



## Nuclear Waste: What to Do With It? (1979)

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NUCLEAR WASTE: WHAT TO DO WITH IT?

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## FOREWORD

Robert R. White  
Director, Academy Forum

This publication is the report of the second Forum of the 1979-1980 series on nuclear activities, held at the National Academy of Sciences on November 19, 1979. Forum Moderator E. Bright Wilson of Harvard, aided by Forum General Advisory Committee Chairman Daniel E. Koshland, Jr., of the University of California, Berkeley, focused the discussion on what we know and what we need to know about the management, transport, and disposal of nuclear waste.

Other Forums in this series are "Nuclear Radiation: How Dangerous Is It?" (September 27, 1979); "The Safety of Nuclear Reactors" (Spring 1980); and "Practical Alternatives to Nuclear Energy and Oil" (early Summer 1980).

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## INTRODUCTION

Daniel E. Koshland, Jr.

Professor of Biochemistry  
University of California, Berkeley

I would like to welcome you to this session of the Academy Forum and to open with a few preliminaries before I turn the program over to the Moderator. I am Chairman of the General Advisory Committee of the Academy Forum which has the responsibility for selecting subjects to be discussed and choosing the panel to discuss them. I am particularly pleased with the distinguished group we have before us at this time.

I might tell you a little about the Forum's objectives to understand the function of the evening. The Academy Forum deals with various issues at the borderline between science and society. It is not required, as are many other Academy committees, to come to a decision, but merely to present to you the conflicting viewpoints or the degrees of consensus present around the subject.

We have in the past had Forums on seaward development, recombinant DNA, drug safety, and so forth. Tonight, the second of two Forums on the subject of nuclear energy, the question of nuclear waste disposal will be discussed. The last Forum was on the health hazards of radiation. In the future we will discuss reactor safety and other problems.

We will focus on only one subject tonight. The format we follow is to consider various questions that the panel has agreed on in informal discussion ahead of time. That the panelists have agreed on the questions doesn't mean they've agreed on the answers, as you will hear. This discussion will be moderated by Professor Wilson of Harvard University to whom I will turn over the program in a minute. At the end of each period of panel discussion we will throw the Forum open to the audience for some questions.

The questions designed by the panel will proceed from a general area of what do we mean as acceptable safety, to such questions as do we have the technology now to store wastes, to questions of transportation, storage for appropriate intervals and so forth.

I will not repeat details printed in the program about our distinguished speakers who have many awards and credits to their names. But I will give you a word about each when introducing them. I should emphasize that each is invited as an individual expert in his own area and does not speak for any institution. They may on other occasions, but tonight they're here to give their own views as experts in these areas and don't represent necessarily Harvard or Stanford or the Congress of the United States, et cetera.

Perhaps starting from right to left, Dr. Bertram Wolfe is the distinguished contributor, scientist, patent holder and so forth. He is an expert on nuclear energy and is probably the one on the panel who has the most "hands-on" experience in dealing directly with nuclear power plants, waste disposal and so forth.

Next is Kenneth Arrow, Nobel Laureate and distinguished economist.



Being in the science profession, sometimes I am not sure in my heart that we consider economics a science. But Kenneth Arrow comes as close to being a scientist as I can imagine. He is a member of the Academy Forum General Advisory Committee and, in addition, of course, to the importance of economics to nuclear power, is an expert on the evaluation of risks and benefits.

Konrad Krauskopf is a Professor of Geochemistry Emeritus at Stanford University. One of the key problems of nuclear waste disposal is to think in terms of geological time and not just the next few months or even the next election.

Terry Lash is a distinguished scientist and eloquent advocate of a point of view in regard to nuclear disposal problems. We searched the country for individuals we thought were the best in their field, and I was enormously impressed at the high regard given to Terry Lash by both the people who are to the left and the right of him.

Congressman McCormack, we're particularly pleased to have you here as it's hard for members of Congress to come for evenings at any time. Mr. McCormack has the distinction, in addition to being a leader in Congress, of being one of the few scientists in that body. Moreover, he was a working scientist at the lab bench, which gets enormous respect at the National Academy of Sciences.

And finally I want to introduce E. Bright Wilson, who is a distinguished theoretical chemist. He contributes in many ways to not only pure research but to the National Academy of Sciences and is at the moment Chairman of the Academy's Committee on Radioactive Waste Management.

Before turning the program over to Dr. Wilson, I'd just like to say that I think you're in for a very exciting evening. I heard a story the other day of a little girl who was drawing pictures for a class in which the children were told to draw pictures of familiar objects. One child drew a chair, another a house, and so on. This little girl had a rather peculiar picture. When the teacher asked her what she was doing, the child said, "I'm drawing God." The teacher said, "Nobody knows what God looks like." The little girl said, "When I finish, they will."

I think tonight when we finish you will know what to do about waste disposal. Professor Wilson.

**E. BRIGHT WILSON:** Thank you, Dr. Koshland. Although we have here a panel of people who have specialized knowledge in various sides of this problem, the problem as stated is really too big for us and we're going to have to narrow it down considerably to accomplish anything.

The first part of our program will be centered on the question: Can we now safely dispose of wastes? But we have to lead up to that first, so there will be some introductory material. Before I begin that, I'd like to set some more boundary conditions.

There are many kinds of nuclear wastes, and we are going to be mainly concerned here with wastes from spent fuel from civilian nuclear power plants. We must point out that there also are large amounts of military wastes. In fact, their volume is a lot larger than that of the power-plant material at the moment. Finally, there's a very large and

widespread volume of what we call low-level wastes from thousands of hospitals and laboratories. We'll come to that, I hope, toward the end of the program.

Our spent fuel can be put in many forms. For example, we could just take the fuel elements that have been used in a reactor. Depending upon your interpretation of President Carter's position on this matter, spent fuel rods currently can be considered as one form of waste, with a lot of hardware and zirconium cans containing uranium dioxide, all contaminated by highly radioactive fission products producing dangerous radiation and a good deal of heat. This radioactivity will decay in a relatively short time compared with the other kinds present.

These other kinds of radioactive products result from the neutrons from the fission reaction activating other elements in the hardware, cans, and uranium. Some of this material produces very long-lasting actinides which are lower in radioactivity but ultimately become the more dangerous part of the spent fuel over a long period.

An alternative to storing away the spent fuel assemblies is to reprocess the spent fuel -- separate out the unburned uranium and the fission products. Several alternatives exist, one of which is also to separate the plutonium produced in the reactor.

These reprocessed wastes can take many forms at the option of the designer. The alternatives include liquid solutions, solids, and materials incorporated in glass beads or ceramic pellets. So we have to worry initially about the dangerously radioactive fission products such as strontium and cesium, and then in the long term we have to be concerned mainly about radium and other daughter elements. The low-level wastes are a somewhat different problem that we'll try to discuss later.

Coming then to our program, the central topic of the first part is whether nuclear waste can be managed safely and for a sufficiently long time. It seems to me that's the \$64,000 or the \$64 billion question. But first we have to discuss what we mean by safely. What are the bad consequences that we're worrying about, and how long is long enough?

At this point, I'm going to call on members of the panel to elucidate these points. Let's start with safety and the bad consequences. Of course, we're worried about the radioactivity getting out from wherever we put it and getting into people or into the biosphere in general.

I'm going to ask Dr. Lash how we can set standards of comparison in this situation. Do we say a plan is bad because it's worse than something else, or good because it's not so bad as something else? Do we have any yardstick we can go by?

TERRY R. LASH: When I was first asked some of these questions I was reminded of a congressman who was complaining about scientists because they always said, "Well, on the one hand, but then on the other hand...." He wanted only one-handed scientists. But I'm going to be unable most of the evening to be a one-handed scientist. And when I'm asked questions about what is the level of safety that would be acceptable for waste disposal, I can refer to some measures that we can use for comparison. But, I'm not certain that we know precisely how to gauge when a waste disposal facility would be safe enough.

The measures of comparison all deal with human health, because the primary hazard that would arise if large quantities of wastes escaped is human disease, particularly cancer. I use as a rule of thumb that during the first 1000 years of disposal of the wastes, we should plan not to have any of the wastes escape into the general environment.

Following that initial period of the greatest toxicity of the wastes, I think we should set a standard such that the expected release of radioactivity would result in exposures to people that are far below background radiation. I'm not quite sure what I mean by "far below" background radiation, because it depends in part on how many people are exposed to that low-level radiation and the cumulative cancer deaths that may arise.

I do not think that we should use as a basis of comparison of safety the benefits of nuclear power nor the risks associated with other waste disposal problems than from nuclear power. Once you expand your horizon beyond the nuclear waste itself, many other factors come into play and it's a more complicated procedure.

WILSON: I wonder if Dr. Wolfe would comment on this.

BERTRAM WOLFE: I would agree with Dr. Lash's criteria in a practical sense. That is, I believe we can dispose of wastes so as to meet his criteria. But in approaching the problem I would set some bounding criteria and then look for ways to improve on them in practice.

For example, a minimum criterion might be that the adverse effects of the wastes should be no greater than the effects of wastes or other adverse effects from an alternate source of energy. In other words, if wastes are going to be used to decide whether we should go forward with nuclear energy, then in a broad sense the major criterion should be that the effects of the wastes should be no greater than the effects of the wastes of a replacement energy source. Otherwise, you run into the paradox of eliminating nuclear power but having health effects from, say, coal or some other source which might be greater.

Although I believe that particular criterion is one that philosophically should be considered, from a practical standpoint it's much too gross. I believe it's easy to meet that criterion. I would step down one level and say in a more practical sense that the effect of waste storage and disposal should be no greater in terms of public radiation exposure than the normal variation of background radiation that one receives. If one moved from a wood to a brick house this would add about 10 millirem to the annual radiation exposure. If one moved from here to the Rocky Mountain states that might add 50 millirem per year. Thus, as a reasonable minimum standard for assessing waste-disposal schemes one might require that over long periods, the waste should affect the radiation which people receive by no more than these normal variations which people accept in moving from place to place and doing normal things.

These first two criteria might, in a sense, be criteria which can be used to help decide whether to move on with nuclear power. But to determine thereafter how one should proceed with the actual disposal of

nuclear waste, I would agree with Dr. Lash's criteria, which say in general that we should attempt to find means -- and I think these can be found -- where the radiation effects on the population are, in fact, substantially below the normal variations in background radiation that people expose themselves to just because they're living beings on this planet.

WILSON: I wonder if Professor Arrow would defend risk and benefits in this connection.

KENNETH J. ARROW: Yes, I'd be glad to. It seems to me the natural question that arises is the comparison between the nuclear waste disposal and the whole cycle of which it is part, on the one hand, and the good that you get out of it. In this case, the most natural way of measuring the good you get out of it is to consider the alternative sources of energy that would be displaced by nuclear energy. In fact, as Dr. Wolfe did point out, it would be pointless to demand a safety level for nuclear waste disposal that is so high as to prevent it from being achieved and then go to another cycle that has higher health hazards. There are many health hazards in the world other than nuclear radiation and, although we have difficulty in a quantitative assessment, we know very well that burning fossil fuels and releasing the products in the air is likely to be one of them. We know we have every evidence that it produces significant mortality due to respiratory diseases and other causes.

I'm not a scientist, as Dr. Koshland has pointed out, so I can merely quote others. But it has been argued that there may even be as much radioactivity put out by burning coal as would come from, let's say, potential nuclear waste leakages or other aspects of the nuclear fuel cycle. So it seems to me that the argument should insist that a minimum criterion is comparison with the alternative energy sources, and it's a very reasonable one.

I will say, to be careful about it, that this comparison is a little more complicated than it might appear at first sight. As Dr. Lash at the very end hinted, the point is a comparison of the total nuclear fuel cycle with the total, say, coal cycle and not merely a comparison of this particular aspect of the fuel cycle we're discussing today -- namely, waste disposal. That's only part of the story. There are other aspects of the matter that we're not taking up today.

So I say, therefore, speaking very roughly, that the risks from nuclear waste disposal have to be very considerably less than the risks from combustion products. But with that qualification, I think the principle is clearly one where risk-benefit analysis applies.

WILSON: Congressman McCormack, would you say something on this? You know there are state laws that essentially require a shutdown of nuclear energy unless the waste problem is solved. I don't know whether these have any standards built into them.

MIKE McCORMACK: There have been laws passed in some states that would prohibit nuclear power plants from operating beyond certain dates

if there is not a demonstration that nuclear wastes can be safely handled. However, these laws would really not have any standing in federal court if they were challenged.

I'd like to respond more specifically to the question about the standards that could be or should be met. I don't think it's possible to say in a scientific community that we have to or that we could remove all wastes from the biosphere in a literal sense, as scientists are inclined to use the word. We do have semantics problems at this point. The scientific community always has difficulty communicating with the nonscientific community in dealing with words like absolute or certain or all or none.

But I believe that we can easily set standards for handling nuclear wastes that will reduce the threat to human beings to a level far below that, as far as radiation is concerned, which we get from normal ordinary background that all of us receive every day. The level would be far below that which would be provided by the best of all control systems for our coal plants.

Incidentally, I wanted to comment on what I think Dr. Arrow was referring to when he spoke of the entire fuel cycle. I presume that he was referring to mill tailings associated with the mining of uranium as being part of the overall problem. I certainly would agree that's part of the problem, but so indeed is the mining of coal and the black lung disease that accompanies it for which we're spending a billion dollars a year today.

I want to cite just one bit of information for you from hearings that were held in Washington State two years ago, not by me but by another congressman, on nuclear energy safety. This information relates to the Hanford reservation, which happens to be in my congressional district, and which, I think one would have to say, is probably the most contaminated of all of the major nuclear sites in the country because of the very large defense activities that have been carried out there since 1943.

The question was on the environmental impact of radiation on the surrounding area. Information was provided by the Environmental Protection Agency and by the Pacific Northwest Laboratories, which runs independent contracted surveys of the area for the Department of Energy. The average dose was 0.002 millirem per year to the people in the area from the entire operation, including the storage of all of that defense waste, which is the largest repository of defense wastes in the United States and not nearly so well packaged as we will ultimately package wastes from our nuclear energy program. When you realize that the average dose to a human being is about 170 millirems per year and the impact from Hanford was 0.002 millirem per year from this very large complex that has a lot of contamination, one begins to put the whole question into context.

In the same hearing the question arose about the problem with tritium contamination in the river. It was pointed out by the same research organization that the amount of tritium from natural cosmic ray bombardment and traces from nuclear weapons fallout normally getting into the Columbia River, which flows through the project, was 350 times the

concentration that came from the plant itself. And finally, the total dose to the population in the area was 0.5 person-rem from airborne effluents and 0.2 person-rem from liquid effluents, as compared to a total of 24,000 person-rem from natural background.

So I think it's obvious that we could very easily package our nuclear wastes and, in layman's terms, totally remove all of them completely from the biosphere forever.

WILSON: Dr. Krauskopf, do you have something to contribute?

KONRAD B. KRAUSKOPF: I don't have a great deal to add to what has been said. I would certainly agree with Dr. Lash that our objective ought to be to keep radionuclides out of the biosphere altogether for 1000 years or even for longer than that. I doubt that that can be guaranteed. If we have to set an upper limit I think the limit that Dr. Wolfe proposed, the variations in the natural radiation all around us, is a good criterion.

Another criterion that is often used in this connection is the radiation from natural ores of uranium. I think the maximum permitted by this criterion would be about the same as that set by variations in ambient radiation.

WILSON: Thank you. I just wondered whether your conversations with the Swedes had provided any enlightenment on this particular question. They demand absolute safety.

KRAUSKOPF: Dr. Wilson refers to the fact that I am currently involved with a review of a report published in Sweden outlining a possible method for disposing of nuclear waste. The Swedish power industry prepared this report because the Swedish parliament had passed a law forbidding the loading of fuel into additional nuclear reactors until a method had been demonstrated for disposing of nuclear waste with absolute safety. This term "absolute safety" had caused a good deal of argument among the Swedes, as you might imagine. In the report that my committee has been reviewing, the Swedes have adopted the two criteria that I just mentioned -- some of them using one and some the other. The Swedish government agencies to whom the report is addressed evidently regard criteria of this sort as satisfactory in judging compliance with the requirement of absolute safety.

LASH: I'd like to comment since I'm in the uncomfortable position of having a number of people with whom I usually disagree agree with me.

First of all, my allusion at the end of my comments about the unreasonableness, in my opinion, of comparing the hazard from radioactive waste disposal to the benefits derives from the fact that nuclear power, in my view, has many risks associated with it. The mill tailings disposal problem is one; reactor safety is another. To that I add the one that's of greatest concern to me: the threat of widespread proliferation of nuclear weapons, including those in the hands of people who are terrorists or subnational groups.

I was on the National Academy of Sciences panel assessing the comparative risks and impacts of alternative energy sources, and the majority of the panel found it extremely difficult to compare the risks of, say, the use of coal to generate electricity with nuclear power -- so difficult that no specific numerical comparison could be reached; indeed, no final conclusion could be reached, and the panel agreed that both coal and nuclear should be avoided to the extent possible through conservation and use of solar energy. So, I submit that as a practical matter, we cannot make the kind of comparison that Professor Arrow urged upon us.

I would also like to remark about the Swedish situation in case it was not clear from what Professor Krauskopf said. The Swedish government did not adopt a zero release forever criterion as the one for absolute safety. They relied on rather normal radiation protection standards for that.

And furthermore, I point out that the geologists in Sweden who were given the task of finding a block of granite that was big enough to handle the wastes from future nuclear power plants in Sweden could not find such a block of granite, and, as a technical matter, they did not meet the law. But initially the government overruled the geologists, which removed the barrier to operating a few nuclear power plants. Before they could begin operation, however, the Three Mile Island accident occurred, and the government agreed to have a referendum on nuclear power, which will take place early next year.

WILSON: I think we're probably ready to go on to the next preparatory subtopic, and that is -- how long do we have to hold this waste so that nothing significant gets out into the environment? Congressman, would you have a comment on that?

McCORMACK: I have a piece of obsidian at home which is about 4 cubic inches, about 1.6 inches on the side, which represents all of the high-level wastes for the entire nuclear program for the rest of the century for one person in this country; one person's share of all of the wastes in all of the nuclear plants in the country for all the rest of the century. If we have about 600 plants on the line at the end of the century, there would be about 4 cubic inches of this material.

The obsidian, as many of you know, is very much like a bar of silicate glass. It's between 15 and 20 million years old. This has been duplicated at Hanford with full-sized containers of high-level commercial nuclear wastes in a demonstration. They have already done studies with the canisters spiked with cerium. They have run them out, as far as radiation equivalence is concerned, to more than 2000 years with no damage. There have been theoretical and computerized models. They have shown that the glass would last its entire lifetime and still be a solid obsidian glass, quite the same as you've seen obsidian when you've held Indian arrowheads or other pieces in your hand.

My point is that we can take all of the high-level nuclear wastes, with the exception of the inert gases, confine them as part of the glass molecule, pour them as molten glass into these canisters, and seal them

shut in the steel canisters for deep geological burial. For all practical purposes, they will be there for millions of years. And you would just simply remove the wastes from the biosphere forever. Of course, the wastes are decaying, and within 1000 years the radiation level is down to the radiation equivalent of the uranium ore from which the fuel was originally made. In 600 years, you've gone through 20 half lives, or reduced the activity level for cesium and strontium to about one millionth of its original activity.

So it seems to me that tying it up in a bar of silicate glass or a calcium alkali silicate glass or any one of the other glasses that are available or other solids, even concrete, you take the material out of the biosphere for all the time that's needed and in some cases a lot longer. I think that's what we can do routinely and inexpensively. The French are doing it every day. That's what we can do and that's what we should do.

WILSON: So your answer to the question is that you don't have to worry about the time because this glass will take care of it almost forever.

McCORMACK: Certainly.

WILSON: Dr. Krauskopf, do you have a comment on this? I've heard everything from 100 to millions of years from various people and I'm a little confused myself.

KRAUSKOPF: I wish I could be as optimistic as Representative McCormack is. It seems to me that the situation is not quite that simple, although I do agree that solid waste forms can be prepared which will slow the release of radionuclides for the necessary long times.

The glass that Congressman McCormack describes is stable as long as temperatures are reasonably low. I'm worried, however, about the stability of the glass for very long periods if the temperature in a waste repository rises, say, above 100° or 150° Centigrade. Regardless of the particular temperature, if ground water eventually gets in contact with the glass, there will be some dissolution of the radionuclides. Depending on the kind of repository and depending on the kind of rock in which it is located, you can imagine various ways in which ground water might carry the dissolved material to the biosphere. The amount will doubtless be small, but I'm not sure that glass can be depended on to keep it small enough unless the temperature is maintained at a low level.

In answer to Dr. Wilson's question about the length of time that is necessary for isolation of the waste, or at least for keeping the release of radionuclides very small, I agree with Congressman McCormack that a matter of 500 to 1000 years probably should be sufficient.

You've doubtless heard other figures, ranging up to a million years or even ten million years. The difficulty here is that the radioactive waste is complex; it contains many kinds of radioactive materials, some of which decay much faster than others.

The two radionuclides that are most hazardous in the first few



hundred years are strontium-90 and cesium-137. Certainly these two must be kept out of the biosphere as completely as possible. After about 500 years -- the figure is a little indefinite but it's on that order -- both elements will have decayed far enough so that they are no longer a problem. Thereafter the radioactivity of the waste is confined largely to the heavy actinide elements and the daughter products that result from their radioactive decay.

These elements, of course, are still dangerous. They would be especially dangerous if, by some strange accident, a repository should be split wide open and its contents exposed to the air so that dust containing actinide elements could become airborne. A situation that would lead to this kind of accident, however, is difficult to imagine.

If the actinide elements and their daughters stay in the repository, most of their compounds are very insoluble and would not be picked up by ground water to any appreciable extent. The small amounts that did dissolve would be largely adsorbed on mineral surfaces as the ground water moved. Therefore it seems to me that these elements, which have very long half lives and which will continue to emit relatively feeble radiation for periods of hundreds of thousands or millions of years, do not constitute a very great danger. The intensity of radiation from waste, in fact, after about a thousand years is little greater than that from the radioactive material of a medium-grade uranium ore deposit. This is why, like Congressman McCormack, I pick a figure of 500 to 1000 years as the time during which isolation of the waste is most essential.

This becomes a very important point. If we have to design a repository that will isolate the waste for a million years, we face a very difficult geologic problem. We simply do not have the ability, so far, to make geologic predictions with assurance that far into the future. For 1000 years, on the other hand, we can make predictions with considerable confidence. So the kind of repository we will need, and the amount of research necessary before building it, will depend very critically on whether we expect it to isolate waste for 1000 or 1,000,000 years. In my opinion, 1000 years would be ample.

LASH: I would certainly like to see Congressman McCormack's colleagues in the U.S. Congress adopt as a matter of law that we will contain these high-level wastes absolutely and forever. That would make my life a lot easier.

Unfortunately, I don't think the solution is possible in an absolutist sense, and I disagree with the statement that glass is so stable that under repository conditions over these long periods of time it will contain the radioactive waste.

There's no doubt but that during the first 1000-year period the wastes are the most toxic. That does not mean, as Dr. Krauskopf has indicated, that there is no hazard remaining in the wastes after that period of time. So I think we should break the problem down into two time periods, the first 1000 years or first few hundred years, and then a very long and extended period after that.

I think that this relates to my initial remarks that after the first 1000 years we should be thinking of a series of mechanisms that we have

a high degree of confidence will restrict the inevitable solubilization and release of the wastes from the repository to such a small amount that relatively few people can be expected to be exposed to radiation at anything more than a few percent of background.

Unfortunately, making predictions about the behavior of those mechanisms is very difficult. We have to rely on various quantitative models both for predicting the behavior of wastes in geological formations as well as for predicting the behavior of radionuclides in the environment once they get out.

That suggests to me that we may have to use analogs, and one analog that we may be able to use successfully is comparing the behavior of the high-level wastes after 1000 years with the behavior of the original uranium ore from which the wastes were derived. There are, in fact, a number of people now who are making assessments of how we can compare the hazard posed by uranium ore to the hazard of the high-level wastes after the shorter-lived fission products have decayed for a period of, say, 1000 years.

If we can make those comparisons realistically, then I think we'll have a proper standard for judging the acceptable level of safety of repositories.

WILSON: What do you think is the risk from intrusion, of people going into these places either accidentally or on purpose years from now when everybody has forgotten about them, and anarchy has reigned for half a century or so?

LASH: One of my greatest concerns is the unintentional removal of the wastes or the intrusion of wells in the vicinity of the wastes in the future, such that the wastes will be released in greater amounts than we would now predict. That type of scenario is not incredible, particularly when the U.S. Department of Energy is seriously contemplating disposal of wastes in salt domes in the Gulf Coast states. These are particularly attractive geological formations for a human activity, including removal of the salt and utilization of the space occupied by the salt domes. In fact, we already are using salt domes for the storage of oil in the strategic petroleum reserve. Removal of the salt is not now routinely monitored for radioactivity. If such an operation happened in the distant future some hundreds of years from now, there could be very serious exposure to people from that removed salt containing the wastes.

WOLFE: I want to respond to several comments that have been made. I'd like to go back to Dr. Lash's comment that he didn't think you could compare nuclear energy with other sources of energy. I'll bypass his remark about proliferation and won't mention, for example, the counter view as expressed by the head of the National Academy of the Soviet Union, that without nuclear energy we increase the risk greatly of a nuclear holocaust because nations will be fighting over the oil in the Mideast. I just point out that one can argue that point on both sides.

But if we're going to decide whether to go ahead with nuclear power or not go ahead -- or with any other activity -- we ought to understand the

basis upon which the decision is being made. The polls show that the biggest public concern about nuclear power is the waste. Thus, we ought to set standards which relate the problem of wastes from nuclear plants with wastes from alternate sources of energy.

To put that in some perspective, consider, for example, just the solid wastes from a coal plant. If one looks at its hazard index -- that is, the amount of water to dilute it to a nonhazardous level -- one finds that the solid wastes from a coal plant and a nuclear plant are about equal after a few hundred years. But in the case of a coal plant the waste is placed near the surface. Some states require that it be at a level that won't be affected by, say, a 100-year flood. But these wastes, of course, do not decay at all, so they remain for millions of year -- forever. Thus, if nuclear wastes are a determining factor in the decision to proceed with nuclear power or not, one ought to compare the wastes to what would result if we didn't go with nuclear. This should include, as I'm sure Dr. Lash would agree, the effects of conservation or insufficient energy.

With respect to the time scale, I would like to add my perspective. The waste is hazardous over the first few hundred years due to the penetrating radiation from the cesium and strontium that Dr. Krauskopf mentioned.

After about 500 or 600 years the nuclear wastes have about the same hazard potential as the uranium ore from which they were originally derived and emit the same kind of radiation -- namely, alpha radiation. Nuclear wastes should be isolated from the biosphere for both the short and the long term. In my view, one should do as much as possible to isolate it forever. But after about 500 years, as I said, the wastes have about the same hazard as natural uranium. We should be able to find a location that is further removed from flowing water than natural uranium deposits. Studies by the Environmental Protection Agency -- hardly a roaring pronuclear organization -- conclude that the hazard from naturally occurring ore bodies is higher, for example, than the hazard from nuclear waste buried in suitable salt deposits even including the probabilities of extreme accident conditions.

WILSON: Dr. Lash, do you have a rebuttal?

LASH: The problem with high-level wastes, as I wish to emphasize, is greatest during the first 1000 year period, due not only to the toxicity but due to the heat that's released from the fissioning of atoms.

However, it is very difficult for anyone, EPA or Dr. Wolfe, to make solid comparisons of the hazard of high-level waste disposal with coal wastes or uranium ore because we don't have a system to evaluate that hazard with. There's no doubt that under the scenario that wastes buried in a salt dome are removed from the salt dome and spread about, many more deaths would result than from the coal wastes or the uranium ore. And the question is whether we're going to take appropriate measures to prevent that kind of accident from happening. Since a major effort of the U.S. Department of Energy is to locate salt domes in the Gulf states and put the commercial high-level wastes there, I'm not convinced that

Dr. Wolfe's statements are correct.

WILSON: Dr. Arrow, I hope you'll talk about ethics and the discount rate, among other things.

ARROW: You're right, that's exactly what I was going to talk about. I'd like to introduce another aspect, another dimension, to the question of how long we should be concerned about the hazards.

I think in all our dealings with the future, if we're going to analyze what we do every time we make a decision about the future, we shouldn't treat the future on a par with the present. We have, in the ordinary commercial sense, a discounting of the future. It's reflected in ordinary transactions through an interest rate, and I think society not only should but does, in fact, act similarly in all its relations to the future. In other words, somebody 50 years hence or 100 years hence is not valued at the same level as we value ourselves today. There are various reasons why I could defend that position, and if pressed I will. But I think it's fairly clear that we always do that.

You see, we're concerned here about the hazards of what might happen in 500 or 600 years. By any rate of interest you can think of, let's say even something as low as 2 percent, the value of anything that happens 500 years from now is extremely small.

Now, you may say, well, what about the ethics of this; we are imposing the risk upon the future, imposing a cost on the future, a potential cost. Supposing the best attainable standards are such that we have some risks 500 years from now. I am saying, if we have the 2 percent discounting per year, it won't come to anything. Others may say, look at the ethics.

Well, we're imposing a cost on people 500 years from now in innumerable ways. For one thing, every time we use up coal or oil, we are imposing a cost on the future; a cost that not only is an economic cost but one that undoubtedly will have health effects. On the whole, one of the main contributors, if I may be parochial, to the improvements of the standards of health in the world has been improvement in economic conditions: better housing, better food, and all the rest. This comes as a result of actions that have been taken. It comes as a result of the existence of energy and other resources.

In fact, undoubtedly a considerable part of our present high standard of living is due to the accumulation of capital, the fact that people in the past did not consume everything they produced, but they left some over for accumulation of buildings and machines and investment in research and development and all the rest of the forward-looking transactions of society. Now, to the extent that we save for the future, this is a comparison for any possible additional injuries in the matter.

So for this reason I think the idea of looking ahead more than a few hundred years really doesn't make much sense. We're not talking here about large catastrophes, we're talking at best about relatively small hazards; and it seems to me when you consider those in perspective, they're small.

There is, of course, a second reason which should be obvious to all of you when you start talking about these long periods of time. We simply don't know what's going to happen. We have no idea what the future will bring. Two hundred years ago no one would have anticipated where we are today. Whether something is good or bad for the future is very hard to assess. And while I think it behooves us as rational, prudent people to look ahead a certain distance in the future, I think it's an illusion to suppose that we can look ahead 500 years and have any idea whether leaving nuclear wastes would be good or bad.

As far as the particular example of unexpected intrusion, it strikes me as being so improbable that it's to be compared with some of the most minor risks. The volume being taken up is relatively small; the probability that somebody, not knowing that there's nuclear waste there, will go into it -- without any examination for radiation, without using techniques which, I presume, will be a good deal more advanced 500 years from now than they are today -- and hit that spot, a relatively small area, seems to me one of the very unlikely possibilities of history.

I am not, by the way, depending on record keeping. I'm quite willing and prepared to believe that in 500 years no one will know where the wastes are. When one looks at the keeping of records, even in modern, highly efficient organizations -- I wouldn't want to count on that. Records will be on computers, and there may be cosmic rays or other interferences with the memory, and I just wouldn't want to count on it. Not to mention the fact that nobody will think of going into the memory and looking for the records even if they are there.

So it's not dependent on record keeping or anything of that kind. It's the idea that people, if they know there's a large amount of waste, will take precautions.

Reference has been made to the possibility that civilization will suffer considerable damage, that techniques will go backwards, that people will lose track of what happened. There is certainly no way of precluding these possibilities; history certainly has not been a record of uninterrupted progress. If those conditions are to prevail, I think that event itself is far more significant and far more costly than any possibilities of some kind of a dangerous discovery. The hazards here are quite small compared to this.

WILSON: Are you counting in your discount rate the probability that we'll blow ourselves off the planet and that there won't be any people around here a million years from now?

ARROW: That would certainly increase the discounting of the future.

In this context, by the way, on the question of proliferation and what we may have to do about that -- this is, of course, getting off the topic here but it must loom a lot larger than many other risks -- some aspects, not of what the standards are but of how you handle wastes, are related to the possibility of proliferation.

WILSON: Do you have something more?

LASH: I'd just like to say that I think even a softer science, if

there is one, than economics is ethics, and I feel quite uncomfortable in discounting human lives if we can estimate them. I understand what you're saying, but I think you would agree that if we can take reasonable measures to reduce that probability, we should.

ARROW: Let me not in any way deny or be attributed as denying that last statement. Obviously, in the first place, we certainly agree that there is a period of a couple hundred years where we're all concerned. It also seems to be agreed that that's the period of most intense radioactivity. And, of course, if as many people certainly argue and have even suggested already today, we can maintain maybe not a zero probability of risk but extremely small probability of risk for a very long period of time at quite moderate costs, and maybe even at high cost, by the way, that's a gain which maybe is well worth it by any kind of benefit-cost analysis.

I may say, by the way, that the proper measure of high cost or low cost in the disposal really should be thought of in relation again to the total fuel cycle. In other words, to the cost of electricity that results from it. And I think it fair to say and I may come back to this point later, that quite exceedingly expensive methods of waste disposal, as compared to other methods of waste disposal, make only a minor variation in the cost of the final electricity. Therefore, it does certainly pay to err, if at all, on the side of high standards because I don't think the costs are very great, relatively.

WILSON: I think we've come to the end of the preparatory remarks. It seems that we have a measure of agreement that the fluctuations in natural background provide a reasonable basis for comparison. It seems to be roughly agreed that the first 500 years are the hardest, and that nevertheless we ought to do the best we can on the scale of hundreds of thousands of years. And there's some feeling that this is easy and others think it's not quite so easy. So let's go on then to the main question, which we're going to put in two different parts. The first question is whether it can be done now. In other words, can we safely store these wastes with what we know now, if we start tomorrow to dig the place and put it away? And if we've answered that one, and suppose it comes out in the negative, then the second question is whether we are quite sure that it can be done somewhat later. Can we prophesy with a high degree of certainty that just give us a little more time and this can be done?

So the first question is -- Can it be done now? I wonder if Dr. Wolfe wants to start out on that one.

WOLFE: I believe it can be done now in the sense that we have the technology to engineer and start the construction of a repository in which these wastes could be emplaced with high assurance that they would remain indefinitely.

Having said that, I think I should, at the same time, point out that we haven't yet done it. We have mined salt in deep mines, and my choice for the first repository is salt because we've done the most work with

salt. Nevertheless I would expect that in a large construction project where one is looking for very high quality salt deposits -- or, say, basalt -- I would expect that there would be construction difficulties of one sort or another. In large construction projects one always runs into difficulties.

In my view, those difficulties would not be difficulties of basic feasibility. They may be site-related difficulties or normal construction problems. Allowing for such difficulties, I believe we do have the technology to develop a repository and to emplace the wastes safely.

If I may go back one step -- we also have the technology to glassify the wastes. It's being done routinely in France at the present time. It has been done in a small-scale operation at Mike McCormack's Hanford laboratory. The glass technology is in hand. Encapsulating a fuel element, if we go without reprocessing, is a technology that is certainly available.

Thus, to take the fuel elements from a reactor; store them as we're doing now in water pools; then either reprocess them or encapsulate them; build a repository and put the glassified wastes or the encapsulated fuel elements into the repository -- I believe all the elements of that technology are here. I would anticipate that in the construction of the repository and other facilities we would have the normal construction and shakedown problems.

McCORMACK: I do think we could go ahead today and with an orderly program. As a matter of fact, we already have it started.

Having said that, I want to back off just one point and say that I find myself in the interesting position of setting much higher standards for myself, for the country, and for the technology than Mr. Lash seems to be willing to accept. I think this is an interesting situation. I am convinced from my knowledge of the technology that we can reduce the exposure to human beings, to the population in general and to the biosphere in general, to a very small fraction of the deviations in ordinary background radiation today.

Let me explain what I mean when I say that we have already started on an orderly program. At this time we are mining in basalt, that is, volcanic rock, at the Hanford Reservation a series of test holes into which, over the next four months or so, we will be putting electric heaters to simulate the heat generated from waste canisters. We are now working on a 1500-foot-deep site in granite in Nevada. We will be putting canisters down in that hole soon, and we're working on a surface facility in New Mexico.

I happen to disagree with Mr. Wolfe on the media to use. I believe we would be much better off with basalt or with granite or even with tuff than with salt. But I don't think it really makes much difference. I believe we could use any one of those successfully. I just happen to prefer basalt or granite.

The tests will be underway soon, first with electric heaters and then with canisters of spent fuel elements. The spent fuel will be canned and placed in these holes in the basalt, and perhaps in granite, to provide

both radiation and heat.

I believe we should go to a deep hole in both granite and in basalt as soon as we reasonably can. I believe we could start right away. This would be a demonstration facility. The important thing to remember here is that we're not in any frantic rush. We can stack canisters of glass for a long time inside decommissioned nuclear reprocessing facilities that have plenty of shielding. And remember, we're not dealing with very large volumes. Each nuclear plant produces about 10 canisters per year, so it's a very small volume of material and we have a lot of storage facilities on the surface for the material if we want to use them.

I would propose that we go for about a 25-year demonstration in a deep hole. I think it's important to recognize that we can go deep enough so that we dramatically reduce the potential for any entry of ground water into the storage facility.

We can simply pick a site, go into it and explore it in all directions for hundreds of feet, and if it's not adequate, then abandon it and go to a different site until we find one that is adequate. In other words, find one that doesn't have any leaks to the outside. There are huge blocks of rock such as this not too far beneath the surface. I'm sure Dr. Krauskopf will comment on this. We don't know for sure what's five feet beyond any hole, but we can run test holes a long way beyond the storage facilities themselves to check out the facility. And we can, of course, use overfill. We will make the glass canisters diluted with inert, nonradioactive glass so the temperature will be low and we'll pack them so that they'll be dry. I believe, then, that we should run about a 25-year demonstration on this with all the waste canisters fully retrievable so that we can go back and pick them up for any reason at all.

I believe we should start because I don't see any reason why we shouldn't. All we're doing now is really experimenting, we're searching. If we find that salt, basalt, or granite is substantially superior to the other two; and if we find three or four good sites; and if we're satisfied that we can go on indefinitely beyond the 25-year demonstration, then we can do so. There's no rush to make a decision. We have plenty of time. We don't have any significant amounts of commercial wastes to speak of yet, because we haven't started reprocessing. Even after we do start our reprocessing, it will take several years before we have accumulated enough canisters of glass to run a decent sized demonstration. So I think we should get started.

**WILSON:** I have some questions which relate very much to your remarks which I'd like to direct to our geologist, and these are comments that I've heard various places. For example, if it has been decided to go ahead, and a site has been selected and drilling begun, how much can be learned from drilling about the suitability of a site?

**KRAUSKOPF:** You can tell a great deal from drilling, from the use of geophysical instruments in the drill holes and from careful examination of the cores that come out of the drill holes. You cannot, however, foresee all of the peculiarities, all of the difficulties, that you may



run into when you get underground. So I would enthusiastically agree with Dr. Wolfe that the disposal of waste is possible using present technology, but with the caution that you must expect to find unanticipated problems as soon as you actually get underground to explore a place for a waste repository.

Just because you cannot determine from the surface everything you will find underground should not mean that waste cannot be disposed of safely at the present time. I agree with Congressman McCormack that it's important to get started now, not only in one kind of geologic medium but preferably in three or four. There are a number of candidate media that look suitable for geologic repositories. We ought to start exploring them underground so that we will have better information than we can get from the surface only.

The exploration shafts and tunnels, I think, ought to be located in places that look to us from the surface as if they might ultimately be good repository sites. But there must be a good deal of exploration and experimentation at any given site before we actually consider developing it into a repository. And we ought to always have in mind that if a site proves very unsuitable, if the difficulties cannot be corrected by engineering techniques, we will simply back out of it and go to some other place.

WILSON: Do you think the public believes that the government will back out, once work has started, if difficulties arise?

KRAUSKOPF: That is a political question which is beyond my expertise. But how to convince the public of the government's good intentions is one of my principal worries. On this one I refer to Congressman McCormack.

WILSON: May I ask you some more geological questions. How about sealing the bore holes? Is that going to be any problem? Has it been demonstrated that they can be sealed up for a million years?

KRAUSKOPF: This is a question about which there is a great deal of current controversy, among experts as well as laymen.

There's a wealth of experience, especially in the petroleum industry, that relates to the sealing of bore holes. Many of my friends think this should be no problem. The sealing of shafts, the larger openings into a repository, may be considerably more troublesome. Much experimental work is currently underway on this, and I'm confident that within a few years we will have satisfactory ways of sealing both shafts and bore holes.

WILSON: If you go to a place which is a proposed site, how do you find all the holes that all the oil drillers, salt drillers, and water-well drillers have made? Do you crawl around on your stomach through the bushes and look for the holes?

KRAUSKOPF: I doubt that that would be very profitable. One of the difficulties at the Kansas site, which you remember was chosen as a possible repository site back in the middle of the last decade, was the

fact that a number of holes penetrated the area about which the drilling and location records had been lost. One reason the Department of Energy has gone to southeastern New Mexico for its present intensive work on salt is that the amount of petroleum exploration in the past was very much less, and the exploration of recent years is all well recorded. Drilling records are so easily available that you wouldn't have to crawl around through the sagebrush looking for the holes.

When repository sites are sought in the future, I am sure that places will be avoided where exploration was intense in the more distant past, say more than a couple of decades ago, when record-keeping was often sporadic.

WILSON: Does that leave much of the country?

KRAUSKOPF: Oh yes, a great deal of the country.

WILSON: I thought parts of our West were just like pin cushions.

KRAUSKOPF: But those are the parts where the rock has characteristics that look favorable for the occurrence of petroleum. In large parts of the West there isn't a chance of finding petroleum.

WILSON: What about the effect of heat on the geology involved? A lot of heat will be released by the waste. Is there a danger of cracking or opening up fissures or otherwise altering the system?

KRAUSKOPF: This is another controversial question, and it's one that I think needs more experimentation than has been done to date.

Regarding temperature, I think first it should be noted that the temperature of a waste repository can be controlled. The amount of temperature rise depends on the age of the waste when you put it underground; the longer the waste is kept at the surface, the less heat it can generate. The temperature depends also on how much waste you put in a canister; that is, how much you dilute the waste when you fabricate it into glass, and how many spent fuel rods you use. The temperature is additionally determined by the spacing of the waste canisters in the repository. Thus the maximum temperature in a repository can be kept to almost any level you wish. In particular, the rise in temperature can be kept small enough so that mechanical effects on the rock will be slight.

Congressman McCormack mentioned the heater experiments that are underway at Hanford to test the response to heat of basalt, which might be chosen as the medium for a repository. Similar experiments are underway at a salt dome in Louisiana; others have been tried, and I believe are still in progress, in granite at the Nevada test site. This is a problem that I don't regard as very serious, but one on which additional data are desirable of a sort that these experiments will produce.

WILSON: Thank you very much. Dr. Lash?

LASH: As I recall, your two questions were essentially can we dig now in preparing a full-scale repository, and, if not, can we be confident whether we will be able to build a repository some time in the future that we can assuredly expect to contain the wastes?

My answer to the first question is no, we do not have adequate knowledge at this time to select a site and develop a repository with sufficient certainty that the wastes will be contained. And there have been a number of reports in the last couple of years that support that conclusion. The latest one was by the President's Interagency Review Group on Nuclear Waste Management, their Subgroup I report, particularly Appendix A, on mined geologic disposal of waste. That report is a litany of uncertainties and gaps in knowledge about geologic disposal.

There is now underway the development of a plan, jointly by the U.S. Department of Energy and the U.S. Geological Survey, to prepare experiments and tests to fill those important gaps in knowledge and to resolve those uncertainties.

And I would mention in answering your second question, I know of no scientific principle that would have to be violated in order to obtain that needed information, nor do I see on the horizon any extraordinary technological feat that may have to be performed to answer those questions. But past attempts to find a suitable site have not yet proved successful.

We have some sophisticated techniques for evaluating potential sites without digging a shaft or even drilling very many bore holes, but these techniques I think today are inadequate to assure that we can locate an acceptable site with certainty.

Additionally, we have substantial uncertainties about the thermal mechanical effects of putting high-level wastes underground; we have uncertainty about waste-host rock interactions, chemical interactions; we have uncertainties about plugging bore holes; and we have uncertainty about the importance of human intrusion and how to avoid that to an acceptable level.

These problems have been pointed out in reports by the U.S. Environmental Protection Agency and the U.S. Geological Survey, as well as some reports by the California Energy Commission. These reports are in addition to the President's Interagency Review Group on geologic disposal.

So, I think the suggestion that we should proceed with testing, experiments, leading to demonstration and hopefully to final disposal of a full-scale nature is well taken, and those programs are and should proceed. Indeed, I think they should proceed more vigorously than they are now. But it is too early, in sum, to say that geologic disposal of wastes has been demonstrated and that it will occur with acceptable safety in the relatively near future.

WILSON: Could I ask Dr. Arrow first?

ARROW: When it comes to these engineering matters, I must confess my ignorance.

WILSON: It costs money, though.

WOLFE: I would like to characterize the IRG report somewhat differently than Dr. Lash did. As I recall, Dr. Philip Smith who headed that IRG task force testified before Congress to the effect that we had, in his view, the technology at the present time to provide very good assurance that with conservative design and construction techniques, we could construct and operate a repository that would successfully isolate the wastes from the environment.

Subsequent to that testimony, which I don't believe he recanted, the IRG report was rewritten and was put in a little softer language to the effect that we have the technology in hand at the present time to start the design and construction of a repository.

In my view, those are basically the same statement -- although there may be nuances between them -- because it says that we have the technology to start, and one wouldn't start costly construction without high assurance of success. Plainly, if we start and we find difficulty, we'll have to regroup before moving on.

In addition to that, there have been at least three recent environmental evaluations of storage of waste. There was a preliminary analysis by the Environmental Protection Agency which looked at salt repositories under the assumption that water could intrude; the accidents that Dr. Lash talked about were, in fact, considered. Water intrusion is not a catastrophe, although one should take great pains to avoid it. First of all the water has to eat away the salt, and these are massive salt blocks. It then has to dissolve the waste glass or other solid chosen for its low leachability. It then has to transport the waste through the ground. Typical ground water rates are feet per year or, in some places, tens of feet per year. If the repository is miles or tens of miles away from rivers, it takes thousands of years for the ground water to flow to the surface.

In addition, as it goes through the ground there's significant sorption, as was demonstrated in the natural reactor that God made in Africa some two billion years ago. In that case, an assemblage of uranium came together and actually formed a nuclear chain reaction. The resulting fission products from that reactor were immobilized in the ground and remain just about where they were found.

The EPA analysis ended up by concluding that the upper-limit risk from the repository was something like 100 to 1000 deaths over 10,000 years with less pessimistic estimates being four orders of magnitude lower.

There's a second environmental impact analysis, by the Department of Energy. This is a generic environmental impact analysis that examined eight or so different types of geological media. It's in two volumes and it's hard to read. But when you dig through it, the basic conclusion is that, with any of the geological media examined, the effect on the population in terms of radiation exposure is far, far below natural background radiation.

There's a third environmental analysis which is based on the more detailed design of the Waste Isolation Pilot Plant (WIPP) facility near

Carlsbad, New Mexico. This analysis put out by Sandia and Bechtel concludes that the major environmental effect is the effect of digging the salt out from underneath the ground during construction and putting it on the ground. There have been a large number of analyses, and I think they all conclude -- at least the ones that I read -- that the problem is within our technological ability.

I think the the public deserves a demonstration of that. I don't think, incidentally, that there's any emergency. The problem we have is one of public confidence, and I believe we ought to satisfy the public by an early demonstration. In terms of the need for storage, all the spent fuel, from now to the end of the century, could fit a a water pool 30 feet deep and several hundred feet by several hundred feet, about half the area of the reflecting pool of the Washington mall.

We have time to do the job right. The urgency is twofold. First, to start doing it so that if, in fact, we do run into difficulties we learn about them at an early date. And second, to reduce the concern of people in this audience and the public in general who have been told that waste disposal is an insoluble problem and thus nuclear power should be abandoned. I think that our toughest problem is to convince you that, in fact, we have the time and we have the technology. In my view, the technical problem, when placed in the context of the difficult problems of our world, is not even one of the harder ones.

WILSON: I will give the panel the chance to come back to this later if anyone wants to argue, but I think at this point the audience ought to have the opportunity to get in the act. We will throw open these topics which we've been discussing for audience questions.

STEPHEN BUDIANSKY, Environmental Science & Technology: Congressman McCormack said that we're not in a frantic rush right now. Would the other members of the panel agree with that, and are there any serious effects of storing nuclear waste for five years or ten years above ground?

WOLFE: I'd be happy to invite you out to our plant at Morris, Illinois, where we're presently storing fuel from reactors. Actually, you can go to almost any reactor and watch them store it at the reactor. So the answer is that the technology is well in hand; we're doing it. The facilities have gone through safety analyses and environmental analyses. I believe the answer is clearly that the technology is in hand to store fuel on the surface indefinitely.

LASH: The storage of spent fuel in water pools is not something that I've spent as much time reviewing, so let me just pass on some comments that I've heard from others that I think deserve some consideration.

One is, we have had relatively little long-term experience in storing so-called high burn-up spent fuel in water pools. Almost all of our experience has been with relatively low burn-up fuel.

Therefore, there is some uncertainty about the long-term integrity of the cladding and the presumption that at some point we'll have to recan

that spent fuel. And presumably, that can be done relatively safely. The question is whether it will be done before the hazard becomes unacceptable.

The second issue concerns a recently translated study from West Germany suggesting that there could be a very serious accident at a spent fuel storage pool if there was a loss of coolant. I haven't gone over that study, but it was an official report, and it's something that we will spend more time taking a look at in the near future.

WOLFE: As I noted, we're storing high burn-up fuel at Morris. In order to store it we've had to go through safety analyses. We've looked at the problem. Actually, if water is lost in the pool after the fuel is there for a few years, there is no melting of the fuel. The problem is that there's some local shine, but there is no disaster.

McCORMACK: Excuse me. People are confused by the words "local shine". Would you explain what you mean actually? Like, if the water comes out of the pool.

WOLFE: At the present time, if you go to our plant you can look at the fuel in the pool through the water. The water is so pure that it meets drinking water standards, but it shields observers from radiation. If the water were to leave -- and that's a highly improbable case for a properly located and designed pool -- you would not then be able to look directly in the pool because you'd get radiation (shine) from the fuel. But if you moved to the side where you didn't get the direct shine and were out a distance where you didn't get reflected shine, you'd have no difficulty.

McCORMACK: I want to point out that as far as the storage of waste is concerned, without deep geologic storage, we should recognize that we've been storing glass at Hanford for almost 20 years. Some of it has been highly spiked, so that the encapsulated material is representative of long-term irradiation.

But more classically, the French are glassifying their wastes and simply putting them in a big block of concrete that is the floor of their building. They have 150 holes in the floor, and every day they fill up a canister about three-quarters the size of a 55-gallon drum with glassified wastes, weld it shut, put it down one of those holes, and put a plug on the top of the hole; you can walk right on top of it. And when they get 10 canisters in there, they'll go to the next hole. They can put 1500 canisters in the floor. They'll just leave them there until they get ready to pick some site to put them in the ground. And when I asked them when they're going to do it they said, "Oh, there's no rush -- sometime."

ANDREW REYNOLDS, Department of Energy: I'd like to carry on that conversation essentially about high-level or high burn-up fuel, which is a distinct waste as opposed to military wastes which you discussed, Congressman, most of the time.

The materials that have been vitrified at Hanford are essentially the result of low-level production reactor fuels for bomb production. And I think you are slightly mistaken on the French instance. The French have just begun to reprocess low-level burn-up fuels and have not yet gone into extensive commercial high-level burn-up fuel reprocessing.

I find it interesting in the discussion of the panel, save Bertram Wolfe, the notion that reprocessing is a necessary step for the concentration of high-level wastes. That is an issue that you gentlemen might address, because I don't know that the audience has appreciated that reprocessing is a necessary step to vitrify high-level wastes to the concentrations of small blocks, as you have mentioned.

McCORMACK: Let me first of all set the record straight. At Hanford, a number of years ago, we filled a number of canisters with defense wastes. Some of this was spiked with cerium. Last year, we filled two canisters of wastes with full-level commercial fuel taken from one of the nuclear power plants. This material had been reprocessed on-site and converted to glass. One of these canisters is being used for examination and destructive testing, and one of them will be used for underground testing.

At Marcoule Nuclear Industrial Center, the French now are reprocessing commercial fuel to obtain unused uranium and plutonium and then glassifying the resulting wastes. It makes good sense, in the logistics of a fuel cycle and in maintaining proper inventory, that the fuel is not reprocessed as soon as it comes out of your reactor. It is allowed to cool as long as it is economically convenient before you reprocess it. So you give it plenty of time to cool off.

It depends on the economics and the size of your equipment and a lot of other things when you reprocess, but an average time could easily be three years. There's no absolute emergency to glassifying at that minute, although I would prefer to do so. You can allow the liquids to stand in a storage tank and cool off some more. Then after you make the glassified wastes in a canister, you can store the canister in a water-cooled basin or you can store it in an air-cooled basin. So you have all those steps for allowing the system to cool off.

REYNOLDS: I perhaps stand corrected on the French. They've begun to reprocess. The demonstration of commercial high-level wastes, as you pointed out, is two years old in this country. I'll offer a third example: the Tokimura plant in Japan which began reprocessing in 1978 and burned out the actual dissolving pot in a period of three months and has been down for fifteen months replacing that pot.

Now, what we're saying is that the character of commercial high-level wastes is very significantly different from the low-level, or rather, the low burn-up wastes from military programs that we have had greater experience with. I'm concerned about the confidence level that extends large commercial commitment of capital to a reprocessing industry that really has not been technically demonstrated. And certainly, West Valley, New York, is an indication of that as well.

McCORMACK: I will not continue the discussion.

LASH: If I could just mention that I did not mean to imply in my remarks that I assumed reprocessing and glassification of the wastes. Indeed, it is my hope that we dispose of the spent fuel after it has been canned.

REYNOLDS: If I'm not mistaken, the Interagency Review Group on waste management, in fact, was leaning that way -- that we should be demonstrating the disposal of spent fuel elements and not reprocessed spent fuel. Thank you very much.

ARTHUR PURCELL, President's Commission on the Three Mile Island Accident: As you know, the Commission did not tackle the nuclear waste issue due to its complexities and the fact that the accident was not directly related to nuclear waste problems. But, how do you view the significance of the Three Mile Island accident, generally viewed as the worst in commercial power history? How do you view the significance of that accident in terms of the progress in resolving this problem and achieving a safe, long-term storage capability?

WILSON: Sir, I'm going to rule that out of order in the sense that we're talking about the nuclear waste problem and we're not really prepared to talk about Three Mile Island.

PURCELL: Could I ask one that may not be ruled out of order?

KOSHLAND: I'll just invite you to a future Forum where we will discuss reactor safety.

KING HUBBERT: I was a member of the original advisory committee of the National Research Council to the AEC on waste disposal. That committee was responsible for originally recommending the storage of these wastes in a solid, glassy slug in salt.

The problems that this committee encountered were not so much problems of technical feasibility. It is my present opinion, and it was the opinion of the committee, that it is technically feasible to handle these wastes, provided we're willing to do what is necessary with regard to them.

The difficulty that we ran into for 10 years was the fact that the people who put up the money refused to spend that money to do anything right. We pointed out over and over again at every site -- Savannah River, Arco, Oak Ridge -- things that were being done that should not be tolerated.

The committee laid down two principles in the early days of its review. The first one was that this material should be isolated from the biological environment as completely as possible at all times. Secondly, that no practice should be tolerated now which would not be acceptable when this got to be orders of magnitude larger.

This second principle was consistently violated in the practices that



were going on at the time. We were discharging low-level wastes into the very poorest basalts at Hanford and in Arco; we were disposing of low-level wastes in open drainage ditches at Oak Ridge and elsewhere. And when these were pointed out, the local people in charge consistently said, "That's all we can do; that's all the money they give us."

In the report which I drafted to President Kennedy for the National Academy of Sciences Committee on Natural Resources it was recommended that the expenditures for waste disposal should be increased by severalfold. That was a recommendation to the AEC.

Going to the Kansas place, we took the people and showed them the site, Lyons, Kansas, underground. There's a place where they could experiment.

WILSON: Sir, I wonder if you could come to the question.

HUBBERT: The question is perhaps a final statement that the real problem is a human problem. Technologically, it's manageable. I'm not at all sure that it's manageable humanly. In other words, we have a short-term responsibility for a long-term problem, and whatever we do now, we'll all be safely dead before very long.

FRANKLIN GAGE, Task Force Against Nuclear Pollution: I'd like to ask each member of the panel who does not advocate shutting down the nuclear industry what they think the correctness is of inflicting the risk of waste problems on those who do not consent to that risk, either in this generation or in the future generations to come. I suppose we have Dr. Arrow's answer on future generations, but I'd like to hear from the rest of you.

WILSON: I'm going to ask Congressman McCormack that because he has to get reelected forever.

MCCORMACK: Of course, it is my belief that it would be a far greater insult to future generations for us not to move ahead now with nuclear energy than to go ahead. Our only option for an adequate supply of energy, as our supplies of petroleum and natural gas decline, is the burning of coal. No matter how much we want to succeed with our solar programs and geothermal programs and conservation programs, the fact remains that no matter how spectacularly successful we are with all of the alternate technologies and with conservation, there is a huge gap easily projected under the most optimistic circumstances between energy supply and demand for the year 2000 and beyond. This can be filled only with the burning of coal or the use of nuclear fission.

Of the two, nuclear fission is by far the cleanest and safest, both for the present generation and for future generations. There's no question about that.

The fact is that the materials we put into the biosphere from mining and burning coal are a great deal more hazardous than the ones from the entire nuclear fuel cycle. Any objective analysis will show that. I think this is an important thing to remember.

Further, the question is whether we maintain our societal stability during the coming decades. It's my hope that by the year 2000 we can have a fusion demonstration plant on the line, and we are pushing very hard on the Administration to fund that program aggressively enough to reach that goal. But even if we make it, and even if we start in the year 2000 putting a 1000-megawatt fusion plant on the line every week, it would still take us 40 years just to replace the existing energy system in the year 2000, allowing for no growth at all.

A simple analysis of growth curves makes these simple facts readily obvious. We must go ahead with our energy production and nuclear energy is by far the safest and the most benign.

LASH: And Congressman, although you didn't answer the question that was posed to you, I nonetheless must take strong exception to your evaluation of what is fact and what, in fact, is speculation about the future.

In my opinion, there are severe impacts from nuclear power development compared to coal technology, and, furthermore, there is no need for a serious gap between energy supplies and energy need around the year 2000. There are several credible technical studies that I'll be happy to provide your office that support that statement. I think your conclusion is simply unsupportable.

WILSON: On this happy note, I think we'll call for an intermission.

#### I N T E R M I S S I O N

WILSON: The next topic is whether the final storage, so-called, should be retrievable and, if so, for how long. Could I get a little comment from the panel first? Can we have retrievability? Do we know how to accomplish retrievability for a sufficient length of time, and how long do you think that is?

WOLFE: I think there are two aspects of retrievability. The first involves initial repository use. When the repository is first operated, it makes sense to monitor carefully the initial emplacement of either spent fuel or vitrified wastes and to have the ability for some period of time to retrieve it if there are unexpected effects.

The second aspect, which is more global, has to do with the present situation: we're discharging spent fuel from reactors and don't know if we will ultimately reprocess the fuel. The energy in that spent fuel represents the equivalent of trillions of barrels of oil, if the plutonium is used in the breeder, so it's a very large resource of energy. It makes sense, therefore, for the spent fuel coming from reactors to be stored on the surface in a readily retrievable form until a decision on reprocessing is made. I would suggest that the water pools in present use are satisfactory storage facilities, although there are other designs that would store spent fuel in shielded air-cooled vaults.

WILSON: I'm really worrying about the permanent storage. Let's say we build a geological repository. Do we insist on retrievability and, if so, for how long?

WOLFE: Well, the duration of ready retrievability that people consider is of the order of 20 to 25 years, and that seems a reasonable period to examine the initial effects from the emplacement of fuel. Thereafter, one could monitor remotely.

WILSON: One of the topics that we heard about was the possible beneficial uses of the waste material, the fission products.

WOLFE: I wonder, before you go on to that, if I could respond to a question that was raised about involuntary exposure. Every time somebody turns on a light switch, gets a job operating a lathe, or does anything else that uses electricity, he requires electrical energy. Whether he thinks about it or not, he requires some electrical generation facility to operate that affects the rest of us for better or worse.

Now, stripped of its emotional overtones, the essence of the question is the choice of the electrical generation plant which is caused to operate, or a decision to prohibit a person from turning on his light. These are the choices that one has. When one looks at the nuclear waste problem one should look at it in the context of the side effects of all the alternate means of providing power, or the effect of not providing power to those who need it or want it.

WILSON: Of course, there are a lot of people who are claiming we could save enough electricity by cutting out waste.

WOLFE: In California, the Sun Desert Nuclear Plant project was abandoned at least partly on the ground that a coal plant could be substituted in its place.

When legislator Victor Calvo of California introduced legislation to permit a coal plant to be built instead of Sun Desert, the Natural Resources Defense Council wrote him a letter suggesting that coal was a bad thing to burn.

WILSON: I'm going to stop you right there and let Dr. Lash come in. Then we'll go back to the topic.

WOLFE: Since Dr. Lash wrote the letter I think it's appropriate.

LASH: As I've explained to you several times, both privately and publicly, the position of the Natural Resources Defense Council in the Sun Desert Nuclear Power Plant proceeding was that we needed neither a nuclear power plant nor a coal-fired power plant. And so our position was entirely consistent and well-documented and, to my knowledge, not refuted.

WOLFE: I know that is NRDC's viewpoint, but if the electricity is not there when people need it or want it, then who will take responsibility for the lack of energy and the effects of that lack?

WILSON: Of course, that's really not quite responsive, since Dr. Lash says that their attitude was that it wasn't needed. Let's leave this.

LASH: I must observe that I've had debates on radioactive wastes and nuclear power for years. In the early days, just before the meetings would start, an official would always come over to me, kind of nervously, and say, "Now we're not going to talk about nuclear power, you understand. We're only going to talk about radioactive waste. Right? Right." And now that nuclear power is in such terrible trouble, I find that every discussion of radioactive waste immediately expands into a discussion of nuclear power overall.

I don't think it's appropriate here to talk about nuclear power versus coal and other generation sources. I obviously have substantial disagreement with some of the other gentlemen here. It's a very complicated issue, and we're not going to resolve it in the next 20 minutes tonight.

WILSON: I agree, and the Academy Forum is going to look at this topic in a broader context later. Let's go back to the retrievable storage.

ARROW: I concur with Dr. Wolfe's emphasis; I must defer to technical experts as to the possibility. But in the idea of retrievability, at least for the near future, I think it is extremely important to preserve the option of not reprocessing. I think we want to keep that option open for reasons having to do basically with the faint hope -- and I must say I can't put it more strongly than that -- of controlling proliferation. We may want to discourage reprocessing, discourage the availability of plutonium in the pure form, and therefore, we'd like to keep the waste in the retrievable state so we can consider this option.

Obviously, it might be better still to bury the fuel rods in a permanent disposal, and that would end the reprocessing as far as this is concerned completely. However, I must say I do shrink from that because there is the fear, which we can't completely discount, that we may be running out of uranium; that the availability of U-235 for light-water reactors may not be lasting very long.

Personally, I think all the latest indications are that there is quite a bit of uranium, but one can't be that certain about it. So the option of the breeder has to be maintained. But there's a good chance that we will not need a breeder for a long time to come and, therefore, everybody agrees that reprocessing for use in the light-water reactor has no particular economic value. So for this reason I'd say the idea of maintaining a flexible relation, postponing reprocessing, is extremely vital.

McCORMACK: I think that the question of proliferation with respect to reprocessing is badly distorted and badly misunderstood. It's important to recognize that the United States, Russia, Great Britain, France, and China had nuclear weapons long before they had any nuclear power plants.

Glenn Seaborg estimates that there are three dozen countries in this world that could make nuclear weapons today without having any nuclear power plants at all and without having any assistance from the United States. Moreover, they could do it in four to five years for \$50 million, 5 percent of the cost of a single nuclear plant.

Further, the plutonium that is produced in a nuclear plant is extremely unsatisfactory for nuclear weapons, although AEC many years ago demonstrated that it could be made to work. It is extremely difficult to make it work, even if you have the experience with using good quality plutonium. I think the proliferation issue is extremely distorted. The potential for proliferation of nuclear weapons in the nuclear energy program is extremely small. If a nation wants weapons it won't go that route.

WILSON: There are some who are alleged to have gone that route, I believe.

McCORMACK: No, I beg your pardon. This is not a matter of opinion. There is only one nation where that point is misrepresented and that is India, and they definitely made their plutonium from a small experimental reactor which was deliberately used for that purpose. They did not use a power-producing reactor. Their plutonium was made so that they could have only one percent plutonium-240. They made extremely pure plutonium, and they made it in a research reactor, not a production reactor.

WILSON: We were on the point a minute ago of beneficial uses, and I think I'd like to hear somebody talk about that.

McCORMACK: I'll be very brief about this. At Hanford for many years we have been extracting the strontium-90 and the cesium-137 from the military wastes, and we have in a storage pool there a large number of capsules of strontium-90 and cesium-137 -- capsules three or four feet long and a couple inches in diameter. These are good for producing heat if one wants it, and the cesium-137 is excellent for producing gamma radiation for sterilizing things. It can be used to sterilize sewage sludge, for instance. You can run sewage sludge over it and completely kill all the bugs. You also can purify city water without putting any chlorine in it.

There are many uses for gamma radiation, including hardening of plastic resins, which are available if we ever want to take advantage of them.

LASH: I'm going to refrain from rebutting Congressman McCormack's

last two remarks just to save time, but I disagree with much of what he said.

WILSON: Suppose we go next for a short, very brief discussion of transportation problems. Dr. Wolfe?

WOLFE: I would say that we are transporting wastes today on a fairly routine basis. The standards for containers which transport nuclear wastes involve such things as being able to withstand drops of 30 feet on unyielding surfaces, drops on nail spikes, falling into a fire of 1500 degrees farenheit and then submersion into water -- very high standards. The DOE has performed tests where such casks were, for example, put on locomotives traveling 80 miles an hour that were crashed into concrete abutments. There were other tests in which a train crashed into casks on a truck. The casks survived these kinds of incidents.

There have been environmental impact analyses by the Department of Energy and the Nuclear Regulatory Commission, which conclude that the major risks from the transportation of wastes in this type of container are the risks of normal motor accidents.

I do want to point out, to respond to the man from Three Mile Island and to King Hubbert, that when one works with any hazardous material -- chlorine, propane, or nuclear fuel -- one has to follow rigid procedures and, of course, safety depends upon following those procedures.

As compared to other hazardous materials that are transported it should be noted that an advantage of nuclear power is the small volume of its waste per unit of energy, or benefit. For example, one can spend \$100,000 to take care of a ton of nuclear waste and still not impact significantly on the economics of nuclear power whereas such costs would raise the price of propane by a factor of over a hundred. Similarly, when there is 8000 times as much solid waste from a coal plant per unit of energy then, of course, one can't afford to spend as much for its care. In my view, the perspective that's frequently missing from discussions of nuclear waste is that, in fact, an advantage of nuclear power is the character and very small volume of its waste, which makes it possible to isolate it and not spread it over the environment as is the case with wastes from other sources of energy and other human activities.

KOSHLAND: I got a handout as I came in saying, "Already there have been over 300 highway accidents, more than 100 involving radioactive releases." Is that accurate?

WOLFE: I don't know whether it's accurate. I would make the following comment. The characteristic of all of the undesirable events that one hears about with respect to waste -- the leaky waste tanks at Hanford; the Maxi-Flats case; the truck accidents with low-level material or natural uranium, about as hazardous as dishwasher soap -- the common ingredient of all of them, including the one that receives the most attention, the leaky waste tanks at Hanford, is that not a single

person has been injured as a result of them, and the environment has been minimally affected. The environmental impact near Congressman McCormack's home town of Richland due to the leaky waste tanks is limited to the soil in the desert several feet underneath the tanks. Despite the picture you may have gotten from the newspapers of this desolate Hanford area, Mike will tell you that the major problem in the area is that people like it so well that the population has increased so that they now have traffic jams.

I don't know whether the number is 300. If one is going to count every minor incident as an event without saying what the consequences are, I'm not sure what the number is.

WILSON: At this point I'll turn to the audience on the last two topics, the retrievability question and the transportation question.

THOMAS GRAFF, Environmental Defense Fund: My question deals with the transportation. In light of the recent actions taken by the pronuclear governors in the three states currently housing low-level waste sites restricting their use, what is your prognosis for finding an hospitable attitude on the part of a sufficient number of states to transport high-level waste and to store it safely in permanent repositories?

MCCORMACK: The waste sites to which the gentleman refers are low-level waste sites, not high-level waste sites, so they have nothing to do with high-level wastes.

The sites for low-level wastes, as you know, receive material from many sources. There are more than 2000 hospitals in this country providing wastes to our low-level waste sites, along with resins containing impurities from the cleanup water of nuclear power plants, and low-level contamination materials from medical research laboratories and from the radiopharmaceutical industry.

The Governor of Washington stopped shipments to the Hanford site because the NRC and DOT were not enforcing their rules and regulations which they had established for the safe packaging and transportation of low-level radioactive wastes. They were simply not enforcing the rules. And the Governor simply said that she would close the site until they agreed to enforce their own rules. When they did, she reopened the site.

The Governor of South Carolina has stated that he would stop accepting nuclear wastes in organic liquids because he was concerned about the liquid itself, which happens to be toluene. It is flammable and a potential source of fire in the waste sites. He said the radioactivity had nothing to do with it; he didn't want that flammable material around.

The response to that has been, of course, a cry from all over the country that we're soon going to have to stop providing nuclear medicine for people in our hospitals. About half of all the people that go to a hospital for a diagnosis or therapy directly or indirectly receive some sort of treatment or tests using radioactive materials. Many of them are life-saving tests. They will soon stop if there are no facilities

for handling these low-level wastes.

Accordingly, I have submitted legislation, as has Congressman Butler Derrick of South Carolina, to try to force people to think rationally on this subject. The Derrick legislation would effectively require every state to take care of its own wastes, and effectively stop the hospital research and everything else unless that state was willing to do so. States could form compacts by regions and agree to handle their wastes in a certain region.

My legislation would create a dozen sites run by the Department of Energy on federal property. All costs would be retrieved by service charges to the various users.

I don't know which one of those or which combination of them is going to be enacted into law, but I'm sure that something is going to be enacted so that we will have some sort of facilities for handling low-level wastes.

Now we are, of course, shipping high-level wastes across the country today, and I'm sure we'll continue to do so. When we have storage repositories or reprocessing facilities the casks will go there. I think a little bit of public education will show the people that the gasoline in the gas tank of the truck is a far greater hazard to people on the highway or along the highway than the radioactive material in the container.

LASH: Mr. Chairman, I'd like to respond as well. Only in the political arena can you compare apples and oranges, and that has happened in Nevada. This September I attended a Department of Energy sponsored meeting at which the former Governor of Nevada, Michael O'Callahan, repeated a story several times that while he was in office he had to close down the low-level waste burial site in his state because of some problems there, the most important being the theft of materials by employees who were operating that site. During the closure, he obtained an agreement from the company that operated the site to meet certain conditions, all of which he said have now been violated. Although he is no longer governor, he has called for the shutdown of the facility. The current governor recently has closed the site.

But what's important and relates to the comment is that at least in former Governor Michael O'Callahan's opinion, the previous acceptance of the populace and the politicians in that state for high-level wastes being stored at the Nevada test site has now been reversed. The people of Nevada now feel that they cannot trust that regulations will be properly followed, because they have been lied to by those in charge of the low-level waste burial site.

So, at least in the view of some of the politicians in that state there is a connection between the problems with low-level waste transportation and burial and their willingness to accept high-level wastes in the future.

WILSON: I'd like to go back to the audience now if you don't mind.



DANIEL BURGESS: I have two questions. The first concerns the latency period for health effects from radiation. It is a well known fact that often you get a 40-year gap. I assume Hanford was started around 1940, we're coming into 1980, that would be 40 years. Therefore, it is meaningless to say that no one has been hurt or injured because it would only just now be showing up. I'd like to get some response from the panel on that.

The second question is that the panel has agreed that we should experiment with various waste disposal alternatives, learn from our mistakes, and progress. I would submit that in the Ural Mountains of the Soviet Union a very great lesson about waste disposal has been taught, and I would appreciate the panel spelling out to this group what that lesson was, and also giving us some assurance that the areas in Hanford and in Oak Ridge which are off limits to personnel, the areas that no one goes in because of shallow burying in the early days of the weapons program, will not have similar mud volcano or worse types of situation. I am unaffiliated, I am a concerned citizen.

WILSON: Dr. Koshland will comment on the health part.

KOSHLAND: The question of the low-level radiation extrapolation I won't dwell on at length here, because that was the subject of our first Forum in this series. I could just say briefly that the Hanford study is in some controversy, as you know, but the figures in general that they come by are that a nuclear regulatory worker getting, by the legal limits, ten times, let's say, what normal people get in their background radiation increases his chance of cancer from natural things by the order of one percent. And the Hanford workers probably have less than this.

Now, the detailed studies on populations that are very small are very difficult when you're dealing with low probability, so this is an area of considerable controversy and I think is probably off the subject tonight. I hope that you will all read the proceedings of the last Forum.

WOLFE: I'd like to respond to the second part because I think it illustrates a problem. The question is about radioactivity in the Ural Mountains which has been attributed by a Russian dissident to a nuclear explosion at a waste disposal site. The questioner implies that in fact such an event occurred. But except for the Russians -- who deny it -- none of us has the facts. Certainly no one understands how, in accordance with the laws of physics, a nuclear waste site could lead to a nuclear explosion. The book by the Russian dissident, Medvedev, speculates on the basis of reports in the literature of radioactivity in the area. In a recent Science magazine there's an article by people at Los Alamos who speculate that the radioactivity in the area is caused by Russian weapons tests.

The question has been asked as though a nuclear explosion was an established fact. I am reminded of the press reports of two years ago about the breeder reactor in Russia whose explosion was observed by a

U.S. satellite. Some of my colleagues have since visited the plant, which continues to operate, apparently unaware of its dramatic demise.

With respect to the Hanford site, I think one could also cite a National Academy of Sciences study of last year on the waste disposal situation at Hanford which, as I recall, concluded that there is not now nor was there ever a significant hazard from the storage of the wastes at Hanford.

JOSH LEVIN, Office of Senator Charles Percy, Illinois: We've touched only briefly tonight on some of the institutional problems associated with the disposal of nuclear waste. Dr. Lash has mentioned briefly that in many areas of the country public distrust has fouled up what may have been very well intentioned plans by the government. This relates in a certain way to the question whether, in fact, we want to build or build up our away-from-reactor (AFR) storage sites at all. Senator Percy is of the belief that, in fact, we have a real danger of such sites becoming de facto permanent storage sites because we are having so much trouble resolving the ultimate question of permanent disposal. He has favored a plan and I favor a plan of keeping nuclear wastes on site with the nuclear reactor itself.

I'm not claiming to be an expert here, and I'm certainly open to differences of opinion. I'd like to be educated by the experts here as to whether, in fact, this is a viable way of storing nuclear wastes temporarily so as to avoid whatever dangers may exist with the creation of possibly de facto AFR disposal sites or storage sites.

LASH: I'd be happy to respond to that. Yes, it is possible to increase storage of spent fuel at existing reactor sites. The Tennessee Valley Authority has preliminarily proposed to do just that at their reactors, and they chose at least to put out for public comment that option instead of building AFR's. So it's not only possible, it's being chosen by one very large utility.

McCORMACK: There is a GAO study on this that came out in the last three months. The GAO suggests that it may not be necessary to build any AFR sites because of the ability to re-rack spent fuel assemblies at existing plants and to use existing facilities such as Morris, West Valley, and Barnwell for storage until we get a reprocessing program underway.

I believe that the demand for fuel and the economics of the situation will determine that we will go for reprocessing in the not too distant future. And I believe that we will not have to worry about indefinite storage, either at the plants or at an AFR. The GAO study should be checked because it essentially supports your position.

WILSON: May I interrupt? Dr. Purcell asked a question in the first question period, and I ruled it out of order because I figured it wasn't related to waste disposal. Then he explained that he would like to know the impact of the Three Mile Island episode on the waste disposal problem. Is anyone able to comment on that?

WOLFE: To the extent that Three Mile Island indicated that care has to be exercised with any of these activities, I think that's a lesson to be taken into consideration in the design of repositories and the procedures under which they operate.

As far as the direct connection, Dr. Wilson, between Three Mile Island and the waste problem, I'm not sure there's a direct relation there. Do you see one, Terry?

LASH: There is one connection. Some states were not willing to receive the low-level wastes that are being generated in cleaning up the accident. I frankly don't know what's going to happen to the higher-level liquid wastes now in the containment. They're not high-level wastes, but they're quite radioactive, I understand. And what's going to happen to them when it's solidified I don't know. I doubt that it's acceptable to put it in shallow-land burial sites, which must mean some kind of surface storage someplace.

WOLFE: There are two parts to the problem. One is the low-level waste at Three Mile Island -- low-level in the sense that it's in the water. It's being cleaned up at the present time with an ion exchange and evaporation process, but it will require off-site shipment and there's a question of where that waste will ultimately go.

There also will be a problem of removing the failed fuel that's in the reactor. Basically, this will require that the fuel be remotely pulled out of the reactor and put into cans, which can be put into casks and transported for storage to some site. Again, there will have to be a choice of a site. Once the fuel is in cans, it basically has the same hazard potential as the standard fuel element and can be shipped in the type of casks I mentioned before.

We do have the political question, which Terry has pointed out, of gaining acceptance. With respect to that point, I think the low-level waste issue brings the whole question of waste into perspective.

There are about six million patient uses of radioisotopes per year in this country. I understand that one out of three diagnoses makes use of radioisotopes. Now, one either has to believe that we know how to take care of low-level wastes so that patients can receive the benefit of isotopes or we ought to require patients to have other, less beneficial diagnostic techniques -- to accept greater medical risks.

It seems to me one always comes back to alternatives. One has to weigh the risks against the benefits. Any discussion about nuclear power or about wastes that does not cover risks, benefits, and alternatives is a meaningless discussion. If the intent of some of the questions was to get me to say that nuclear power is not perfect, and that the disposal of nuclear waste has problems and that it has to be done with care and diligence, then I'll say it -- all of that is true. The real issue is how the risks compare to the benefits from nuclear power, as compared to alternatives, including lack of energy.

LASH: Let me mention just very briefly that the amount of radioactivity for diagnostic and therapeutic purposes is very small

compared to the low-level wastes that come from operating nuclear power plants.

WOLFE: It's about half of the low-level wastes at the present time.

LASH: Not on a longer-lived basis it's not. The central problem with low-level waste disposal is the longer-lived, low-level wastes from commercial nuclear power plants, and not from diagnostic or therapeutic uses of radioactivity.

WILSON: Let's go to the audience.

OSWALD ANDERS, Dow Chemical Company: Would the panel agree that a definition of radioactive waste is really fundamental to the issue? We've heard that some of the high-level waste will eventually decay by a factor of a million and that the Governor of South Carolina worries more about the toluene than about the radioactivity. There's a need for a definition of what radioactive waste is so that we can face that; zero and infinity are concepts which are not in our experience and we just are frustrated as all get out to deal with those. The philosophical concepts have to be translated into something that's technically meaningful.

WILSON: We'll go on to the next question.

ANN CAREY, The Futures Group: I'm sure we're all going to go home feeling safer tonight having heard most of you say that, yes indeed, we have the technology today to dispose safely of nuclear wastes. If, that is, as Mr. McCormack suggests, a 25-year demonstration program proves successful; if we don't encounter insurmountable construction difficulties or geological problems, as mentioned in our discussion, we can do it today.

WILSON: Is this going to be a question?

CAREY: No. I will not ask you to explain the apparent inconsistencies of some of those statements. Rather, my question is perhaps a political one and that is, who is responsible for the safe disposal of these wastes, and why isn't it being done now? Dr. Wolfe, is General Electric responsible for the wastes generated at their reactors, or is the now defunct Atomic Energy Commission, or the Department of Energy responsible for private, commercially generated nuclear wastes?

WOLFE: By law, the federal government is responsible for the permanent disposal of high-level wastes. There has been some suggestion that maybe it would be more expeditiously handled if that weren't the case. And to the extent you're arguing that the program of the federal government over the past decade or so has not been effective, I would agree with you. In fact, I would ask your question once more and ask

who is responsible, in the government, for the high-level waste program? You'll find that it's very hard to get an answer to that, and I think that's a disgrace. I've testified in front of Congress that in the Department of Energy we should have someone set up at, say, the assistant director level who is responsible. If you're implying that the federal government is not doing an effective job of demonstrating permanent disposal of high-level wastes, I agree with you. And I think that members of the public ought to write to their congressmen and say: We understand that this is a serious problem. We want nuclear energy if we can take care of the waste -- get on with the job!!

CAREY: Has G.E. passed the buck by having the federal government legally responsible for this disposal?

WOLFE: It was taken away by law. G.E. is not allowed to dispose permanently of the waste.

WILSON: I'm sorry about the remaining questions. We have to cut it off, but those who have questions could bring them up afterwards. One last quick one.

EDWARD GROTH, Consumers Union: Our organization is concerned with smoke detectors which constitute a low-level beneficial use of radioactive material but possibly a significant disposal problem in the long run. We're concerned with if you will, the proliferation of these devices and the responsibility being dispersed among nontechnically trained citizens for their ultimate disposal and proper handling. And we wonder whether there are any analogies that the panel could draw between that and some of the issues that you've been discussing already.

McCORMACK: Let me make one comment. There are various types of radioactive materials out there on the market that are not really controlled by NRC. I believe the americium that's used in smoke detectors falls in that category.

You may be interested to know that a mantle for a Coleman lantern is very radioactive by comparison to our standards. Those can be purchased in a hardware store. As a matter of fact, I have a demonstration where I use just one little mantle, and I get one millirem per hour on a geiger counter. This is as much as you get sitting at the gate of a nuclear power plant, 365 days a year, 24 hours a day. And you can get this with a mantle from a Coleman lantern that you can buy in a drugstore or hardware store anyplace in the country.

This is just outside the normal realm of controls by NRC. There are things in the marketplace that are not under control and that are a lot more radioactive than a lot of the low-level wastes that we're packaging and transporting to special burial grounds.

WILSON: I think we'll ask the panel for wrap-up comments that will end our session. So I'll start with Professor Arrow.

ARROW: It seems clear in view of the disparity between the economic value of nuclear energy for electricity purposes and the, what I consider more important, health gains, the avoidance of the health hazards of coal-fired plants, that there's room for spending a great deal more on waste disposal than is now done. The need for settling the possibility of permanent disposal is really quite urgent. It's not so necessary that we actually go to it, but it is essential that we know and have established publicly that this is a viable entity, which I presume it is, but this has to be established.

The question of responsibility has been raised here, and also by Mr. Hubbert in his earlier remarks, and Congressman McCormack, in fact, referred to the failures to enforce transport regulations by the NRC, and it is a very scary question. If there is not a distinct line of authority I fear for the future of the program.

KRAUSKOPF: Two items from this discussion stand out in my mind as particularly important. First is the fact, mentioned repeatedly, that there is no immediate hurry about disposal of the wastes. The wastes can be kept in temporary storage indefinitely as long as surveillance is maintained. Second, a demonstration is urgent that waste disposal can actually be accomplished. For this purpose we need investigation of various geological media by means of exploratory shafts and tunnels, so that actual underground conditions can be documented and the necessary preliminary in-situ experimentation can be carried out. This program should have high priority.

Another thought occurs to me that needs mention. Our discussion tonight has been limited entirely to deep geological disposal, the method of disposal that currently seems most promising. But other possibilities exist that need further study. For example, putting the wastes into the sediment at the bottom of the deep sea; putting the wastes above the water table in some of the arid lands of the West; or putting wastes in very deep holes, so deep that the waste would be below the zone of ground water. These other methods give us further options for disposing of nuclear waste, hence provide additional assurance that the problem can indeed be solved.

WOLFE: I would like first to indicate to my friend, Dr. Lash, that we have been on the stage together some half dozen times over the past few years. In each case, I've made the same point that perhaps I have repeated too many times here: In discussing nuclear wastes or any aspect of nuclear power, one has to look at alternatives. It doesn't make any sense to ask whether nuclear power is a perfect source.

Now, with respect to the waste, it seems to me there are three things that ought to be remembered. The first is that we've been handling wastes safely for some 30 years. Although there have been some problems, the consequences of even the most extreme of those, involving military wastes at Hanford, were trivial in terms of health effects or even environmental effects.

Second, we should recognize that there is no emergency with respect

to the technical requirements of taking care of the wastes from the operating plants, providing we construct the storage pools necessary for storing spent fuel. It isn't necessary to permanently dispose of spent fuel in the near future, and there may be some technical and political reasons why we shouldn't.

The third point I'd like to make is that the urgency in demonstrating a means of permanent disposal is one of convincing you, the public, and, as a matter of fact, me, that at the time that we decide to permanently dispose of the waste, there will be acceptable facilities. My assessment of the technical problems is that we have the means to permanently dispose of the wastes in a sound way. We need some verification of this.

So in my view we should get on with the job of doing the demonstration. We should do the demonstration in several media in several places, and we should do it with all urgency. Then we can take our time to decide when and if we want to reprocess and when we want to permanently dispose of the wastes thereafter.

McCORMACK: First of all, I agree with the criticism of the federal government with respect to handling the waste problem. In 1975, I participated in hearings and in 1976 I chaired hearings in which we had underway programs for solidification of waste and for geologic studies. These programs have been essentially held up. The fact is that the Interagency Review Group study takes us back to some date prior to the 1976 hearings which I conducted, and I am extremely frustrated with this situation.

We have been pushing the Administration as hard as we can to try to get them moving. This year we added to the authorization legislation for the Department of Energy a program for glassifying the wastes at West Valley, New York. This is the only civilian high-level nuclear waste that we have in the country. West Valley has mostly military waste, but there is about 40 percent civilian high-level waste in one tank at the reprocessing plant.

We have initiated a program, which we hope the Administration will accept, to demonstrate at West Valley the glassification of a substantial amount of waste. We will simply pump the liquids back into the plant, glassify them in the plant, and store them there until we get ready to put them underground for testing various sites.

I want to say that my statement early on that I find myself setting much higher standards than some of the other members of the panel is meant very sincerely. There's an old cliché about sending a thief to catch a thief. I've had a lot of personal experience with handling nuclear wastes and radioactive materials of all sorts, and I am convinced that we can handle them safely; but we do have to set high standards. We can do it, and we can maintain them.

Finally, with respect to this whole question of high-level wastes, I'd like to read to you just a couple of sentences from a hearing that I conducted in May of this year when Dr. Rustum Roy was a witness before my subcommittee. Dr. Roy is Director of the Materials Research Laboratory at Pennsylvania State University. Dr. Roy pointed out in a

public statement in Denver in January that when borosilicate glass is subjected to very high temperature and very high pressure, then brines would leach the glass.

What he meant was what every single chemist in the world knows. It was absolutely no surprise to anybody. And when he came before our subcommittee he testified that everybody knew that. However, he didn't set the conditions as being representative of the conditions of a proposed repository environment. He was simply describing what someone found happened to glass under those particular conditions, which were created in high-pressure and high-temperature brines. He pointed out that the way you handle it is simply to store wastes under conditions where there would not be damage.

We got into a discussion about the value of various types of solidification. He happens to be supporting a technique involving cermets. There was another scientist at the hearing from Florida who is a specialist in glass. He said that he would be much more comfortable using one of the two favored types of glass for solidification. I asked Dr. Roy what he thought about that statement. He said, "They're all overkill. In the system it will be overkill." This is the thing we should remember. We can do it. The technology is there.

LASH: Professor Arrow mentioned earlier that history has not been an uninterrupted line of progress, and that is certainly the case with radioactive waste disposal. In fact, the recent studies of the problem, including the often mentioned IRG report, have increasingly emphasized the uncertainties and gaps in knowledge in radioactive waste disposal in deep-mined formations.

In my opinion, doubt has been cast about the acceptability of glass as a waste form under repository conditions, and doubt has also been cast on the acceptability of salt as a waste disposal medium.

But more important, I think, than these technical uncertainties is that whatever technology is dreamed up on a piece of paper must be put into effective operation, and the history of the radioactive waste disposal program is not one that gives me confidence that the U.S. Department of Energy or any other federal agency that may succeed it will, in fact, accomplish this goal along the lines that have been suggested by technological optimists.

In fact, I have great concern that, in the effort to move expeditiously, undue risks will be taken in selecting sites and developing them for high-level waste disposal. In that regard I can agree that we do not need to move immediately to commercial-scale disposal of wastes; rather we should move toward, as Professor Krauskopf has indicated, a demonstration in three or four different geological media to test out our current understanding of the response of high-level wastes to the geologic environment. During that time I think it's going to remain a societal question, one that I can't answer, as to the importance of all this in the future of nuclear power.

WILSON: And that, it seems to me, is the proper adjournment of this Academy Forum.



