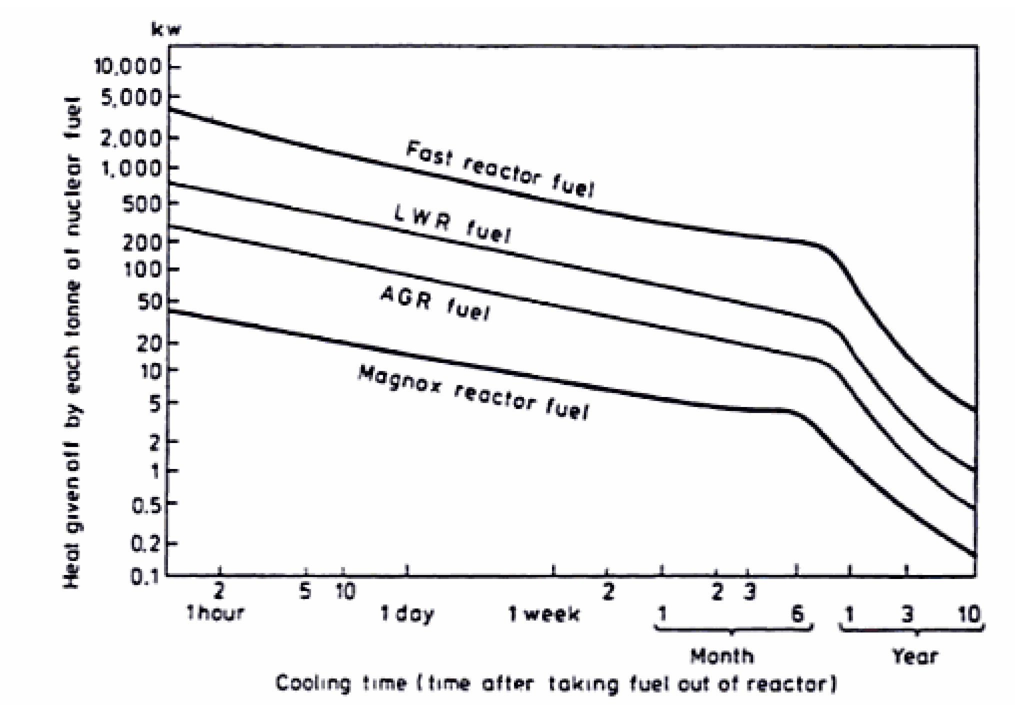

Fig. 4 Heat Release from Spent Nuclear Fuel [26]

The wastes then should be entombed in a geological material whose properties, including leachability, and stratigraphy are well known and in a location that is relatively stable geologically. It must be recognized that, except possibly in massive blocks of sedimentary and igneous rocks, surprises underground will be continuous. That does not mean that such engineered structures will always fail, there are many successful tunnels built beneath waters, through mountains and storage facilities for gas, oil and other commercially important substances. It is also clear that oil and gas can be found in geological formations that may be 250 million years old. Such liquid and gaseous substances have been contained so it should be immeasurably easier to contain solidified and immobilized materials if the surrounding geological material is not profoundly disturbed. It is also clear that the more thermodynamically stable the waste immobilizing material is, the less likely the waste material will be leached into the environment. However, all models in such environments are extrapolations for which there are no entirely similar natural analogues and the extrapolations extend for times for which we have no quantitative data. Therefore,, the facilities must be monitored to determine if they are functioning as designed. If not, then remedial action can be taken and the problems solved by repair, modification or even retrieval if necessary. The malfunctioning parts of the system should in most instances be reversible and if not, retrievable. Reversibility demonstrations should be carried out as part of the design. It is not clear what will be accomplished by retrieval since the "best" sites, immobilization procedures and remediation have already been utilized. Where will the waste be put?

Further, as time passes, the heat released per unit time and the amount of radioactivity decreases so that the driving force for alteration decrease dramatically so that the repositories are safer. Finally, and perhaps most importantly, the intrinsic energy in the wastes by time they are placed in a geologic repository is greatly diminished so that energetic releases are less likely and there is time to repair or modify the facility if so required.

The intent in the earlier years of the program was that the wastes would be taken care of by those who created them. It is clear that the majority of the defense wastes were created during World War 2 and the cold war. No production reactors have been in use in the USA since 1998. (Savannah) Some of these wastes are over 60 years old so that those that created them can no longer take care of them. Further, better methods of disposal are being invented so to some extent we shall leave future generations smaller burdens than we might have than if we had proceeded to prompt burial. Further, when one talks about leaving future generations no worse off than what we received from previous generation, one could say that by using nuclear power for energy, we have left less polluting material for them to deal with if we had used alternative energy sources. In addition, we have left them far more complicated carbon chemicals that have widespread other uses than they would have had.

High Level Waste Disposal

If the present system is so bad, what should replace it? As emphasized earlier, the new system must be scientifically and technologically correct and believable and socially acceptable. Therefore, one should design for periods and with procedures for which we have some hope of being accurate. Such an approach was outlined in the 1990 NAS Report, Rethinking High-Level Waste Disposal [27] (NAS 1990). The flexible approach advocated said: Start with the simplest description of what is known so the largest and most significant uncertainties can be identified, Meet problems as they emerge since there will always be surprises in underground work and Define the goals broadly in ultimate performance terms. It also emphasized that the choices are not between the ideal site and imperfect reality but between imperfect options. The goal must be realistic and if you expect to retain control over every atom of radioactive waste for eternity or even one thousand years, then the "problem" can never be "solved". However, if the "problem" is defined as finding a "sustainable solution", then the "problem" can most likely be "resolved". To accomplish this you must set a realistic objective for the number of generations that you have some concern for, approximately 3-5; Design the system for that time frame but making sure that there will not be a catastrophic release at the end of that period; Since the energy content of even high level waste after that time is low, the releases, if any, will be slow and remedial measures can be taken; and Design the system to be reversible, modifiable and the wastes retrievable if necessary.

High Level Waste Disposal Options

If we agree that we should design these systems to last for 3 to 5 generations and be amenable to changes that would be suitable for another 3 to 5 generations or more if the science and technology are available, then some options that should be considered are shown below. For each option to be considered the following questions should be asked at each stage:

Would we be more or less safe than if we sent the material to a geological repository?
Would it cost more or less than the present system?
Would it more publicly acceptable, that is able to be implemented, in comparison to geological disposal?

Option 1. All spent fuel will be removed from their reactor pools and stored in concrete casks on the surface at the site for the next 100 years. At the end of the 100 year time period, make the next decision. Continue surface storage for another hundred years or decide for emplacement in geological storage-WIPP or similar simple geologic and engineering facility. Would conditions then be more favorable for disposal and at less cost? Just the reduction in heat energy emissions would make it less costly per unit of radioactivity installed. Would we have lasers that would open shafts and tunnels at far lower cost and damage to humans and the environment? At the end of the second 100 year time period, make the next decision and ask the same questions about the options at that time.Etc.

Option 2. All spent fuel will be removed from their reactor pools and stored in concrete casks on the surface at a centralized site for the next 100 years. Then, at the end of the 100 year time period, make the next decision asking the same questions as in a.

Option 3. High Level Wastes are sent to the Waste Isolation Pilot Plant at New Mexico that is already accepting TRU waste.

Option 4 Disposal in deep sea sediments should be reconsidered. The technical results of the international study of disposal in the sea seemed to be favorable. The withdrawal of the USA from the program and the banning of disposal into the sea have terminated any further discussion of this possibility. It should be noted that there were legal arguments that the banning did not include disposal into the deep sediments. The unlikelihood of large environmental and human effects would warrant another look at this option.

CONCLUSIONS

I am sure that there are many more options that could be studied with the premise that the methodology is technically available, the science is correct and the projected outcome socially acceptable. Some of these or other options will be more believable than Yucca Mountain, just as protective of public health and the environment over the same periods as the presently proposed system. The capitol costs will be much lower than the capitol costs for the 1,000,000 year protected facility. If repairs are needed, they can be made with the science and technology and with the social expectations available at that time. These costs on a present worth basis surely will be less the differences between the capitol costs and may even be lower than the undiscounted sum of the yearly expenditures. Of course, these are assertions and the calculations and pilot testing need to be carried out to verify these claims. The calculations should be carried out on a probabilistic basis for all the input data including the range of effect of low doses of radiation from zero to linear as stated in the report of the French Academy of Sciences-French National Academy of Medicine [28] and that of Beir VII [29] It should be emphasized that the present radiation limits are based upon prevention of harm. However, in this instance, the radioactive material is present and the dose limits should be based upon overall limits of effects while keeping the upper limit at a level that is acceptable to society.

It is likely that in the time available before a final decision is made that much work needed to improve the scientific status, utility and public credibility of risk assessment. could be carried out. [30] The Committee's recommendations, such as giving as much emphasis to the utility of risk assessments as to the methodology, should be heeded. Therefore, risks should be done on a life cycle analysis basis. The comparison should be based on realistic alternatives, not idealized alternatives that would be technically and economically impossible to achieve. The comparison should also take into consideration the likelihood of long term increased economic activity if the proposed actions are undertaken. The comparison should take into account the intra-generational and intergenerational benefits and costs.

Will there be opposition? Of course! Whatever is attempted will cause controversy but the objective function should be primary-Will there be sufficient energy for human welfare without sacrificing the environment or the future? We need to remember that the primary reason to avoid the use of nuclear energy and perform the cleanup now is to avoid the production of and/or secure the existing fissile materials. Will the suggested action make fissile materials more or less accessible? That is a serious question that needs to be answered. There still remain major political problems. How do public officials explain their demand for absolute control for these long periods when it is patently impossible to do so?

However, as is well established, admitting the truth and then moving on is always the best solution. Any other course only leads to further misinformation and then even greater public mistrust. As Thomas Mann wrote, "In the long run, a harmful truth is better than a useful lie." [31]

There are many books that argue that for such complex problems that extend over long periods of time, there can be no mathematically optimal solution and that the major problems are the exogenous ones that we do not know how to forecast. Such books include The Black Swan [32] (Taleb), Muddling Through [33] (Fortun) and Clumsy Solutions for a Complex World-Governance, Politics and Plural Perceptions [34] (Verweij). They describe ways to work your way through these difficult problems and/or how to prepare for various end states even though they do not know when and if they will occur. After spending the whole book describing means to sort through these problems, the final sentence of Muddling Through is **"Let's Hope It Works**".[33]

It will not be easy. As Nicolo Machiavelli wrote about 500 years ago "the reformer has enemies in all those who profit by the old order, and only lukewarm defenders in all those who would profit by the new order." [35]

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