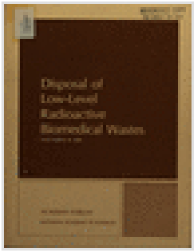

Disposal of Low-Level Radioactive Biomedical Wastes (1980)

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DISPOSAL OF LOW-LEVEL RADIOACTIVE BIOMEDICAL WASTES

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FOREWORD

ROBERT R. WHITE
Director of the Academy Forum

The Forum is a platform that is offered by the National Academy of Sciences for the public discussion of national issues involving the uses of science and technology. The purpose of the Forum is to provide an opportunity for a diverse group of experts and citizens to exchange varied viewpoints on these issues. Its goal is to illuminate rather than to reach firm conclusions.

Since the fall of 1979 the disposal of biomedical wastes has been very much in the forefront of concern among various groups in the National Academy of Sciences: the Assembly of Mathematical and Physical Sciences, the Assembly of Life Sciences, the Commission on Natural Resources, and the Academy Forum. Of course, that was a crisis time; the disposal facilities had become unavailable; the whole topic became very much a moving target as to what we should do.

It wasn't until the spring of 1980, when the National Institutes of Health suggested that an Academy Forum would be in order, that we received the vital spark of ignition that produced this gathering. Interest and support also have come from the Nuclear Regulatory Commission.

I would point out that a forum is very different from a symposium. We discourage elongated presentations and the delivery of papers in favor of perhaps a more blunt approach: to simply state the problem and get the responses to it from a panel of people who we think are rather qualified to answer, and from an audience that we hope is interested and also qualified. The essence of a forum is dialogue, and the audience is just as important as the principals that we gather together as part of this resource called a platform.

The key person in an affair of this sort, particularly if the discussion gets hot and heavy, is the man who directs traffic. We have provided for you a chairman who is an expert at directing traffic. In 1965 he was elected to the National Academy of Sciences and in 1973 to the Institute of Medicine. As Dean of Science at the Massachusetts Institute of Technology, he is not only interested but also involved in the problems that we will be discussing.

WELCOME BY THE CHAIRMAN

ROBERT A. ALBERTY
Dean of the School of Science
Massachusetts Institute of Technology

I want to welcome you to this discussion of a problem that we think is of real national interest. This particular Forum has been stimulated by problems of disposing of low-level radioactive biomedical wastes. Radioactive isotopes are so useful in biological and medical research and in some kinds of medical treatment that their use has been expanding and now is very large. This is particularly true of the use of scintillation fluid, which is something we are going to hear a good deal about today.

The disposal of these wastes is a problem at the present time because of the very limited number of disposal sites and because of uncertainty about the continued availability of these sites. There is a concern about the fact that research and medical treatment may be jeopardized by future developments concerning these sites. We believe that other possible means of disposing of these low-level wastes are not being adequately utilized, and so that is going to be discussed in detail.

The General Advisory Committee of the Academy Forum has been following this developing problem over the last several years. We are grateful to them and to the Director for bringing together a group of people to discuss it and making the arrangements for this Forum.

PURPOSE OF THE FORUM

CHARLES U. LOWE
Acting Associate Director for Medical Applications of Research
National Institutes of Health

I bring you greetings from Dr. Donald Fredrickson, the Director of the National Institutes of Health (NIH). I know I speak for him when I express the hope that this particular Forum will prove to be useful. We hope it will generate a series of steps leading to a resolution of some of the problems facing those institutions of higher learning that support biomedical research and those health service organizations supporting programs in nuclear medicine.

The NIH is the principal national source of funds supporting biomedical research, particularly the so-called basic research that produces the largest portion of the low-level radioactive biological waste with which we are concerned at this Forum. In fact, it has been estimated that about 85 percent of the low-level radioactive waste produced in this country is generated either by those scientists supported by the NIH or by the laboratories of the NIH on the campus in Bethesda. We obviously, therefore, have both a responsibility as well as concern that our constituents have publicly acceptable methods for the disposal of the radioactive waste generated by their research.

We find ourselves at the NIH in an anomalous position. We acknowledge our concern and responsibility but find that the National Institutes of Health has no statutory authority to deal with these matters. We have chosen, therefore, a second-order type of solution. We have encouraged the National Academy of Sciences to convene this Forum, to bring together in one place those who are regulated and those who regulate. It is our expectation that communication will constitute the principal product of this meeting. Those who regulate will understand the problems of the scientists, and scientists will have some perception of the constraints that operate upon the regulatory agencies.

We were encouraged to proceed with this Forum because of our belief that the amount of radiation generated by biomedical research makes a trivial contribution to environmental radioactive contamination, and therefore these wastes can in large measure be disposed of at the site of production. Until recently, most research organizations and scientists had access to burial sites for disposal of their wastes. This was an easy and satisfactory solution, and it discouraged institutions and individual scientists from studying the current regulations to determine whether there were other methods of disposal of wastes that were either less expensive or provided greater automony and independence of trucking contracts. Examination of this issue should convince you that local disposition is, in many instances, not only quite safe but also complies with the national regulations.

Having said that, and having urged scientists to deal with the problem locally, we note that statutes in a variety of jurisdictions appear to preclude local disposition. Jurisdictions have enacted the statutes to which I refer in the belief that there is a health hazard created by local disposal of these wastes. To repeat our perception that the health hazard is trivial or nonexistent, it would be our hope that, as a result of this Forum, those with responsibilities in these matters will be able to convince political bodies that restrictive local statutes are unnecessary and, in fact, create problems that need not exist.

The American Association of Medical Colleges (AAMC) has developed what I believe is an extremely useful and carefully written document that deals with these health issues. I hope that the AAMC will make this document available to you and in addition assure that it has wide distribution. You will find it, I believe, an unusually helpful document.

The specific and limited purposes of this Forum are twofold, and I would urge all who participate in the discussion, both the speakers on the platform or those on the floor, that you keep these purposes clearly before you.

We intend first of all to describe the nature of the problem as viewed by the nation and by scientists. What is the issue that we need to face in considering disposing of low-level ionizing radiation generated either by biomedical research or by those who use these isotopes in the process of diagnosis of illness through what is known as nuclear medicine? Why does the problem occur now? What is the magnitude of the problem? How general is the problem? I believe it is important that this first set of questions be answered.

Then we move to the second purpose of the Forum, and that is to identify solutions that are available here and now, tomorrow, the next day, and over the next year or two. We are not attempting to address long-term solutions, nor are we prepared to discuss the need for new statutes or a change in current regulations, though these seem to be imminent.

We believe that if these solutions are examined today, those in attendance will leave with a sense that the scientist can in fact regain some measure of control over his own destiny and become independent of what has appeared at times to be an idiosyncratic if not whimsical opening and closing of the currently available burial sites.

I encourage you to enter into these discussions vigorously. I know the product will be a constructive document, and I hope it proves to be useful to all those who are engaged in research and the generation of these low-level wastes.

WHERE AND WHAT ARE THE WASTES?

OVERVIEW:

LELAND R. COOLEY
Radiation Safety Officer
University of Maryland at Baltimore

Working in a medical academic research facility for the past 11 years, I have gained deep knowledge of these wastes. I have been up to my elbows, up to my knees, and now up to my neck in them for the past 2 years.

The University of Maryland, which can be characterized as a typical medical research facility, annually generates about 400 drums of low-level waste that we process, package, and ship for burial. Other work in the area of waste management includes two studies for the Nuclear Regulatory Commission (NRC) characterizing institutional waste generated by the nation's large medical and academic institutions in both 1975 and 1977. We also have studied the biological waste component.

I will begin with a description of what low-level waste is. It also is important to understand what low-level biomedical wastes are. For the purpose of NRC regulations, low-level waste is defined as that which is not high-level waste, or that which is not a by-product of mining and milling of uranium, that which is not a by-product of reprocessing nuclear fuel, or that which is not waste containing transuranic elements at more than 10 nanocuries per gram.

That leaves a rather broad spectrum, an open catch-all for everything else to fall into. In 1979, the latest estimates suggest that this country produced and buried in the three commercial shallow land burial sites some 79,900 cubic meters of low-level radioactive waste. In volume comparisons, that would translate to roughly 366,000 55-gallon drums. Of this, 40 to 45 percent of these wastes came from the nuclear power industry; 8 to 10 percent from governmental sources, primarily defense-related wastes; up to 25 percent from the industrial-commercial sector; and another 20 to 25 percent from biomedical research facilities. The institutional fraction translates to roughly 73,000 drums.

As to where biomedical wastes come from, more than 70 percent of institutional waste originates from medical and academic institutions east of the Mississippi River. Considering how the materials are used in research and medical settings, it follows that the majority of the radioactive wastes are generated by the population centers along the Atlantic Coast, primarily the mid-Atlantic and the northeastern United States.

With respect to the physical characteristics of these wastes, roughly 45 percent is liquid scintillation counting wastes. This is roughly equal to 32,000 drums.

I think it is worth pausing to discuss further what liquid scintillation wastes are, for those of you who may not know. The most commonly used substances in research are radioactive hydrogen and carbon, that is, hydrogen-3, or tritium, and carbon-14. These are exceptionally useful tools in research in that hydrogen and carbon are the fundamental elements in any organic compound. To trace the movement or changes of organic compounds in cells, tissues, or organ systems, you need to employ compounds that can be detected—and carbon-14 and tritium are the most common building blocks in making labeled compounds.

In order to detect the very, very weak radiation emitted by hydrogen-3 and carbon-14, you must place small quantities into liquid scintillation fluids. As described in the fact sheet, these are primarily toluene, xylene, or some other aromatic hydrocarbon. The energy from these radiations, as low as it is, is transformed into light by the liquid scintillation media. The light is detected and the event recorded.

Because of current packaging methods, each of the 32,000 drums of liquid scintillation waste contains roughly 2,500 individual little vials. The glass vial is no more than 2 inches tall, three-quarters of an inch in diameter, has a little plastic cap, and on the average contains 10 cc's of liquid scintillation counting media. The total volume of what you would call radioactive waste in a 55-gallon drum is roughly 6 to 8 gallons of organic liquid. On the average, each drum contains about 200 microcuries of tritium and possibly 1 microcurie of carbon-14.

As a comparison, approximately 2 million curies of tritium are produced in the atmosphere every year. This leads to a calculated steady state somewhere in the neighborhood of 35 million curies of tritium. The total amount of tritium in the liquid scintillation waste, which is the largest component of biomedical wastes, is estimated to be between 8 and 10 curies.

As for carbon-14, the average activity of 1 microcurie per drum of liquid scintillation vial waste is quite small compared to roughly 38,000 curies of carbon-14 produced annually in the environment by natural means, and a steady-state environment of some 315 million curies.

Liquid scintillation fluids are toxic by their chemical nature, but are presently treated as low-level radioactive waste and are dutifully packaged in drums. The absorbents added to each drum amount to more than twice the volume of the liquid. The majority shipped to Hanford, Washington, entails a rather expensive cross-country trip for wastes produced on the East Coast.

Right now, the average cost for a relatively large East Coast institution to transport and bury a drum of waste is $160. Small producers may pay as much as $240 per drum to get rid of these vials.

The other significant portion of the wastes, approximately 40 percent, is dry solids, which is equivalent to roughly 29,000 drums. Here we find normal wastes from the laboratories: paper, disposable gloves, bench covers, plastic, glassware, pipettes, and other various solids that may or may not be contaminated with radioactive materials. Probably less than 10 to 20 percent of the institutions producing dry waste employ volume reduction techniques simply because they can't afford a compactor. In general, most institutions are sending out drums that weigh about 200 pounds of general refuse.

Another 10 percent of the institutional wastes, some 7,300 drums, contain biological waste. In our studies, we found biological waste to be primarily animal carcasses. These wastes are principally dogs that have been used in the development of radiopharmaceuticals or in the research stages of developing new techniques for nuclear medicine. Another significant portion is smaller animals such as rats and mice, which have been administered carbon-14, tritium, or other tracers for metabolism or basic science studies.

I think it is also important to understand how these 7,300 drums of biological waste are packaged. A 55-gallon drum contains a 30-gallon drum packed in an absorbent. Inside the 30-gallon drum are the animal carcasses, which are mixed with lime and more absorbent. The completed drum may contain 60 to 80 pounds of animal carcasses. Add to the disposal cost of $200, the cost of the steel drums, plus the lime, plus the labor, and you are talking about filet mignon prices to get rid of animal carcasses that contain very low levels of radioactivity.

The last significant fraction of biomedical waste is absorbed or solidified liquids. This is roughly 6 percent of the institutional waste volume. From our studies, we found liquid waste to be roughly equal in terms of aqueous or organic liquids. These are absorbed or solidified in drums, and then sent off to the burial site.

The total amount of radioactivity in the institutional wastes, in very overstated terms, may amount to 3,500 curies. However, nearly 60 percent of this activity is in the form of discrete sealed sources, such as tritium targets from neutron generators or very large tritium gas targets from accelerators, calibration sources, etc. This leaves perhaps 1,500 curies that could be considered as distributed throughout the biological, dry solid, or liquid wastes. Almost one-third of this activity consists of radioactive materials with half-lives of less than 90 days. If left for a period of 3 years, this third would have disappeared by natural decay. Another one-half of these 1,500 curies is in the form of tritium. Looking at liquid scintillation fluids, you can see that a very small fraction of it is distributed in a very large volume. The remaining one-sixth of the activity is carbon-14 and other long-lived radioactive materials that are distributed throughout the waste forms.

I think it is worth sharing some personal experiences and understanding of why we are where we are. As Dr. Lowe asked, why is there a crisis with handling institutional waste? Well, I have some opinions that I think are shared by my colleagues who are responsible for radiation safety programs and waste management at other institutions.

Until recently, waste disposal was rather simple and inexpensive. We paid about $50 for disposal per drum. There were six or seven sites operating. We could just pop our waste into an $11 drum or other suitable container and send it off. With the closings of at least three of the sites, and the volume restrictions placed on Barnwell, South Carolina, transportation and disposal costs have been driven up from the $50 a drum figure to between $180 and $240 a drum. We are also faced with the prospect that the sites currently operating may be denied to us. The passage of a voter initiative in Washington to close down the Hanford site to all but institutional wastes raises the question whether there will be sufficient economic support to maintain that site. If half to three-quarters of their business is stopped, the cost of institutional waste disposal may go up again by a factor of three or four.

The continued operation of the Beatty, Nevada, site is in question, as there has been a very definite expression that local government is not particularly in support of keeping that site open.

The Barnwell, South Carolina, site has already been given an annual volume limit on the waste it can accept, in addition to the restriction against accepting liquid scintillation wastes or other organic solvents.

Institutions have been lulled into relying on commercial shallow land burial as the most acceptable and defendable waste disposal method. Shallow land burial did two things. It allowed institutions to dispose of waste in an economical way and it kept the regulators off our backs. If we could show that 100 percent of the radioactive material received by our institution would be used in the laboratories, and everything that could be considered radioactive was thrown into drums and sent off for burial, we were covered. There was no worry about public or regulatory reaction, and no one was questioning our practices.

With the pressure of increasing costs and the potential closing of the burial sites, we have been forced to take a second look at this approach. This is the purpose of this Forum. What are the alternatives? What can reasonably be done? And what should be done in the very near future to improve our situation?

J. CALVIN BRANTLEY
Vice-President for Administration
New England Nuclear Corporation

I am starting out as commentator primarily because I represent the companies that make radioactive products for use by my fellow panel members. It might interest you to know that there are only eight companies in the world that produce most of the radioisotopes for medicine and research. There are two that produce most of the radiochemical materials for biomedical research, one in the United States and one in Great Britain. There are four companies in the United States that produce radionuclides for medicine. There are about three foreign units that make material. It is a fairly limited group of companies that originate most of this material.

Radioactivity is an important part of medicine today. If it weren't for radioactivity, we would know much less than we do about the mechanisms of disease. We would not find it so easy to develop drugs for diagnosis or therapy; and we wouldn't have some of our best therapeutic processes.

For the purposes of this Forum, I would like to divide up the use of radioisotopes into four areas:

1. Medical research or biomedical research that uses carbon-14, tritium, phosphorus-32, iodine-125, and sulfur-35.

2. *In vivo* nuclear medicine, that is, the diagnostic nuclear medicine that is based primarily on technetium-99m with some iodine-131 and increasing amounts of thallium-201 and gallium-67.

3. *In vitro* medicine, the very growing field of radioimmunoassay, which is primarily based on iodine-125 and tritium.

4. Therapeutic applications that are primarily based on iodine-131, cobalt-60, and iridium-192.

Who generates the wastes? Right at the moment it is mostly industry, universities, and teaching or research hospitals. Community hospitals, which use mostly very short-lived materials, really generate quite small amounts of waste. They are perfectly capable of storing waste for a few weeks or a few months to let it decay to disposable levels.

However, those of us who are using longer-lived materials and large amounts of materials generate a very large amount of the waste. Leland Cooley's figures indicate that it is about half of the total and that half is divided between industry and universities.

Industry has been working since July 1979 on about four different things. After the governors raised the issue, it became obvious that industry and universities had a very serious problem in quality control with respect to how to pack the materials, how to send it to the waste sites, and the amount and form of material that was in the disposal barrel. This problem was taken up by industry through the Atomic Industrial Forum. Last month we presented to the three states that operate sites our suggested program for quality control administration and audit throughout the United States. That program is now being considered by the State Planning Council, and we believe it will be utilized fairly widely in the United States.

The second problem is waste reduction to save money and to reduce the volume of land burial. Dr. Cooley has described very vividly the increases in costs that have occurred in the last year and a half that make waste reduction desirable for all licensees.

Part of the trouble also is just poor administration of waste. One doctor says that when he started to look into it in his hospital, he became completely convinced that they were burying a lot more radioactive labels than radioactivity. People were not managing their waste. They were throwing anything suspected of being radioactive into the drum. People are learning not to do that. They are learning to set up waste compactors to compact it. It is an absolute necessity that we all do that because volume reduction not only cuts down on the costs but also cuts down on the amount of space we are taking up in the ground.

The third item is liquid scintillation liquids, which I won't go into because it is going to be discussed considerably later on.

Industry has been doing research on how to handle some of these materials and how to develop methods for handling organic materials and aqueous materials.

The last thing I have been asked to discuss with you is what happens if there is a shutdown. At the time of the shutdown, which lasted from October 4 to roughly December 1 of 1979, it became apparent that industry probably had between 100 days and 1 year's capacity for storing waste on site. Universities were in much worse shape. Those of you who are from universities realize that there is not very much room in most universities to store drums of material that have no use for anything. In my own community in Boston, Harvard and MIT were beginning to get very hard up for space to store drums by the time the whole thing ended.

Industry today is beginning to build additional temporary storage sites. A lot of us have approached our state governments for additional interim storage sites to allow us to have more emergency backup. All of us realize that we have got to keep working hard on trying to get more sites.

To sum up, my ideas of the problems we all face are very largely based on a perception problem. The public is afraid of radioisotopes, and the political agencies of this country have played upon this fear. The very large amount of the fear about the sites that have failed is based upon extremely low levels of radioactivity that have gotten into groundwater, very much below what you are allowed normally to put into sewer systems. We and you as biomedical people need to get busy and try to make people understand more about how it is used.

WILLIAM H. BRINER
Associate Professor of Radiology
Duke University Medical School

Clinical uses of radionuclides principally occur in departments of nuclear medicine throughout the country in some 3,300 institutions in which this medical specialty is offered. As a matter of fact, in order for a hospital or medical center to be accredited by the Joint Commission on Accreditation of Hospitals, nuclear medicine service must be available to or for patients in that hospital. It does not mean that there must be a nuclear medicine service in each hospital, simply that that service must be available in a fashion responsive to the needs of those patients. So it is about 3,300 institutions about which we are talking.

Basically there are two kinds of studies or examinations that are provided clinically. Several people have alluded to the in vivo kinds of procedures; these are most frequently diagnostic in orientation, the imaging function studies. People frequently want to hang numbers on things, it seems, and it has been estimated that in any given year, there may be from 10 million to 20 million of these imaging and function types of studies performed in hospitals, medical centers, and clinics.

These procedures involve both anatomical imaging, if you will, and functional information. Nuclear medicine has changed rather dramatically in the last 10 years in that additional emphasis on the functional aspects of the patient are being examined in nuclear medicine procedures, in such organ systems as the heart, lung, liver, and kidney, as well as the skeletal and central nervous systems and the thyroid, to name but a few.

Now, in this kind of clinical use, the disposal of low-level waste that accrues from such uses is a lesser problem than that which is encountered in the other category of clinical utilization of radionuclides, the in vitro area of interest. In in vitro studies, no radioactivity is administered to the patient. Rather, a sample, usually of blood, is removed from the patient and subjected to reactions with radioactive compounds in the laboratory.

In vivo (imaging function) studies make use of radioactive drugs with short half-lives measured in hours or small numbers of days. In the in vitro areas, it is somewhat longer, still measured in days for the most part, since the majority of them are done with a particular radioisotope of iodine (iodine-125) and, somewhat less frequently, tritium or hydrogen-3. Here we get into some waste disposal problems because of the more prolonged half-lives of the nuclides used for this purpose.

In vitro tests measure such things as hormonal and therapeutic drug levels (for example, thyroid hormones, the digitalis glycosides, and aminoglycosides). In addition, a wide variety of chemical and biochemical substances, antigens and antibodies, all of which are important to the health of the patient, can be measured rather exquisitely and extremely sensitively by this method. Indeed, there is someone on a panel later today who has forgotten more about this aspect of the problem than most people will ever know. I refer, of course, to Dr. Rosalyn Yalow.

A few words about research in the medical and the biomedical arenas. Tracer methodology, as has been said, is used to investigate most of man's ills. It has been used to investigate physiologic processes that demand investigation. It is capable of providing answers that at the very least are quite difficult to obtain by any other modality, using small levels of radioactivity, as is evidenced in Dr. Cooley's and Dr. Brantley's remarks.

One of the things that the average member of the public does not realize when he thinks of biomedical research involving radioactive material is the fact that over the past 20 to 25 years, the overwhelming majority of all of the nonradioactive prescription drugs that physicians prescribe for a variety of illnesses were developed as a result of early research involving radioactively labeled counterparts of those drugs.

The Food and Drug Administration is quite specific about the requirements that must be met before any drug can be introduced into interstate commerce. The early stages of those investigations quite logically are accomplished by a tracer methodology, usually in animals, although occasionally in humans in the later stages of the investigation. This all generates low-level radioactive waste. The development of new radioactive drugs that are so very, very critical to nuclear medicine practice also generates that kind of waste.

It is difficult to overestimate the importance of the whole area of low-level radioactive waste production. It was said at the time of the closing of a couple of sites about a year and a half ago that clinical nuclear medicine really had nothing to worry about because of the short half-lives of the drugs with which they were concerned in that practice.

Well, that wasn't quite so. Although in nuclear medicine we can, and have, allowed many of our former waste streams into the low-level radioactive waste disposal sites to decay on site to the point where they can be disposed of by other means, we are still very, very dependent on the suppliers of these materials, the industry that produces them, companies such as Dr. Brantley was talking about a moment ago.

There is one step prior to that. There is at least one commercial isotope production reactor in the United States that deals principally, indeed almost entirely, with medically usable radionuclides. So it goes much beyond the clinic; it goes back to companies that produce these compounds, and even further back to the isotope production reactors, occasionally cyclotrons, that produce the radionuclides.

HARVEY M. PATT
Professor and Director
Laboratory of Radiobiology
University of California Medical School

Let me move from the patient or the person to the molecule to add to what has already been said. I think it is evident that most if not all of the tremendous achievements in recent years relating to our understanding of genes and chromosomes, the behavior of cells, the way in which they proliferate and differentiate, are all derivatives of studies in which radioisotopes have played a very important part.

Those of us who work with radiations are aware of some of the advantages, and knowing about radiation effects, we also have an awareness of the fact that working with radiations poses some disadvantages. But I think it is important, if I can use the words of Merril Eisenbud, to separate unrealistic fears from justifiable concerns. And let me--perhaps this is a bit repetitious--refer to some statistics that were reported by Eisenbud: in 1978 there were about 1,000 curies of tritium and carbon-14 shipped to waste burial grounds from about 2,500 facilities. This amount represents only about 1/2,000 of what is produced naturally by cosmic-ray interactions in the atmosphere, or putting it in still other terms, this represents only about 1/400,000 of the steady-state inventory of tritium and carbon-14 in our environment.

If one takes the estimate that carbon-14 and tritium in the environment contribute less than 1 percent, perhaps only about a half of 1 percent, of natural background, and then views that in perspective to the 1/400,000 added from biomedical wastes, I think you can appreciate the really trivial amount of tritium and carbon-14 radioactivity that we are talking about.

There is one other little calculation that I made while listening to my colleagues. If one takes our experience in San Francisco, which says that there is at most about 7 millicuries of radioactivity per

55-gallon drum shipped off for storage--and this estimate of radioactivity is not corrected for decay--the amount of radioactivity, at the extreme, in a 55-gallon drum corresponds to about the amount needed to do a tracer experiment in man using, say, tritiated thymidine, which localizes in the genetic material. So we are indeed dealing with a very small amount in a 55-gallon drum, an amount that would probably be inadequate even to do a single complete tracer study in an individual.

There has been a lot of reference to east of the Mississippi. Let me tell you about the experience at our school, at UCSF, where even though we are closer to the burial site, disposal still costs a great deal.

In our medical center about 1,200 of some 8,000 employees work with radiation in one capacity or another. There are about 450 work locations in which isotopes are used, and there are at any one time some 500 to 600 approved activities. These are activities that require approval by a committee of peers in order to ascertain that those who want to use radioactivity really know how to use it and are doing sensible things with it.

We produce about twenty 55-gallon drums a week at our medical center. About 25 percent is related to research and 75 percent to nuclear medicine applications.

Our present waste disposal costs, despite our relative proximity to the Hanford dump in Washington, which include administrative and survey costs, are about a quarter of a million dollars annually. But we have been advised that waste disposal costs will double this year from about $100,000 to $200,000 simply for burial of the drums.

LIDIA ROCHE-FARMER
Research Analyst
Division of Fuel Cycle and Material Safety
U.S. Nuclear Regulatory Commission

The liquid scintillation wastes and animal carcasses that contain primarily tritium and carbon do not represent a radioactive hazard, but a chemical or other type of hazard. Let me explain this.

The liquid scintillation wastes contain toluene, xylene, and other solvents that are flammable and potential carcinogens. They have posed problems in transportation and at the burial sites due to their flammability and also due to the fact that they have spilled out of the 55-gallon drums in which they were buried. Thus, they may compromise the integrity of the burial grounds by serving as a vehicle for transport of other radionuclides in the site.

Drums containing animal carcasses have exploded en route to the burial sites due to pressure buildup by the gases produced from the biological decomposition.

As for radioactivity, they contain small concentrations, and, indeed, the best way to dispose of these wastes would probably be by combustion in which the chemicals are broken down into less noxious materials such as water and CO_2. In fact, there is a newly proposed amendment to the regulations that would add Section 20.306 to Part 20, which would permit the disposal of these wastes without regard to their radioactivity for concentrations of up to 0.05 microcuries per gram.

The amendments also propose raising the cap, for the sewer disposal of radioactive materials that are soluble or dispersible in water, of up to 5 curies/year for tritium, and to 1 curie/year for carbon-14, in addition to the 1-curie limit for all other isotopes.

DISCUSSION

UNIDENTIFIED: Dr. Patt, I thought I understood you to say that the cost of disposal at your particular medical center will double from $100,000 to $200,000 of your waste. Do you have any national figures, projections, or something like that?

PATT: No, I do not.

ROCHE-FARMER: Maybe I can help there. The national figures go anywhere from $250 to $400 per drum, so the cost varies depending on the volume of the waste generated and the distance and other factors like that.

OTTO F. ZECK, Assistant Professor, Radiology, Medical College of Georgia: I would like to ask Dr. Brantley a question. You mentioned waste reduction as a valid way to reduce disposal costs. Since New England Nuclear is mostly responsible for the volumes of liquid scintillation cocktail as well as the radionuclides, have they given any consideration to recycling this material and reusing the scintillation cocktails at least?

BRANTLEY: Yes, that has been looked at rather extensively. The trouble is that the liquid scintillation cocktails today are one of the most complex mixtures of materials used in science. They are extremely sensitive to impurities as far as making them more chemically active and chemically fluorescent. At this stage of the game we have not had any luck, but we are looking into the matter.

LAURISTON S. TAYLOR, NCRP, Retired: The panel has implied that today we really have all the knowledge and information, the technology that we need to dispose of radioactive material in a variety of ways. They have touched primarily here on the matter of burial. There are two methods that have not even been mentioned by the panel. One is incineration; the other is burial at sea.

I am quite familiar with the political reasons as to why these are not employed, but the fact is that they are undoubtedly the most economical and the most efficient methods for making radioactive material disappear as far as the public is concerned.

Dr. Patt referred to Merril Eisenbud's statement. Some studies or some estimates have been made that would indicate that the incineration of the biological type of material that you have in hospitals and so on would not add a measurable amount to either the carbon or the tritium that is produced normally in the atmosphere. You would probably be unable to measure that increase in level of either of those things more than a few feet away from an incinerator, and certainly not at all in the ocean.

PATT: Alternative methods of disposal will be considered by others later in the program.

ROSALYN S. YALOW: The panel addressed the amount of carbon and tritium waste, but did not put any numbers on the iodine-125 waste for in vitro testing.

In our hospital, which, as you know, is something of a radioimmunoassay center, for those tests where we develop the ingredients, we use about 5,000 tubes a week, and there is residual on each of these tubes of a thousandth of a microcurie. So a typical active laboratory like mine has to dispose of 5,000 tubes containing a big 5 microcuries of iodine-125, which we could give to a patient as a tracer test without worrying about it at all.

I also calculated what would be required for commercial disposal of radioimmunoassay kits. There the average cost is about, say, plus or minus $10 a test. It could be as high as $60 to $80 for a parathyroid hormone assay, and as little as perhaps $3 to $4 for T_3 or a thyroxin assay. These kits contain on the order of a hundredth of a microcurie per sample, which means that if you want to do 100,000 tests, it will cost you $1 million, and you will generate 1 millicurie of iodine-125.

I think we can appreciate that our country could not afford in its gross national product enough iodine-125 in these kits to represent any type of a hazard.

JANE H. BERGLER, Federal Emergency Management Agency: I would like to ask a question of Bill Briner, not just because he is from Duke, but also because he is from North Carolina. Our understanding is that Governor Hunt has been something of an innovator and is looking at the disposal of radioactive waste as a part of the total hazardous materials concern. I would like to find out what is really happening in North Carolina.

BRINER: About a year ago, through the auspices of the Governor's Science and Policy Advisor, Dr. Quentin Lindsey, who is a panel member here today, there was convened a group of people who were biomedical waste producers in North Carolina to look at the situation in the state with regard to an intrastate solution to a national problem.

We came up with some data that were quite accurate. Then the sites reopened, and the impetus to do something at that very moment seemed less urgent.

In July of this year, Governor Hunt appointed a task force on hazardous waste management, which includes both hazardous chemical waste and low-level radioactive waste. The mission of the task force is to come up with a strategy for North Carolina to help to take care of its own problems.

Coincidentally with the appointment of the task force was the appointment of two technical advisory committees to the governor: one on hazaroous waste, one on low-level radioactive waste. I guess I was lucky Pierre for I was appointed Chairman of the Technical Advisory Committee on Low-Level Radioactive Waste Management.

On September 30 we submitted a draft report that has attained rather wide circulation at this point, offering some strategies that North Carolina may follow to take care of its own low-level radioactive waste of all kinds, not limited only to biomedically generated waste.

What the outcome of that will be is anybody's guess. The governor is quite persistent in his efforts to have us assume our part of the overall problem, since it is a national problem, not one related only to three states that happen now to have commercial low-level disposal sites.

E. H. STONEHILL, Research Planning Officer, National Cancer Institute: I don't know whether this is appropriate now or during the next section on the health effects, but the question I would like to ask is whether anyone knows what is the accumulation in the normal human being over an average span of his lifetime of radioactive compounds in the absence of any interventions of a nonnatural sort? In other words, when a person is buried, what has he got? Do we become more radioactive as we become older?

YALOW: When I testified before the McCormack Committee last year on low-level radioactive waste, I was considered to be rather sensational for pointing out that if we are alive and we are an adult, we contain a tenth of a microcurie of carbon-14 and a tenth of a microcurie of potassium-40, the principal radioactive constituents. We obtain exposure to radioactive materials in all sorts of ways. We breath radon that comes from building materials such as granite. The halls of Congress are probably the worst offenders in this case, and according to the NCRP, those of you who smoke get 8 rads per year to your bronchial epithelium from the radioactive materials contained within cigarette tobacco.

One could go on and on and point out a large number of natural ways of accumulating radioactivity.

RALPH O. ALLEN, Director of Environmental Health and Safety, University of Virginia: In their radiation safety programs, universities have often packaged radioactive material that probably was not radioactive. In fact, sometimes chemicals went into it because there seemed to be no better way of disposing of them. In order to keep regulatory agencies off of your back, you likely took a very conservative approach. Even though the NRC allows a certain amount of material to be put down the sewers, we have taken the stand that we don't want people in the laboratories to intentionally put anything down the sewers. So we increase the volume of our waste greatly, even with the regulations that there are.

At some point we decide that isn't very smart, that we should do something else with it. Immediately the community responds that if it was so unsafe that you didn't do it before, why can you start doing it now? Public awareness is one thing, but it becomes very difficult to educate a large public that is very fearful of radioactivity, particularly when the people they don't trust are the people who in fact have the greatest amount of knowledge and technical background to make these sorts of pronouncements. So what do we do?

BRANTLEY: That is exactly why I made the statement that I thought most of our problem is perceptual rather than real. I think part of it is caused by some of our own regulatory agencies. You made the comment that you would like to keep the regulatory agencies off your back. Well, it happens to us, too.

The regulatory agencies can get wrapped up in some awfully minor kinds of problems and much publicity about minor problems. Then the public does not have any yardstick against which it can measure the issue. They do not know whether it is a major safety issue or a bureaucratic furor over rules.

I don't know really what the solution is. Incineration appears to be a resolution. You could incinerate your material and we could incinerate ours. Yet I wonder what would happen if we announced that we were going to start incinerating materials in our fuel oil in Boston. I suspect, to put it mildly, that all hell would break loose.

ALLEN: Well, from experience, I know. You immediately come under great public fire as to why you are the first ones to do this.

LOWE: It seems to me that one answer to your question is that we should, we can, and I think we must establish a broad enough base of interested and informed people who agree with the position that you have enunciated, that is, the relative safety, the absolute safety, the lack of hazard of the disposal methods that are available to institutions. If we are able to do that, we can in fact reassure the public and begin to change this perception that has handicapped all of us with a concern for the disposition of these wastes.

BRINER: If I can get back to our experience in North Carolina for just a moment. In answer to your question, too often in the past we have attempted to accomplish things by public education or public information campaigns. Once a decision is made, the public is informed that this is how it is going to be done.

Now if you add to that equation one more factor of public participation, of getting people involved in the decision-making process and at the same time establish some credibility with them during the decision-making process, then I think things will move a little more smoothly.

But I am personally convinced after more years in this business than I want to remember that it does absolutely no good to try to educate the public without bringing them into that participatory function.

BRANTLEY: We might point out that the cameras here today are part of such an attempt. The American College of Nuclear Physicians has a grant to develop a program for educating the public about the use of nuclear medicine. That is why they are recording this meeting.

LAURISTON TAYLOR: Excuse me for another try. The Nuclear Regulatory Commission has been made the scapegoat or the malicious organization or whatever. Our real problem is with our news media. We today here are talking to ourselves. We are not talking to the public. Some of this will leak out. I guarantee, if anything gets out of the meeting today, it will be a distortion of trivial things into something that is magnified so as to alarm the public. The news media are quite open and honest in saying that stories reporting that things are safe do not help them sell their newspapers.

ANDREW GLASSBERG, House Energy and Power Subcommittee: Dr. Patt quoted a figure earlier that in 1978 there were 1,000 curies of radioactive isotopes generated which equaled 1/400,000 of the steady-state radioactivity around from tritium and carbon-14, but that sort of ignores the dynamics. In a steady state, those curies are in a dispersed form, whereas now you have 1,000 curies that you are concentrating for disposal.

So would you advocate that we are taking the wrong approach to disposing of these wastes? What we should really do is incinerate and disperse them so they get back into their steady state rather than concentrating them.

PATT: I think that diluting and dispersing, or D&D, is certainly the way it ought to go, and the only reason for citing the Eisenbud figures is to point out the very trivial contribution with release to the environment.

MARY DROB, D.C. League of Women Voters: I wanted to say to Dr. Briner that I absolutely agree that if you get us involved in the decision-making process, we will be much more interested in finding out what we can do about it.

JEANNE MALONEY, Friendswood, Texas: My husband happens to be in the interim storage business. I want to tell you that I talk to the public in my own area, and I completely agree that today you are talking to yourselves.

People compare one waste barrel of completely decayed radioactive material to Hiroshima and Three Mile Island. What are the rays coming out of this one drum that are going to affect me when I live 5 miles away? What is it going to do to me if you have 4,000 drums near your facility and over half of them are decayed? I want to be guaranteed that no act of God will ever touch them, no lightning bolt, no earthquake, nothing, and only when you can guarantee me of that will I allow you to keep those decayed drums near me.

ARE THERE HEALTH EFFECTS?

OVERVIEW:

GEORGE W. CASARETT
Professor of Radiation Biology and Biophysics
Professor of Radiology
University of Rochester Medical Center

It appears that the annual average per capita whole-body integrated radiation dose in the United States from disposal of low-level radioactive biomedical wastes may be unlikely to exceed a few millirem for radiation workers, or 1 millirem for the general public. Therefore, this brief overview may be limited to the stochastic, that is, the probabilistic or chance effects, namely radiogenic cancer and genetic health effects for which zero dose threshold cannot be scientifically dismissed at this time.

For perspective, the recent report of the National Research Council's Committee on the Biological Effects of Ionizing Radiations (generally known as BEIR III) places the average annual per capita radiation dose from natural sources in the United States at about 84 millirem, with a range from 65 to 125 millirem, depending on location.

The average nonoccupational, nonmedical per capita exposure of the American public to manmade radiation sources has consistently been only a very small fraction of background levels, or of the 500 millirem maximum permissible annual dose limit for individuals of the general public. A 1972 Environmental Protection Agency report estimated that the annual average per capita nonmedical, nonoccupational dose to the general public from manmade sources was 6.6 millirem in 1970, and that this would be 6.4 millirem in the year 2000. Most of this dose is due to residual radioactivity from above-ground nuclear weapons tests in the world before 1962.

Radiogenic cancers and genetic effects are qualitatively indistinguishable from the same effects caused by other agents or conditions and therefore can only be detected statistically in terms of increased incidence in irradiated populations in comparison with appropriate control populations, taking proper account of other potential competing causative or contributing factors, and other possible variables. Radiation is only one of many possible causes of these effects, and the smaller the dose, the less likely it is that radiation is the cause or the sole cause.

There is relatively little scientific controversy about the potential health effects of intense irradiation at dose levels above about 50- or 100-rem tissue dose equivalent. The major problems and controversies here are concerned with low dose rates, and especially with lower doses at low dose rates, and most particularly, for example, at dose and dose rate levels of the order of those concerned in maximum permissible annual dose limits for members of the public.

There is no direct, conclusive, unequivocal evidence of radiogenic health effects at such low radiation levels, and it is highly improbable that such evidence can be obtained. If radiogenic health effects do result from such levels, they would be so low in incidence as to be masked markedly by similar effects resulting from other causes.

Therefore, at such radiation levels, the potential risks of radiation induction of human health effects can only be inferred at present by extrapolation from observations at much higher doses and dose rates using mathematical procedures and functions that must be based on assumptions concerning dose threshold, dose response relationships over the whole range of dose and dose rate, inductive mechanisms that involve application of risk estimates to populations other than those from which they were derived, and other assumptions.

Zero risk is not excluded at low radiation levels by the data available, but neither is zero dose threshold excludable by available information and theory.

Human radiogenic cancer risk estimates have been based largely on human epidemiological data, on mean absorbed doses usually above 100 rads (or rems), often at high dose rates.

As important as they are, however, there are many unavoidable deficiencies and limitations in the human data as compared with controlled experimentation: the epidemiological data are highly uncertain in regard to dose response relationship functions, especially at low radiation levels; the influence of dose size, dose rate, and radiation quality on incidence and latency; precision regarding absorbed radiation doses in tissues and organs; duration of risk and lifetime cancer incidence in exposed and control populations; and the roles of competing environmental, host, and medical treatment variables--there are no identical control populations--among other factors.

Although in a few instances a statistical association has been shown between increased incidence of human cancer and mean absorbed doses of a few rads, the relevant doses and the extent of causal relationship are uncertain or equivocal. While these data suggest what has been generally assumed for radiation protection purposes anyway, that is, that cancer may be induced in some incidence even at low doses, they do not provide a reliable basis for estimating the frequency or risk of cancer induction at such dose levels because of the large statistical uncertainties, as well as the uncertainties involved in the designs of the surveys. Much more information on the highly complex and varied mechanisms of radiation carcinogenesis is needed before the radiogenic cancer risks at low radiation levels can be estimated more precisely from the epidemiological data.

Extensive experimental data and the human epidemiological data indicate complex and various dose incidence relationships for different kinds of cancer. For available epidemiological data, advisory groups have simplified dose effect relationships by reducing the number of parameters. Such simplified models, as considered in the BEIR III report, for example, in the order of increasing complexity of the shape of dose effect curve include: the overall linear, that is, overall straight line; the overall quadratic, for example, $dose^2$; the linear quadratic, with a straight line component of relatively low slope at low radiation levels, followed by an accelerating component, for example, $dose^2$ with further increase in dose; and finally, the linear quadratic form with an exponential modifier to account for influence of excessive cell killing.

The constrained linear quadratic model appears to be best supported by currently available information for low-LET radiation and results in risk estimates at low radiation levels that are intermediate between the higher estimates for the linear model and the lower estimates for the purely quadratic model.

In the past, the overall linear, zero threshold hypothesis for extrapolation from high doses and dose rates to zero dose and effect was chosen by various national and international advisory groups, in a sense by default, at least partly for pragmatic rather than strictly scientific reasons, because of its simplicity and ease, the great difficulty of doing otherwise at the time with the uncertain human data available, and for radioprotective prudence, that is, to ensure that errors would be on the safe side, on the side of overestimation of risk. The need for risk cost-benefit analysis, of course, requires more realistic risk estimates.

The linear nonthreshold hypothesis permits: averaging of different individual doses to form data points in preparation of dose-response curves; the utilization of average per capita dose or the collective dose (person rem); the arbitrary selection of ranges of doses for such averaging; the averaging or integrating of nonuniform tissue or organ doses; the neglect of differences in dose rate; and the simple derivation of risk coefficients, that is, risks per unit dose, for application to any dose at any dose rate.

Indeed, the application of such procedures to raw data to produce dose-response curves for examination and extrapolation tends to preimpose linearity.

For low-LET radiations, risk estimates for low radiation levels derived by overall linear extrapolation from data at high doses and dose rates in the rapidly rising part of the dose-response curve are likely to be overestimates because the effectiveness of low-LET radiation per unit dose decreases with decreasing dose size and dose rate, at least down to the low radiation levels where the low-slope linear component of the linear quadratic dose-response model may pertain. For the more effective high-LET radiations such as neutrons and alpha particles, the dose-response curves tend to be more linear, and there is comparatively little or less reduction of effectiveness per unit dose with decreasing dose size or dose rate over this moderate to low radiation-level range.

More recently, however, with advances in knowledge, the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) and the International Commission on Radiological Protection (ICRP) in effect have concluded in their radiogenic cancer risk estimates for low-LET radiation, regarded as still conservative, a reduction within a factor of three from the levels that would pertain to estimates from overall linear extrapolation. The BEIR III Committee has also in effect taken dose size and dose rate influence into more account in its utilization of the linear quadratic and the quadratic models.

The use of the linear quadratic model, as in the BEIR III report, for example, may be regarded as the most representative of those scientists' current best judgment, despite the fact that the presently available data will not permit definitive conclusions.

Using the linear quadratic dose-response model and an absolute risk-projection model, the BEIR III Committee derived an average value of approximatly 77 excess cancer deaths per million persons exposed per rad for an arbitrary situation in which the million people are exposed to a single increment of 10 rads of low-LET radiation.

The 1977 UNSCEAR report gives a range of estimates, the comparable lower end of which--about 75 excess cancers per million per rad for low-dose, low-LET radiation--is close to the BEIR III value I just cited. However, the cancer risk is influenced by age at the time of irradiation and by sex, as well as by radiological factors.

For purposes of radiation protection, the ICRP has taken the average individual lifetime radiogenic cancer death risk at low levels of low-LET radiation exposure to be 1 in 10,000 per rem, which corresponds to an average for the population, all ages and both sexes, of 100 per million per rem.

Proportionally, these various risk rates would reduce to one or less per 10 million per millirem, simply dividing by 1,000 to get into the range of doses of interest here.

For perspective, according to the American Cancer Society's cancer facts and figures in 1979, about 25 percent of the people in the United States will eventually develop cancer (lifetime risk rate of 250,000 per million), and about 15 to 17 percent of these people, or about 60 percent of those who develop cancer, will eventually die of cancer (lifetime risk rate of about 160,000 per million).

The radiogenic cancer death risk rate of 100 per million per rem is about 6/10,000 of this natural cancer death rate, and that reduces by a factor of 1,000 more for the 1-millirem dose, or 6/10,000,000.

There is virtually no human evidence of radiation induction of any genetic effects. Recent estimates by advisory groups of the risk of radiation induction of human genetic health effects at low radiation levels are based upon data from experimental animals, mainly mice, and particular dose-effect data obtained at the lower dose rates employed in such laboratory experiments, which are less effective than the high dose rates used by a factor of about three.

There is no direct evidence for the induction of genetic effects in animals at very low doses and dose rates. The effects of doses below those of the order of a few tens of rems are too small to be detected statistically.

The BEIR III Committee estimated 5 to 65 induced dominant disorders during the lifetime of a million live-born children following parental exposure to 1 rem, and from 0 to 10 per million per rem genetic disorders from induced chromosomal anomalies, for a total of 5 to 75 per million offspring per rem parental exposure in the first generation.

The BEIR III Committee also estimated the number of genetic disorders to be expected in each generation after many generations of parental irradiation when an equilibrium has been reached between the rate of induction of new genetic ill-health in each generation and the rate of elimination in each generation through expression in affected individuals. This equilibrium estimate is about 60 to 1,100 affected individuals per million live-born per generation per rem parental exposure in each generation.

The estimate of the current natural incidence of genetic ill-health in the U.S. population is 10.7 percent of all live births. Thus, the first-generation increase of between 5 and 75 cases per million live births per parental rem may be expressed as increasing the 10.7 percent natural incidence to somewhere between 10.7005 percent and 10.7075 percent. One can divide this change by 1,000 to obtain the change associated with 1 millirem.

The "all-time" equilibrium estimate of from 60 to 1,100 cases per million per rem is more difficult to put in perspective because the total number of human generations and the future population dynamics are not known. Assuming 1,000 generations, the current natural incidence of genetic ill-health, 10.7 percent, would rise to a level between 10.700006 percent and 10.70011 percent, averaged over the 1,000 generations, with most of the expression in the first few generations. Again, one can divide the change by 1,000 to obtain the change for 1 millirem.

The 1977 UNSCEAR report presents a central estimate of substantial radiation-induced genetic defects of about 200 per million per genetically significant rad at low doses of low-LET radiation, with perhaps one-third or less of these expressed in the first generation.

The ICRP's genetic review suggests a similar total for all generations, with half of these expressed in the first two generations, and the other half expressed in all subsequent generations. The corresponding value for 1 millirem would be 2 per 10 million.

The risks of radiogenic health effects, if any, from disposal of low-level radioactive biomedical waste would appear to be very small, even compared with those that might be estimated for natural background radiation.

ROSALYN S. YALOW
Senior Medical Investigator
Veterans Administration
Chairman, Department of Clinical Sciences
Montefiore Hospital and Medical Center

Unlike the other speakers on this panel, I came without any notes because if I can't remember to tell you some numbers, then you won't remember to keep these numbers in your head.

In 1973 the average dose to airline crews was 160 millirems per year. This means that airline crews, on the average, represent one of the most exposed of radiation workers.

In a recent trip to Argentina, I carried a calibrated dosimeter with me to see what my radiation exposure would be, and that week I received 10 millirems of radiation, more than I have ever received as a radiation worker in my laboratory working for 33 years with the medical uses of radioisotopes.

If you now consider how many of you have flown in the past few years, you can appreciate that you should perhaps bury yourself in a hole to avoid the effects of cosmic radiation, except that you will thereby increase your exposure to the natural radiation in the soils.

Now, clearly, no one can say that there will be no health effects from a level of radiation close to natural background radiation. All you can say is you will not be able to measure any health effects.

I would like to point out as a physicist, not even as a radiation physicist, that it is not always safe or appropriate to extrapolate beyond the range in which measurements can be made. For instance, Newton's laws, which are equally valid for planetary motion, dropping a stone off the Tower of Pisa, or even how automobiles move, tell us nothing about the behavior of matter at velocities approaching the velocity of light, or the behavior of matter at the submicroscopic scale of the atom. Most of the predictions that Dr. Casarett was telling us about depend upon theoretical extrapolations from a known dose range, usually in excess of 100 rads, frequently in excess of 100 rads acute exposure.

I believe that one cannot extrapolate from this no matter what model you choose simply because of the fact that unless you can experimentally test the model, you don't know whether the theory is reasonable or unreasonable.

Now, there has been a series of reports concerning exposure to low-level radiation published in Science in July of this year. There is a very interesting article based on a study of 150,000 Han peasants, half of whom were exposed to our usual 100 millirem per year, another half of whom were exposed to about two-and-a-half times this level. The progenitors of this group have probably lived in the same place, they said, for six generations. It may well have been 60 generations. You would have expected to have had the cumulative genetic effect of two-and-a-half-fold increase over usual background exposure for many hundreds of years. They have a similar genetic background, they have similar work habits. The investigators looked for many abnormalities that might be related to radiation. Differences between the two groups were not found in a variety of hereditary aspects. Nothing was found.

This isn't the first time one has looked at levels of the order of two to three times the background that we have in the East and on the West Coast. I might point out to you that in Denver the average exposure due to the radioactivity in the soils and cosmic radiation is about twice what it is in the East and on the West Coast. And what about the age-corrected cancer death rate? Fifth lowest among the 50 states.

We hear so much about the problems from operation Smoky, the fallout from the bomb testing in Nevada. It fell out in Utah. Which state in the continental United States has the lowest death rate from cancer? Utah, undoubtedly because of life-style: the Mormons don't smoke, drink, or perhaps have other pleasures that increase it. The message I would like to leave with you is that we cannot ever say there is no health effect. But there are many papers describing groups of people studied for health effects at two to three times natural background exposure and for whom nothing was found.

I question all these extrapolations from high-dose levels to low-dose levels, irrespective of your theories. Eventually you are going to have to examine the group at the low-dose level to see whether or not these theories make sense.

And the last idea that I would like to leave with you is that in these times of emphasis on conservation--conservation of natural resources, conservation of energy, conservation of everything--I think the most important thing to conserve is our scientific talent, and if we waste it looking for small effects or undetectable effects, we will not be making the discoveries that really save lives. I would like to encourage all of you to help conserve our scientific talent away from this nonsense of looking at the effect of my laboratory disposing of 5 microcuries of iodine-125 a week.

S. JAMES ADELSTEIN
Dean for Academic Programs
Harvard Medical School

There has been much discussion of liquid scintillation waste that causes problems both in radiation and chemical exposure.

To estimate the potential radiation effects, the Nuclear Regulatory Commission has calculated the potential effects from combustion of a curie of tritium and 10 millicuries of carbon-14 including the highest exposures in the immediate neighborhood. It estimates about 10^{-2} millirems for those people who would be most exposed.

If you do the arithmetic and make an assumption about how many people are likely to be exposed under such circumstances from Dr. Casarett's dose estimates, you can derive the probability of an increase for a single case of cancer; it is in the very low fractions. Consequently, from the point of view of waste management, the radiation hazard can be minimized.

The chemical hazard, however, is one that needs to be examined further. Recall that liquid scintillation wastes are both flammable and potentially toxic. There are potentially short-term poisonous effects such as liver and bone marrow failure and long-term effects such as carcinogenesis and mutagenesis.

It is important, then, in looking at the system as a whole, not to have the radiation-risk potential prevent our minimizing the chemical hazards or the biological hazards in the development of disposal practices. One has to be careful that the change in behavior that has recently taken place in response to the crisis in waste management doesn't subject those who work in radioassay laboratories to these other types of dangers.

In talking about health effects, one really has to talk about the costs as well. If we really are serious about putting a cap on the costs of medical care, then we are going to have to talk about how we are going to spend our resources for doing this, and if we increase the costs of waste disposal, it will have to be taken out of some other portion of the health care system.

One research project that I know of has had an incremental cost for waste disposal of about $10,000, in a project that spends about $60,000 to $70,000 a year. Perhaps they are not as efficient as they ought to be, but that is a large fraction of the direct research costs that are going just into waste management.

I think it is very important for this Forum to address itself to what really needs to be done and to cost-effective methods for accomplishing it.

MARVIN GOLDMAN
Professor and Director
Laboratory for Energy Related Health Research
University of California, Davis

The problem is more a function of what we know rather than what we don't know. In a Forum like this, with perspective being one of the areas that I feel we scientists have not done well at, I thought I would try to answer your question in three parts: What is the dose? What are the effects? What is the risk? I will sum up with something that has to do with what we need to know for things to be acceptable. At that point I stop because I am not the one who determines what is acceptable, and I would like to take off on that a bit later.

What is the dose? We have been talking about tritium and carbon and other radionuclides, and you could be regaled with numbers ad nauseum. One simple way that I have tried to handle this is to convert everything in terms of millirems. You have heard Dr. Yalow say that we have approximately 100 millirems of absorbed dose each year, and because of cosmic ray interaction, tritium and carbon are ubiquitously part of our natural background radiation. They have always been here. They are not strange new nuclides.

From the tritium generated by cosmic rays, which has always been a part of living things on this planet, we get a dose of about 1/1,000 of 1 millirem a year. That is a lot of airplane flights. From the carbon-14 you can add another 0.9 of 1 millirem a year, a total of approximately 1 percent, let's say, of your total annual background radiation.

Everyone in this audience contains about 20-millirem-a-year equivalents of another isotope, potassium-40, which is by far the overwhelming contributor to the uniform distribution of ionizing radiation within all living things from natural sources.

An increase or decrease in this tritium dose, which is thousands of times smaller than the potassium dose, is indistinguishable with regard to what the cells will see.

What are the effects of radiation? At high doses we have acute effects. At intermediate doses, as Dr. Casarett has pointed out, we know much about cancers and genetic effects. At low doses these cause controversies, conferences, and queries.

A low dose is sometimes defined as the dose below the high dose. It is usually enveloped by this Pandora's box below which our extrapolation from known effects becomes a bit uncertain. And what I would like to point out is that we do know what the upper limit of that uncertainty is and that it is very important that the public understand, as Dr. Casarett mentioned, that when we talk about a risk of 1 in 10,000 for cancer induction per rem of radiation absorbed, the debate usually is whether it is 1 in 10,000 or 2 in 10,000 or 3 in 10,000; that is, the coefficient rather than the exponent is debated.

This problem of perception is so difficult for scientists to get across to the public. We have been so careful to include the caveats about age and dose distribution and quality of radiation that at times we split rather than lump, or count beans or trees rather than see the forest.

What I wanted to point out in the few moments available to me is that throughout your lifetime--and let's say you live 70 years absorbing 1/10th of a rem or 100 millirems a year--all of us would receive approximately 7 rems of radiation. And if you use a per-rem risk of 1 in 10,000 as the cancer value, it says, depending on how you read the cancer statistics, that you are adding 1/200th of 1 percent of your "normal" cancer risk from background radiation.

Background radiation is known to vary from place to place. Buried in that variability are the doses that we are now dealing with when we consider the medical contribution.

Someone mentioned earlier that perhaps a proper approach would be to disperse and dilute rather than to concentrate and contain so as to assure that the low levels remain low and that no focal or local hot spots or superconcentrations would occur.

But remember, with regard to the tritium, we are talking about increasing levels by more than factors of 1,000 in order to increase the natural tritium background level to the point where it amounts to 1 millirem dose-equivalent.

I wish to end by saying that the more we know--I have estimated that some $2 billion have probably been spent on radiation research--the more intelligent our questions can become and the more we can focus on the unknown. But I think that the real controversy that brings us to meetings like this relates to how one converts these numbers to what we would like to call an acceptable risk, realizing as the public is now becoming aware, the fact that there are no zero risks in life. Therefore, we can compile these either in terms of volitional risks or involuntary risks, but not in terms of acceptability. If I tell you that it is a 1 in 10,000 risk, is that a value you could accept? Who makes that determination? I believe that someone earlier today mentioned that it must be done in a collegial way, that we experts can determine what the risks are, but that the public has to assist us in determining what an acceptable policy is, not only for this risk but for the myriad of risks that we have to look into as scientists and about which we know very little.

EDWARD W. WEBSTER
Chief of the Radiological Sciences Division
Director of Radiation Safety
Massachusetts General Hospital
Professor of Radiology, Harvard Medical School

I would like to make three points in connection with this waste disposal problem. In answer to the lady from the League of Women Voters, there is no external hazard, incidentally, from carbon-14 and tritium because the radiation doesn't get out of the barrel. The only hazard would be if there was some inhalation or ingestion of this material.

I would like to go through the scenario of what would be the risk if somebody drank all of the carbon-14 toluene in one barrel. Hopefully they wouldn't do that because the toluene is toxic and also carcinogenic. However, let's think about the radioactive hazard.

A typical barrel of carbon-14 toluene waste contains about 2 microcuries. That is about 2,000 vials, with about 1/1,000 of a microcurie per vial. If that was all drunk by one person, the radiation dose averaged over the whole body would be about one millirem, depending on what we call the effective half-life, how long it stays in the body.

If we take the maximum likely risk from these very low levels of radiation, which hasn't indeed been observed--and it may be zero--and if we take the BEIR III report estimate of 1 fatal cancer in 10,000 people per rem--that's 1,000 millirems--of radiation, then we find that the 1 millirem from drinking this radioactive liquid would produce a chance of 1 in 10 million of dying with cancer as a result of that unfortunate episode.

Now, what are we doing today? We are actually spending at least $100 per barrel to remove this hazard; $200 perhaps is a better number, as we heard earlier. If you were to rework those numbers and ask how much we are spending to prevent one cancer case in this situation, the answer is $100 a barrel, multiplied by 10 million, which is about $1 billion per cancer case averted; $1 billion to save a death from cancer. And since people are not actually drinking the radioactive liquid, the disposal cost to save a possible death will be very much greater.

I would like to put that in an economic perspective. With $1 billion, you could build about 50 modern cancer treatment centers. Massachusetts General Hospital recently invested $20 million in one such, so we could put 50 of those up.

Or if you like, you could put it in the context of the total health care budget for this country in 1 year, which is approximately $200 billion, only a part of which is devoted to the roughly 1 million cancer cases that occur each year. It seems that the perspective is all wrong if we are going to pay that much for disposing of these trivial amounts of radioactivity.

The second point I want to make has to do with the incineration. I have heard that about 7 curies of carbon-14 per year is being disposed of in the United States from biomedical waste. This is considerably greater than the amount in scintillation vials. That has to be compared with about 5 million curies of carbon-14 in the atmosphere now.

The dose that people are getting, as several people have already said, from natural carbon-14 in our environment is about 1 millirem per year. That is 1 percent of background. Much of this carbon-14 dose comes from the food we eat rather than the air we breath.

If you were to incinerate this 7 curies of carbon-14, you would increase the concentration of carbon-14 in the atmosphere worldwide by 1 millionth, so that people will be breathing 1 millionth more carbon-14 than they are now. Since the dose now is 1 millirem per year, the added dose would be no more than 1 millionth of 1 millirem that everybody in the world would receive, which is, in mathematical terms, 10^{-9} of a rem.

The cancer risk on a pessimistic basis, let us say, is one fatal case in 10,000 per rem, and if you were to apply that risk figure per rem to the 10^{-9} rem that the world population would receive, you get a cancer risk of 10^{-13}.

There are in round numbers about 10 billion people in the world, so that if you then take the 10 billion people in the world and you increase their cancer risk by 10^{-13}, you find that there is a risk of only 1 in 1,000 that there would be even a single extra cancer fatality occurring in the world population. That is the product of 10^{-13} and 10^{-10}. So it looks like burning this little bit of carbon-14 carries a minuscule and possibly even zero risk.

Finally, I want to give you an analogy to put this incineration risk in perspective. Where I come from in New England there has been a tremendous upsurge in wood-burning stoves in the homes. It is a nice thing to do to conserve energy, use our own resources. In any wood-burning stove of course there is some carbon-14 being burned--there's about 6 picocuries of carbon-14 in every gram of carbon. You could estimate that about 20 microcuries of carbon-14 would be released per year per wood-burning stove assumed to burn about 200 pounds of wood per day during the winter months. Now, let's suppose we have a million homes in the United States burning wood throughout the winter. They will be releasing into the atmosphere about 20 curies of carbon-14, which is three times more than we are now contemplating releasing through an incineration program of biomedical waste. I think that puts it in pretty good perspective. Wood-burning is more dangerous.

DISCUSSION

ROBERT L. CARTER, Professor of Electrical and Nuclear Engineering, University of Missouri: One of the problems we confront is the virtual impossibility of establishing epidemiological data on the effects of low exposure.

I would dare say if each of us examined our average experience over the last 10 years or so from medical procedures that we have been told we should undergo for our welfare, probably another 20 millirems per year has been elected or at least tolerated by members of this group.

Further generalizing the curve you mentioned earlier--the curve with the linear parabolic quality--I infer that if we should follow that parabola on back up to the zero exposure point at which the welfare or the risk is increased, then there is a minimum risk point perhaps in the region of 20 or 30 millirems per year, looking at it from the broadest health and welfare of the individual point of view.

Has anyone considered, since we are worrying about communicating with the public, looking at this in a more general manner to avoid this inability to measure or to make definitive statements about the low exposure risk?

YALOW: Well the point I was making is that we have a very large group of people exposed to an extra 100 millirems per year, the people who live on the Colorado Plateau. I must admit, coming from New York, that more people are leaving my town and moving to Colorado, so they are probably not that worried about the doubling of radiation exposure. And in fact, even in the regions of Colorado where there is increased exposure due to the higher content of the soil, they simply haven't found anything.

It is unlikely that doing epidemiologic studies with reasonable numbers of people, like 5 million or 10 million, would permit definitive answers. Must we continue to do these studies that cost an enormous amount of not only money but scientific talent that could otherwise be used to save lives?

ADELSTEIN: It strikes me, in listening to many of these conversations, that the perception of risks is very contextual. If you move from a wooden house to a brick house, you increase your radiation commitment by an amount greater than anything we are talking about. The same applies if you move from New York City to Denver, or as Ted Webster has just told us, you burn wood in your home stove.

Nobody takes these matters into consideration when they make decisions as to whether they ought to move from a wooden house to a brick house, whether they ought to move from New York to Denver, whether they ought to burn wood, or whether they should insulate a house, an act that can raise the natural radon level significantly.

There are two reasons why that may be. One is that the cost-benefit is so clearly in the direction of the benefit that nobody cares about the risk. Those making the decisions don't realize that this sort of risk is being taken.

I think that the matter is highlighted in discussions of biomedical waste management because we are focused on radiation uses. To move the broader discussion into a public arena where these perceptions can be compared, somehow or other the participants must appreciate that one is trading off those risks and benefits all the time. If we could bring the biomedical context into line with the context of everyday living, I think that some of these matters would be better understood.

Another consideration is the bearing of this risk by the public, as opposed to the bearing of this risk by groups who are the most obvious beneficiaries--patients, their families, their friends, and the people who work with these materials. The public has some commitment to research applications insofar as the public has a commitment to medical research, which it feels is a widespread good.

LEO GOODMAN, Chairman, Split Atom Study Group: I have been making studies of accidents in the atomic industry for 25 years, first in behalf of the trade union movement, and subsequently as Chairman of the Split Atom Study Group. I find that the discussion is inadequate. It is at a theoretical level, so I would like to introduce a few cases.

Ever since Louis Slotin died from radiation effects at Los Alamos, we have known that there are dangerous levels of radiation, and those of us who work in the industry have known that there has been every effort to hide the facts of those accidents that have occurred. It is inadequate for the National Academy of Sciences to present a probudget point of view, which basically this discussion is, on how we reduce the costs of disposal of wastes from biomedical research in the nuclear field. We ought to discuss a few cases.

I would like to ask Dr. Adelstein and Dr. Webster, for example, how was the waste disposal handled and what were the effects of the handling of the waste disposal when the Harvard-MIT bubble chamber exploded and spread a rather substantial disaster around the Harvard-MIT facility.

Are they aware of the effort to dispose of wastes from Waltham, Massachusetts, when hundreds of barrels of waste disposal at the wharfs in Boston exploded and spread radioactivity around the area?

I would like to ask them if they know about the conflict between the staff and New England Nuclear, who burned up the radiation exposure level in the bank of one employee after another and dismissed them when they reached the so-called permissible level?

What are we doing about the actual cases? What about lost isotopes? The Mexican government has issued a remarkable report that I doubt this audience knows about, entitled The First Radiation Accident. It tells of a young boy playing near the town dump, finding a mislaid isotope, picking it up, taking it home, playing with it, and the entire family dying as a result.

Can't we talk about some actual cases? I know this will offend Dr. Yalow, may offend Dr. Goldman, but I know those who come from Boston, as I do, know that there are some real problems in that metropolitan area.

WEBSTER: Well, first of all, let's go back to where we were this morning. We differentiated very strongly between high-level waste and low-level waste.

GOODMAN: What's the definition?

WEBSTER: Well, we were talking about levels of waste that give radiation comparable to normal background radiation to people, and that is the takeoff point of this whole meeting.

GOODMAN: You know that the NRC defines high-level waste as only the fuel elements that have been through a nuclear reactor.

WEBSTER: Well, there are intermediate levels.

GOODMAN: There certainly are.

WEBSTER: I am not sure that any radioactivity was involved in the bubble-chamber explosion. But let me comment on your Mexican case. That was not a situation involving low-level waste. It was, as I recall, a cobalt-60 source--

GOODMAN: Yes.

WEBSTER: --which was very strong. I believe it was used for radiography of metal welds and similar to the kind that is used to treat people for cancer and give them large radiation doses to destroy that cancer.

GOODMAN: What was it doing out in the town dump?

WEBSTER: Well, now, you had better ask the Mexican government about that.

GOODMAN: No, I asked my question, sir. I did not separate that from asking what has happened about the lost isotopes in this country? I have a record of 100 isotopes that have been lost. Where are they and who have they affected?

WEBSTER: Well, if they were low-level sources, as far as we can tell we don't know if there are any health effects at all. We don't really know that external occupational exposure to such sources, which you were talking about in connection with New England Nuclear, is in fact creating any cancer. One study that has been done recently is the Mancuso Report--

GOODMAN: Well, I will list the individuals who have died from the effects. Here they are if you care to see my file.

WEBSTER: Well, what I am saying is that we can't prove there are any effects from low levels of radiation exposure.

For example, let's take the Portsmouth Naval Shipyard situation, which has been very much headlined. That study has now completely collapsed because the dose data have been released, and the people who died from cancer were not especially in the exposed groups. In other words, there was very little difference, in terms of cancer incidence, between those who were exposed and those who were not exposed in that shipyard. So that situation provides no evidence.

GOODMAN: Well, if I may differ with you on that case, I was the advisor to the local union at the Portsmouth Shipyard during the construction of the Thresher, which now is down at the bottom of the sea. The workers were not given adequate instruction or facilities for recording the doses they were exposed to during the welding of that submarine.

WEBSTER: What I am saying is that you can't show--and I challenge you to show--that there has been any adverse effect--

GOODMAN: Yes, I agree--

WEBSTER: --from current levels of occupational exposure to x-rays or gamma rays in this country, including Portsmouth Naval Shipyard. I challenge you on that.

GOODMAN: Yes, sir, I am prepared to take up that challenge.

YALOW: In my commentary on the Curie series, I pointed out that a large number of people died from high exposure to radiation, starting with Marie Curie and her associates.

I do not accept that Slotin died in the same sense. In fact, I have pointed out that Slotin died as a fireman going into a burning building or a policeman shot in the line of duty. He knew that the reactor was going to go critical during the early stages of working with reactors, and, as a hero, he broke up that reactor, that pile, with his own hands.

Now, this is a completely different situation than what we are now talking about. In the Mancuso Report that dealt with the Hanford workers, the excess deaths presumably were attributable to those who received more than 15 rems during their entire working time, which is equal to living in Denver for 10 to 20 years, and the total death rate due to cancer among these workers was 14. Compare this figure to an expected death rate due to cancer of 28, so that one then attributes this to the healthy worker idea, that these workers are healthier than the general population, and therefore they had half the cancer death rate.

He then goes on to tell you that there were two types of cancer that had been increased threefold: in multiple myeloma and in pancreatic carcinoma.

How frightening! It turns out that the expected death rate was 0.6. The actual death rate was 3. Now, in the case of pancreatic carcinoma, only one of these three has already been proven. The other two are questionable. But in fact, it is much less frightening to say there were three cases of pancreatic cancer than to say the death rate was increased threefold.

Let me point out to you that the likelihood of pancreatic cancer resulting from radiation can be gleaned from the very high dose levels that were given at Hiroshima and Nagasaki, and in the survivors there was no evidence for increased pancreatic carcinoma in patients receiving 100 rads as an acute exposure.

Therefore, there is absolutely no scientific basis for saying, even if there were three cancer deaths due to pancreatic cancer at Hanford, that this was attributable to a radiation effect.

Now, I know it is a great idea to talk about big business and big reactors, and they are always bad. In fact, as Dr. Webster points out, this is not the subject of discussion today. Perhaps we should ask the National Academy of Sciences to consider the general health hazards of airline pilots--

GOODMAN: I would appreciate that--

YALOW: --and other radiation workers. We are talking about something different.

GOODMAN: I accept that suggestion gladly.

YALOW: This is relevant, but it is not relevant to today's discussion, which is the disposal of medical waste.

Now, essentially what we have to do is match these low-level wastes against what they have done. In our country, 1 in 4,000 children are born with the hypothyroidism of the newborn and will be irreversibly mentally retarded if they are not detected and treated in time. With a few microcuries of iodine-125, we can protect them against irreversible mental retardation.

These are the kinds of issues that we are discussing today. We are not discussing what is happening at nuclear power plants or in uranium mining, or the coal miners who are dying from black lung disease. These are different issues, and I think you should restrict your questions to those issues.

E. H. STONEHILL, National Cancer Institute: I was interested some years ago in a report that concerns some of the data that Dr. Yalow referred to regarding the health effects of living in the Rockies area. I can't cite the exact reference, but I do recall that the authors were somewhat chagrined and upset at the time. Recognizing the increase in radiation exposure due to both terrestrial and cosmic rays in the Rockies area, they found the lower cancer rates, they found the lower death rates that you referred to, Dr. Yalow. But in trying to find some rationale, they looked at a lot of other things, as I recall the report: they found a lower homicide rate; they found a lower divorce rate; they found a lower fingernail-hanging rate. They looked for everything and found it to be lower and in the direction of longer life or healthier life.

Has anyone followed this up? Is there any claim for the reasons for this other than the radiation association, which was the intent of the researchers when they started, but not necessarily the reason, other than the possibility again that Dr. Yalow mentioned--and I don't know the Mormon content of that study either.

YALOW: Well, it is really very difficult to deal with things when you are working at these levels close to natural background. The changes in the composition of the population, for instance, the fraction black, the fraction Hispanic, perhaps even where they come from. The point we are making really is that at these low dose rates and low total doses the effects are so small that one cannot simply design an experiment to give you an answer.

And the question I raised is if at this time we cannot design the appropriate experiments to give us an answer, then because of my concept of conservation of resources, including scientific talent, might we not be spending our time and money otherwise in doing the kinds of things that will save lives rather than continuing to examine and reexamine the effects that we have not been able to observe at these very low levels?

GOLDMAN: I think Dr. Stonehill is referring to a report by Norman Perjurio of late at the Argonne Laboratory in which the natural background rate for each state was plotted against the age-adjusted cancer mortality rate for those states, and, as we have heard, those in the Colorado Plateau had the highest exposure levels, about a factor of two higher, and much lower death rates from cancer.

If you look carefully at those data, you find that one of the deficiencies is in lung cancer. And if you look again carefully, most of the states in the United States are clustered around 100 millirems. The variation from state to state with a constant dose rate in the mortality rate was far greater than the drop in the higher states. And you have heard that one plausible explanation might be the lack of tobacco and certain other things in the mix of folks there.

If you also add to that the fact that radiation seems to have a preference for certain kinds of organs, if the dose is uniformly distributed, all organs are not at equal risk, and if you then correct for that, you will find that there really is no relationship other than the major influence of a lack of a large fraction of the population with smoking histories.

If you wanted to reduce cancer in the United States, the single most effective thing would have to do with our policy regarding the tobacco plant. But that is another Forum.

OTTO ZECK: Dr. Webster presented a scenario of drinking whole barrels worth of carbon-14. I wonder if you would follow through on the scenario for iodine-125, say the amounts that Dr. Yalow is working with, 5 microcuries.

WEBSTER: Well, the situation would be somewhat different, of course, because a substantial fraction of the iodine-125 would localize in the thyroid gland, and the thyroid gland dose, therefore, would be considerably higher since it is a rather small piece of tissue. We are talking about 20 grams worth of the thyroid instead of 70,000 grams worth of whole body.

Nevertheless, because of the very tiny amounts of activity that are going into these tubes--Dr. Yalow mentioned I think 1 nanocurie per tube--and the order of 5 microcuries per week, if that was ingested by one person (I don't know how you would do it, frankly, chewing up all that glass, but nevertheless, if you did it), we are talking the order of about 5 rads of dose to the gland, roughly a rad per microcurie of iodine-125 in the form of iodide. That is actually less dose than people receive who are going to the hospital and having diagnostic tests for thyroid function, for example, a thyroid scan.

So that I would place it in that perspective, that it is still a small dose, even for iodine-125. Actually, much of the material would not be in the chemical form of free iodide and this would substantially reduce the thyroid dose.

YALOW: Can I add that when Dr. Webster was having them drink several gallons of toluene and he was worrying about the late carcinogenic effects, they would die acutely from liver disease. I would say that anybody who was choosing to chew up 5,000 tubes of glass would hardly be around waiting for it to affect the thyroid in such a case. I think they are much more likely to die from something else.

ANDREW GLASSBERG, House Energy and Power Subcommittee: I would like to first compliment Dr. Webster and then take issue with him. I would like to compliment him for comparing the incineration of these low-level wastes to wood-burning stoves. But I would like to take issue with him when he described the amount of low-level waste that is generated a year and then dispersed into the atmosphere. All this assumes sort of an instant dispersal, uniformly distributed.

Now, I think if we are going to consider the health effects of incinerating some of these low-level wastes, then we should consider a scenario that would reflect the wood-burning stove type scene where you have some concentration of these wastes, and then incinerate it over a local area and what the effects would be on that locale, and whether that is a problem at all. What levels are we talking about then?

WEBSTER: Well, it is obviously a different scenario. I was considering an idealized situation where all of this carbon-14 is universally dispersed so we have a new steady state in the world. That would take some time to occur.

That would bring me to my suggestion that indeed we do not burn the whole national amount of carbon-14 in biomedical wastes in one place. I would think that it would be much better to combust it in a large number of devices. There are a number of ways of doing that. It could be put into oil-burning equipment all over the country. Toluene waste could be burned by the U.S. Navy cruising in the middle of the Atlantic by putting it in diesel oil. There are lots of ways to disperse it so it is not near any population center.

But, even if it was near a population center--and the Nuclear Regulatory Commission has worked out the numbers on this--the amount of radiation that anybody living close to it would receive at 40 meters from the incinerator is still extremely small. It is on the order of millirems. The NRC cost-benefit analysis of the proposal contains those numbers.

JAMES J. SMITH, Veterans' Administration: Dr. Stonehill's comment makes me observe that he might be interested in looking into the theory of hormesis, which has nothing to do with hormones, but is the theory that toxic substances in small amounts may actually be beneficial, and probably Denver is in such good shape because of the small amount.

I would also like to call the attention of the group to the current issue of The Economist and the picture on the cover for which the legend is "The World Health Crisis, Your Money or Your Life."

We are spending billions of dollars trying to determine how one person may be a victim of cancer or may lose his life. How about the same amount of money and the correlation between the lives that may be saved? Now, this is a tremendous epidemiological problem, but we must be doing something right in the money we spend on research. The life expectancy has increased greatly, and I therefore think it would be very wise to pay attention to what Dr. Yalow has said, that some cost-benefit analysis, some epidemiological evaluation should be made of the lives that we are saving by research and investigations.

To spend our time in a negative way as to how many people we may be demolishing or causing cancer in seems very, very negativistic to me, and it doesn't seem to be the human spirit at all.

With respect to the comments about the Mexican incident, I am just back from a week at Oak Ridge in which we went into all of these things. As most of you know, there have been fewer than 50 people who have lost their lives from 1945 to the present time in accidents and exposures incident to the use of atomic energy during that period of time. We knock off 1,000 more people every year with our automobiles.

So it would be nice to have some perspective on this whole problem. And to close out the comment on The Economist cover, I am reminded of the story of the man who was held up and told to surrender his money or his life. He says, take the life, I need the money for something else.

IRVING M. STILLMAN, Physicians for Social Responsibility: We have heard addressed the problem of the perceptions that are spread among the public and the fear that these perceptions are misconstrued. Why do they occur in the first place. I would suggest particularly to you, Dr. Alberty, that perhaps if we had in addition to the people we have heard this morning a mixed panel with some who have been arguing on the other side, people who are well qualified--Alice Stewart, who is a fine epidemiologist, Irwin Bross, John Gofman--instead of having a completely uniform, one-sided presentation of the problem, I think that that might encourage a little more credibility. That's my comment.

Why don't you do this? Why do you constantly present a uniform, monolithic picture when there are serious arguments against many of the things that people said this morning, such as some of the things that Dr. Yalow said? But you never give us the chance.

YALOW: Can I answer that? I have been for a long time seeking to have a one-on-one discussion with Helen Caldicott, who is president of your organization.

STILLMAN: Correct.

YALOW: I have put out fliers all over the country. They came to New York and had a symposium at my institution, which was the Einstein School of Medicine, and, in fact, they have never invited me to participate in any of their symposia and permit me to answer their questions.

STILLMAN: May I extend an invitation to you, Dr. Yalow--

YALOW: I would appreciate a formal invitation at any time.

STILLMAN: --if you will do the same with us. If you will let us speak at your symposia, we will--

YALOW: I haven't had symposia.

STILLMAN: Well, you have one right now--then we will permit you very comfortably to appear at ours.

My second comment and question is that since we are talking about the effects of low-level radiation--

ALBERTY: I would like to emphasize that we are talking about a very limited subject today, and that is low-level biomedical wastes. Although you have mentioned the names of some people, I am not aware that they are opposed to the use of low-level concentrations of isotopes in biomedical research and in solving the problems that must be solved to dispose of those things. I don't hear them calling for halting this research.

STILLMAN: No, no, nor am I, but what we are questioning is the fact that low-level waste can be extremely dangerous, and the impression that is being given here today is that it is not.

ALBERTY: Well, would you be a little more specific? In what way is it extremely dangerous? What is your view of what that hazard is, because that's a pretty strong statement.

STILLMAN: Yes, and I would be willing to appear on one of your panels and discuss it in detail.

Let me just point out, for example, to be specific in one area, we have heard a lot about tritium and how harmless it is. However, it turns out that when you actually calculate the population dose for tritium that the previous estimates that are now used by the ICRP, where you have a relative biological effectiveness, for example, of 1 to 1.7, that there have been many studies that now indicate that the relative biological effectiveness, or the QF of that particular isotope, happens to be probably closer to 4 or 5. And even Ted Radford, who is the head of the BEIR Committee, has admitted to that.

It also turns out that there is a factor like bioaccumulation that has been neglected, as one proceeds up the trophic levels of a terrestrial or aquatic chain, which has been neglected, indicating that DNA, for example, accumulates three to four times more tritium than previously anticipated and plugged into the equations. And I could go on and on, but I don't think this is the time.

The second point I would like to make is that when Dr. Yalow says that we don't have the time or talent to investigate the problems of low-level radiation effects, I really think she is doing us all a disservice. I don't know about epidemiological studies--that's not my field, I am a biophysicist--but I know that there are many kinds of studies that can be done on low-level radiation involving microscopic pathological types of investigations, for example, strand breaks in DNA, chromosomal aberrations as a result of exposure to radiation, that can be done very comfortably. If she would like me to help her set up the experiments, I would be happy to. And I wonder if she would just address that aspect of research.

YALOW: Yes, I will be glad to address those aspects of research. We are concerned now with these effects. The whole panel today is discussing these effects at levels about two to three times the background radiation that we have in New York and Washington. Now, these studies have been done. They have been done in a Chinese group. They have been done by the people at Kirala in India. They have been done in studies in Brazil where the dose levels are several times natural background. And these human studies and studies in, say, the rats in the area and other relatively large-sized animals have revealed nothing.

My question is how often must we repeat these studies, unless somebody from your group or any place else can describe flaws in these studies that would require repeating them?

I am not talking now about doing studies in bacteria or such things. I am talking about doing human studies at levels comparable to the background radiation, twofold to threefold higher, and without describing how the existing studies are flawed. I see no reason to continue to repeat and repeat such studies.

HOUSTON BAKER, American Society for Pharmacology and Experimental Therapeutics: I wanted to throw another comparison in the ring here with respect to the wood-burning stove, which I don't believe is adding to the natural burden. I think I am just accelerating the process of the decay of that wood by pyrolytic process, because I know the leaves in my yard are routing more of that carbon-14 back into the air than the wood stove is putting out. I don't burn most of the stuff coming on my woodlot.

It is my impression that the natural burden, worldwide average of carbon-14 is roughly in excess of half a curie per square kilometer. Now, half a curie per square kilometer as a natural burden for carbon-14 tells me that, say, the NIH campus, which is about 1 square kilometer, produces a considerably greater amount of carbon-14 in the natural environment than there is in use in those laboratories during the course of the year.

The question in my mind, if in fact the natural environment contains so much more, why aren't we burning this trivial quantity and sending it out and dispersing it into the natural environment instead of messing around with all this very complicated rigamarole to satisfy anxieties that really have very little basis?

WEBSTER: That was my thesis. You just enunciated it very, very well. I think the next panel will go into this in more detail when they talk about the methods for disposal other than shipping it to Hanford, Washington, at enormous cost. So thank you very much.

BAKER: You are quite welcome. I had other comments I wished to make. For instance, I was in the environment of the bubble chamber when it blew up. That bubble chamber was not tritium, that was cold hydrogen.

GOODMAN: What caused Mr. Reed's death?

BAKER: I don't know Mr. Reed, but the man who--

GOODMAN: Mr. Reed was an employee in the bubble chamber.

BAKER: Oh, well, Mr. Reed, is he the man who was sitting on top of the apparatus when it exploded?

RALPH ALLEN, Director of Environmental Health and Safety, University of Virginia: As a chemist charged with being the chairman of the Radiation Safety Committee, I have found that the burial of organic solvents in the ground, even though they are slightly contaminated with radioactivity, is a real mistake. But when we tried to have some public input as to how to best relieve the concerns of the public where incineration would take place, a question arose. It is one that I would like you to address, if possible, because it resulted in a county ordinance that limited the release of any radionuclide that had a half-life of greater than 12 years, in other words, aimed at tritium and carbon-14, for fear that it would accumulate in the biosphere, particularly in the region near the incinerator. I guess I would like any comment as to whether that seems to be a reasonable basis, rather than using the NRC regulations, which take a lot more factors into account.

ALBERTY: Dr. Webster, you seem to be the recipient of several of these questions, but is there any danger of accumulation of tritium or carbon-14, just to take specific examples, in the vicinity of an incinerator?

WEBSTER: Well, it depends on how complete the combustion to carbon dioxide and water vapor is. If not complete there may be some local deposition of condensed vapors or ash, but at a very low activity level, since the concentration in the burned material is low. Local rainfall during incinerator operation will bring down some tritiated water vapor and carbon-14 carbon dioxide. But even if 1 curie per year were burned in one incinerator, I believe any local contamination would almost certainly be undetectable except possibly at the base of the stack, compared with normally occuring level in soil and vegetation, which is of the order of 100 millicuries per square mile. Rainfall will wash away much of any surface deposition so that a buildup is unlikely.

ALLEN: Well, the specific question is, if you incinerate it and release it as carbon dioxide and water, are there grounds for fear and therefore grounds to limit the release of this kind of material?

WEBSTER: Not compared with what is being produced every day by cosmic-ray bombardment of the atmosphere, which, as several people have already pointed out, contributes only a small fraction of background radiation.

YALOW: We calculated in New York that the amount of carbon-14 released when we burn about a quarter of our garbage in the city is about 5 to 10 curies of carbon-14 a year, which is fivefold to tenfold the amount of carbon-14 in all the scintillation fluids in use all over the country. Either we are going to have to stop burning garbage or not permit, as the environmentalists would like us to do, the burning of agrimass as a source of heat. All of this releases carbon-14 to the atmosphere greatly in excess of the numbers we are talking about.

Essentially what we are talking about is recycling carbon and tritium back to the atmosphere in amounts that represent an insignificant fraction of the recycling that takes place every day. For instance, the evaporation from the waters of the Hudson River each day would greatly exceed anything that we could possibly burn in the New York area from the biomedical uses of tritium.

ALBERTY: I would like to ask Dr. Quentin Lindsey to comment. He is on our program this afternoon.

LINDSEY: Let me just speak to this last question, if I may. We made a study in North Carolina of incinerators, one type of which was for the state as a whole. The study had several objectives, but I will only touch on one, namely, that related to the emission question. The emission of tritium and carbon-14 at the top of the stack (before it leaves the stack at, let's say, the maximum rate of burning when the concentration would be the highest) would exceed the NRC standards that are established, but I don't recall the numbers. But at what we would construe to be the boundaries of the facility (several feet from the stack, but again I do not remember the numbers) the concentration dropped to below the standards as established by the NRC, and very close to the background levels.

HAROLD TSO, representing Peter McDonald from the Navajo Tribe: Dr. Yalow, if one believes in the Mormon faith, then you and I may be kith and kin, for the Mormons say that the American Indian is one of the lost 10 Tribes. Perhaps that may have some bearing on something that is not scientific.

It seems to me that we are dealing with a language problem. Mr. Chairman, members of the panel, we are a people who are catching up with the rest of the world, and in catching up we have a language problem. We are a people who are just becoming aware of radiation and its significance to our lives, and our language does not even have a word for radiation. And so when we begin to explain radiation and its significance to our people, we have to build word pictures to convey the idea.

Suffice it for the moment to say that radiation can best be explained at the moment as a giant x-ray machine that cannot be turned off. That is how our language lacks in this technical terminology.

Going on in the way of language difficulties, we are talking about health effects, and there is a trauma with the omniscient physician who says you have got to use radioisotopes in the diagnostic work, and this produces a trauma of its own. It is traumatic enough for the twentieth century American, but to explain it to an American Indian who does not know what radiation is, it is even more traumatic.

The notion of your sophistication and your statistics is commendable, but to the American Indian, life is very simple; you are either alive or you are dead. The chances for staying alive if you stay inside, there is no such thing. You are alive or you are dead. And again that becomes a language problem.

Various Indian tribes are now going into various energy development scenarios. We understand that these development scenarios will have impacts on the health of the local peoples in many different ways. These health impacts can probably be measured, for instance, by the use of radioisotopes for medical work, and this is coming for the Indian tribes.

I believe that I speak for not only the American Indians, but also those minority groups and others who lack knowledge and the sophistication in radiation principles. We would like medical practitioners who can explain knowledgeably these things on which you wax so eloquently. You are research specialists, and I appreciate that, but our medical practitioners down there in our clinics lack this information and lack this sophistication that you exude. I would encourage the Academy to do all it can to educate the medical practitioner to alleviate this medical trauma of radiological diagnostic work.

And that leads me to my question: How can the Academy direct its efforts to educating not only the scientific personnel who deal in these research things, to explain to the layman, how can the Academy use its accumulated knowledge to explain these things to the minority groups who have no understanding in these things about which you are very intelligent and educated?

YALOW: I take issue with your saying that the minority groups, and particularly the American Indian, are undereducated. Although I have been decrying the fact that represented among the doctoral candidates in engineering in our country we have 35 percent nonresident aliens, indicating the lack of interest of American students in engineering as a vocation, as it turns out, the American Indians are represented proportionately to their numbers in the population, and I would like to congratulate the American Indians on recognizing that their future, like the future of the rest of us, depends upon technology.

If I wanted to describe to the uneducated what radiation means, I would not say it is that which comes from a giant x-ray machine, I would say it is that which comes from the sun and the stars, because these, in fact, are the sources of cosmic radiation. These, in fact, are the sources of natural radioactivity from the earth. This was made when our world was made, and I would not describe it in terms of an x-ray machine. I would describe to the Indian that it is that which comes from nature.

WHAT ARE THE CURRENT OPTIONS FOR DISPOSAL?

OVERVIEW:

JOHN G. DAVIS
Director
Office of Nuclear Materials Safety and Safeguards
U.S. Nuclear Regulatory Commission

First, just a few words about the Nuclear Regulatory Commission. As an independent regulatory agency it has a responsibility to regulate, among other things, low-level waste disposal in areas of its jurisdiction. The NRC is not authorized to promote or to establish the development of commercial nuclear activities, including the establishing of low-level waste disposal methods, nor do we believe it appropriate for an independent regulatory agency to do so. However, we do have an obligation to develop and implement suitable regulations for disposal that provide adequate protection to the public health and safety.

The overview remarks that I will make are focused on identifying what can be done now under existing regulations to dispose of low-level radioactive biomedical wastes. They are limited to radioactive biomedical wastes and are made from the perspective of the regulator, recognizing that certain options now exist or are under active consideration for disposing of this type of low-level waste. The regulations now provide these options, but it should be clear that the generator of the wastes must perform responsibly to meet requirements that are associated with these options, demonstrating that low-level radioactive biomedical waste has been disposed in conformance with requirements.

Viewed from this perspective, what are the current options? Basically these options entail good waste management practices and allowable practices now existing under NRC regulations. First, users of radioactive material for biomedical purposes should exercise care to minimize the generation of waste. This means exercising good waste management practices. It is not a matter of regulation.

Work involving radioactive materials should be carefully planned to minimize the volume of waste generated. Minimizing the generation of radioactive waste requires administrative procedures for careful preplanning of work, effective management control, and care in the use of radioactive materials, and most specifically it requires management attention to this minimization.

Proper waste management, administrative procedures, management attention, and care can lead to minimization of radioactive waste generation and segregation of waste as it is generated.

The first step in waste management is to assure that waste treated as radioactive waste is in fact radioactive. Care must be exercised to separate radioactive waste from nonradioactive waste as it is generated. Apparently, as Dr. Cooley remarked, many laboratories as a matter of convenience, caution, and "to keep the regulators off their backs" have treated as radioactive any waste associated with the use of radioactive materials.

A first option is to make certain that nonradioactive waste is disposed of in normal waste channels. So, first aim attention at volume minimization. Now, once efforts have resulted in volume minimization, the radioactive waste can be further segregated for disposal.

Some commonly used isotopes in medical facilities have relatively short half-lives measured in terms of hours or a few days. If waste containing these radioisotopes is held for decay for approximately 10 half-lives, it approaches background levels: that is, it cannot be distinguished from background using typical survey instruments. And once stored for about 10 half-lives and reaching background levels, it can be disposed of through normal waste channels insofar as NRC is concerned.

Specific license approval, that is, an amendment or a condition on the license by the NRC, is required for holding these materials for decay prior to disposal as normal waste. For consideration for such approval by the NRC, the applicant should demonstrate first that he can actually store the material safely, and second, that he will perform appropriate surveys both by administrative control and by instrumentation.

As all regulators, I will, of course, quote a lot of the regulations. There is a section in 10 CFR 20.303, Part 20, "Standards for Protection Against Radiation," that allows another option, and this is the release of radioactive materials under certain conditions into the sanitary sewerage system.

Now, no specific license approval is needed from the NRC to do so. The authorization is built into the regulations. There are certain conditions that the licensee must meet to use this option, and these are: the effluents must be soluble and dispersible in water; the radioactivity concentrations using dilution from the sewage must not exceed certain limits specified in the regulations; and the gross quantity of radioactive material must not exceed 1 curie per year.

However, we have now under consideration a proposal to amend the regulations, which would raise the limit of tritium disposed of in this fashion to 5 curies per year, and carbon-14 to 1 curie per year in addition to the 1-curie limit for all other radioactive radioisotopes.

Now, this morning my compatriot spoke about scintillation fluids and animal carcasses containing tritium and carbon-14. The NRC has proposed a new section to its regulations. This would permit the disposal of scintillation fluids and animal carcasses containing less than 0.05 microcurie per gram of tritium and carbon-14 as nonradioactive waste. However, due to hazards other than radioactivity, there are other federal, state, or local laws with which the licensee must comply governing their disposal as nonradioactive wastes as a matter of caution.

After segregating waste streams as described, there may still remain some bulk radioactive waste to be managed, and it may be convenient to reduce this volume. Two volume reduction methods that may be appropriate are compaction and incineration.

Compaction can be accomplished quite simply by proper packaging techniques or by mechanical compactors. Particularly if a mechanical compactor is to be used, care should be exercised to assure adequate health physics and controls. Incineration requires specific approval by the NRC under the provisions of the regulations. This requires careful evaluation and procedures administration to assure worker safety and control of effluents. Again, institutions considering incineration should be aware that state and local regulations also may apply.

Another option for consideration that is included in the existing regulations involves burial of small quantities of radioactive material in the soil on the licensee's site. An institution can apply for NRC authorization to bury small quantities of material on the site in which it operates. Factors considered for approval of such applications include site control and suitability and the need for no further control for radiation protection purposes at such time as the institution no longer has control of the site. Use of this provision, we believe, is limited but may have some value under certain circumstances.

In order to allow for the ingenuity of the licensee, the regulations also provide that the NRC will consider any other means that a licensee may devise to dispose of radioactive material. Such proposals will be considered on the merits of each proposal.

After there has been strict management of radioactive waste generation and the consideration of the options and, hopefully, use of some options, the remaining waste generally is sent to commercial low-level waste burial grounds. The NRC believes, however, that by careful waste management and by use of the options that now exist in the regulations or that are under active consideration, the volume of waste going to commercial burial grounds can be significantly reduced.

In summary, what options do we have? First is the minimization of waste generation by proper waste management; second, the following options now existing or under consideration within NRC regulations:

Hold short half-life material for decay and survey and disposal as normal waste.
Release under certain conditions into the sanitary sewerage system.
Burial on site.
Incineration.
Compaction.
Transfer to an authorized recipient.
Disposal of scintillation liquids and animal carcasses under certain conditions as nonradioactive waste.
Specific methods proposed by applicants that are reviewed on their merits by the NRC.

WIL B. NELP
Professor of Medicine and Radiology
Head of Division of Nuclear Medicine
University of Washington

You have heard an overview of what we could do regarding waste management. I would first like to comment just a bit on several aspects of waste management, and one of the important things is management. When we started to look seriously at what was going on in institutions--and I think our institution was typical--we found that we were sometimes managing very poorly, and for convenience or by habit we were putting volumes of materials out under the label of radioactive biomedical waste that really weren't radioactive as such, i.e., they had basically decayed. Just pointing these things out to individual users will reduce volume considerably. Of course, simple compacting of waste is another effective way of significantly reducing volume.

Also, I think there will be a major reduction in carbon-14 and tritium waste volumes through a change in the regulations, permitting us as a group to get rid of materials that are very lightly radioactive in our common disposal sites under those plans currently proposed by the NRC for waste containing less than 0.05 microcurie per gram concentration. Overall this will have an impact in decreasing the volume of materials that will go to commercial low-level waste sites from the biomedical users by close to 50 percent.

Now, it is obvious to me, and I hope it is obvious to many of you, that the real long-term solution for wastes that must be disposed of as low level is combustion, that is reducing these things to CO_2 and water, a technology that is very approachable. It has some problems, but I think it could be instituted very effectively. We are going to have to work at it. We will want to consider regionalizing it among groups of states. But the safety of it is obvious to me.

The relative simplicity of combusting the carbon-14 and tritium wastes and recirculating them in the environment where they contribute virtually nothing to the current environmental burdens seems very appropriate. I would hope that we would work and move in this direction immediately, not only for biomedical waste, but also in other areas of waste control. This would be a very big step forward.

Now, what has recently happened to potential waste disposal capabilities in the United States? Well, an interesting thing happened on the way to the polls in the State of Washington. As mentioned, I was an adviser to the governor and I have had the opportunity to interact in relation to biomedical affairs and waste disposal.

As many of you know, in the State of Washington during the November election, Initiative 383 was placed on the ballot and was passed. This initiative stated that the state (including the Hanford low-level waste site) would be closed to receipt of out-of-state nuclear wastes (high and low levels) after July 1, 1981, with the exception that out-of-state medical and biomedical research waste would be excluded, i.e., it would still be permitted to be left at the Hanford low-level waste site after July 1981.

Before we analyze what this does, I should tell you a few things about the low-level site at Hanford. It is a site that has 100 acres and has been operational for 15 or more years. It has used about 6 or 7 acres of the total site capacity. It has an enviable health and safety record. It is the only site of the three in the United States that will receive radioactive liquid scintillation materials at the present time.

Now, if all the liquid scintillation materials come from biomedical waste streams, as most of them do, then we will be protected. But there is a problem for universities and research institutions, since 10 to maybe 15 percent of liquid scintillation waste and other low-level radioactive waste generated probably comes from departments of physics or other hardcore sciences that can't strictly be related to the biomedical field, so this may pose some real difficulties.

So, on the surface it looks as if medicine and biomedical researchers will be protected even though Initiative 383 was passed. That may not necessarily be true, because the way the initiative is written poses some very serious interpretive questions about how waste from national manufacturers who supply us with radiopharmaceuticals and other radiochemicals will be handled. This will have to be determined. Also, there are very serious questions about the constitutionality of the initiative, which may be tied up by legal considerations for some time, since it seems to be preempting certain interstate commerce and federal laws.

Now, let's look at the effect of Initiative 383 from another point of view. I have analyzed what came into the Hanford low-level site in the past 6 months and have annualized this experience. This site receives about 500,000 cubic feet of out-of-state low-level waste. And as far as I can tell from the records, about 30 percent of that comes from the biomedical waste stream that we are concerned with, which will be permitted to keep coming.

If you are privately managing that waste site (as is the case), you are in need of a profit. This is federal land that is leased to a private enterprise that is a commercial waste depositor. The enterprise suddenly loses 70 percent of its business because it has been excluded by law.

Now, the initiative says that it will in fact permit reentry of out-of-state waste into this site under interstate compacts after July 1, 1981. I don't think it takes much imagination to know that it takes a long time for this political process of interstate compacts to be agreed upon, and in addition Initiative 383 states that such compacts must be approved by both houses of the U.S. Congress! As you can see, it may by 4 or 5 years before this could come into fruition.

I am very supportive of regionalization. I think it is the only fair way to go. The passage of Initiative 383 permits that, but the July 1981 cutoff date is much too soon to arrange compacts, and the site operator now is sitting there without 70 percent of his business. (This may be as high as 85 percent when alternate methods for biomedical waste disposal become effective.) What is the site operator going to do? What would you do?

I think the answers are obvious. You can go out of business, because your fixed costs are so high you can't afford to run a losing operation, or you are going to have to triple or quadruple your rates for disposal. Instead of $10 a cubic foot, it is now going to be $30, $40, or $50 a cubic foot. This cost will be passed on to the biomedical groups, because they are the ones who are going to have to use the site, and foot the bill! So any way you cut it, the cost for our waste burial will go up manyfold.

Now, alternatively, it the site operator goes out of business, there is a real potential for shutdown of the site on a temporary or perhaps a prolonged basis, and who would open it up? As Calvin Brantley was saying, if we close it down for more than 100 days, we get seriously concerned about interrupting daily medical care. Would the Wasington state government come in and open it up, would FEMA and the federal government come in and open it up, or what would be the options? In each case, the cost of operation would not be any less, and the potential for prolonged political and administrative delays are very real.

QUENTIN W. LINDSEY
Science and Public Policy Advisor to the
Governor of North Carolina

Let me begin by explaining a bit why the State of North Carolina is involved in waste disposal activity. First, North Carolina happens to be the fourth or fifth largest generator of low-level radioactive waste among the states in the country. This rank stems from the number of nuclear reactors we have and from our nuclear-material-processing and rather extensive research facilities, including medical schools and other types of research institutions, some of which are at Research Triangle Park. Second, we are also generating each year what we regard as a far more difficult and complicated aggregate of waste, namely, chemical and other forms of toxic and hazardous waste that emanate from our various industries.

Given these conditions, we believe that the state government must contribute to the solution of the problem of waste management, at least within our borders. The point is that with a number of research institutions, with two power companies operating nuclear-generating plants within our borders, and with private industry of one sort or another generating waste, it is difficult for the whole collection of generators to get together to solve the problem in the absence of overall state leadership. Consequently, in July of 1980 Governor Hunt appointed a waste management task force to address both the hazardous and the low-level radioactive waste problems that we have.

Given this array of waste that we generate in North Carolina, we have found it essential to differentiate among the various types of waste. In the low-level radioactive field, we recognize that the waste being generated by nuclear plants is different from most waste generated through medical diagnosis and various forms of research, but all may be radioactive to some degree. I distinguish here, of course, between the high-level radioactive waste found in spent fuel rods and the low-level radioactive waste that nuclear power plants accumulate in the form of discarded protective clothing, used filters, exposed piping that has been replaced, and so on. The operation of nuclear reactors results in low-level radioactive waste as well as high-level radioactive waste, but both categories of reactor waste represent different radioactive isotopes from those found in scintillation vials and in animal carcasses emanating from medical and research institutions. In addition, the quantity of radioactive material, i.e., the level or concentration of radiation found in scintillation vials and experimental animal carcasses of the types we are discussing today, is much smaller than the quantity of radioactive material normally found in low-level nuclear reactor wastes and even in wastes stemming from research wherein larger levels of radiation are essential.

Therefore, as the panels have discussed this morning, identifying wastes such as scintillation vials and experimental animal carcasses as having such low levels of radioactivity as to be excluded legitimately and properly from identification as low-level radioactive waste means a great deal to us. Proper methods of waste disposal include recycling or reclaiming, incineration, and burial in a properly designed landfill. We believe that the chemical toluene, in scintillation vials, is more dangerous than the small amounts of radioactive materials found in the vials. Toluene is toxic and highly flammable, and, when accumulated as waste in the vials, is more appropriately recycled or incinerated in accordance with the procedures defined by the Resource Conservation and Recovery Act than by NRC procedures for radioactive materials. Likewise, experimental animal carcasses, depending upon the experiment and the level and half-life of the radioactive material used, are often better disposed of according to appropriate biological considerations rather than according to rules relating to radioactivity.

One of the critical issues that we face in properly managing the disposal of waste, then, is the misconceptions that we have with respect to waste. There is a strong tendency to classify, as observations from the audience indicated this morning, all radioactive waste as simply one glob of waste that is very dangerous. This is a total misconception. Until we begin to differentiate between high-level waste, and then, in the low-level category, the various types and amounts of waste that are generated, and from whence they are generated and how one must deal with them, we will have difficulty in getting on top of the problem.

To be specific, we can identify the types and the amounts of radioactivity in scintillation vials and in animal carcasses. Those who do the research and medical diagnoses can determine this because they put the radioactivity there. When we compare the levels of radiation in the vials and carcasses with background levels of radiation, and with the costs of disposing of such waste in the manner prescribed for radioactive waste, it simply makes more sense to treat them as nonradioactive waste.

In revising the classification, we must not, of course, just indiscriminately throw away scintillation vials and animal carcasses. We must treat them in proper fashion, whether this is in accordance with regulations under the Resource Conservation and Recovery Act or according to biological considerations, or both.

Turning briefly now to the public understanding and participation aspects of waste management, in North Carolina we find that it is absolutely essential to get at the facts behind each type of waste with which we must deal. We must lay these facts before the people of our state in ways that they will understand and that will enable them to compare the risks and the benefits associated with the waste. We are confident that full public participation will then result in support of the facilities needed for proper waste management. In the absence of this forthright approach, fears arising from misunderstanding and mishandling of wastes will make it difficult to develop necessary disposal facilities, and thus our research and industrial growth will be seriously inhibited.

We have extensive medical and other research facilities, we have industrial growth, and we have nuclear-generating plants, from all of which we are benefiting. We are moving toward developing additional research and industrial facilities, many of which will generate some form of waste. We are a low-income state, and these measures are designed to improve the economic status of our people. But, unless we can get on top of this waste management problem, it will seriously constrain us in terms of the basic objectives that we have as a state.

In closing, I should note that we are not seeking to operate in isolation. We hope, for example, to work out arrangments with South Carolina for the use of the Barnwell facility if the compact arrangements that are being discussed in Congress today are worked through. In a reciprocal fashion, we are seeking to recycle used lubricating oil from both our state and South Carolina in an oil re-refining plant that we have just developed in Raleigh. We are much interested also in the outcome of this discussion here today and in the possibility of reclassifying certain types of waste that we have been calling low-level radioactive. To do so will mean a great deal to us in terms of the method and the cost of disposing of some of our waste.

ROGER W. BROSEUS
Chief, Radiation Safety Branch and Radiation
Safety Officer
National Institutes of Health

I would like to look at this from a practical point of view of what people can do today. It may sound a little bit like a broken record, but I think it is important to emphasize some of the points that have been made and to note how an operating program can benefit from changes.

Before doing that, I would like to raise one other point, and that is my own personal pessimism about the continued availability of adequate shallow land burial capacity for medical institutions. I think that many of us are aware of this problem; it has been around at least since the summer of 1979. We need to continue to be aware of the problem and to look at why we have had problems with respect to disposal of waste.

Leland Cooley spoke about some of these problems, which basically relate to a lack of time to implement solutions. Institutions have been forced into playing a catch-up game. We have to allocate space for decay. We have to reallocate our manpower resources. We have to acquire properly designed equipment. We find the Department of Energy funding studies to define what proper equipment is, and in the meantime we are trying to find equipment that we can install today to help solve our problems.

It is important for us to make management and administrative personnel in our various institutions aware of these needs, the gravity of the situation so that we can reallocate our resources to develop alternatives. This will help to alleviate unresolvable problems such as those that occurred in late 1979.

Now, to get to some of the practical solutions that we can implement today, some of which have been discussed by the NRC representative and others. I would like to suggest some practical points.

First of all, consider that fraction of waste, shipped for burial, that does not contain liquid scintillation vials. It has been suggested that this represents roughly 50 percent of the waste that a typical institution ships out. I would suggest that if you are at that level now, you should aim for a reduction to about 10 to 20 percent. I will mention in a moment the effectiveness of some of the things we have done at our institution, but we see the non-liquid scintillation waste fraction of our shipped waste being about 10 or 20 percent. It may be easy to reduce very drastically the volumes you have to ship for shallow land burial.

Disposal by decay has come up again and again. There is a very big potential for volume reduction by decaying wastes. At our facility, by combining this with incineration of some relatively low-level waste, we have found that within a year's period of time we reduced the volume of non-liquid scintillation vial wastes going to shallow land burial by over 50 percent: from 1,000 barrels to about 350 per year. I emphasize that this occurred in a period of 1 year, and we were already compacting much of this waste previous to this.

Make sure you are not shipping items that need not go into the radioactive wastes, especially short half-life materials. This cannot be emphasized enough. Studies done by Cooley, by NUS, and others have indicated that a very significant fraction of the waste (in terms of activity) was technetium-99m, which has a half-life of only 6 hours!

If you use the 10 half-life rule of John Davis, that represents 60 hours for technetium-99m, which is about 2 or 3 days of decay time. In fact, many nuclear medicine departments use very short half-life radioactive materials and can dispose of virtually all of their wastes by on-site storage and decay.

Disposal combined with incineration is a very important option available to many generators today for nonscintillation vial wastes. By decaying short half-life radioactive materials and incinerating the low-level wastes, we can realize very significant savings. I mentioned that we dropped from about 1,000 to 350 drums shipped in 1 year. This resulted in a cost savings of over $65,000 a year for our institution. This underrepresents the savings for many, by the way, because we realize economies of scale. It costs us around $110 a drum to ship and bury radioactive waste. Many institutions are paying $200 and $300 a barrel. Of course, if the predictions of Dr. Nelp come true, these cost savings can be even greater.

There are a lot of other things we can look at, sewer disposal and so on, but I believe that the biggest problem we have to look at, again, is liquid scintillation vial wastes. This is the main source of my pessimism. We find, as Dr. Nelp pointed out, that we have only one site that will receive liquid scintillation vial wastes. When South Carolina authorities found themselves receiving 85 percent by volume of the nation's radioactive waste, they shut us off. Washington may well feel the same way about liquid scintillation vial wastes.

Aside from the pessimism, though, one can again look at cost savings; liquid scintillation vial wastes do constitute at least half of the total waste we have to ship. If one were to install a crusher for vials and even ship the crushed vials to a radioactive waste disposal site, a volume reduction of about 80 percent could be realized. So, instead of having to ship 100 barrels, for example, you would only have to ship 20 barrels. I would hazard to guess that, at a larger institution, one could realize enough cost savings just in transportation costs and burial fees that within 2 or 3 years could offset the cost of installation of crushers and other apparatus needed to dispose of the liquid scintillation vial wastes on site.

We need to keep in mind the point that Quentin Lindsey made about the Resource Conservation and Recovery Act. The proposed change in NRC regulations with regard to disposal are welcome changes and will give us more leeway with respect to disposal of radioactive waste; however, we then will have toxic chemicals instead of "radioactive waste" to get rid of. If these wastes cannot be shipped to a commercial burial site, if they cannot be burned or otherwise disposed of on site, you may find yourself with an insoluble problem. As I understand it, there is no reasonable technology available today to solidify toxic chemical organic wastes. Because of the immiscibility of organic solvents with water, the typical types of solidification processes we try to use don't work. The organics cannot be bound as we would like to see them. There is a fear that we may end up with a situation analogous to the Love Canal problem.

In summary, the current practices with respect to burial of organic toxic wastes will probably not be continued for too many more months; thus, we must give some strong consideration to on-site disposal of liquid scintillation vial and other organic liquid wastes.

The last point I would like to make is that institutions will always have, in my view, a small, irreducible volume of radioactive waste for which the most reasonable disposal alternative is shallow land burial. The problem relates to the length of the half-life for a particular nuclide and the feasibility of disposal by decay. Some institutions are building storage facilities to store iodine-125 wastes. I'm not talking about the small quantities contained in RIA tubes, but about wastes containing millicurie levels of activity. Being more radiotoxic, radioiodines deserve special attention when we get into significant levels of activity. With a 60-day half-life, if we used the 10 half-life rule, we would have decay for 600 days, which would require 2 years of storage. The volumes of waste that are involved would demand quite a sizable storage facility, and it may be that, if reasonably inexpensive shallow land burial strategies were available to us, burial would be the better way to go. One can think of analogous situations with other radionuclides used in biomedical research. There may be a need for shallow land burial sites to accommodate these types of wastes. Some shallow land burial sites may not require 100 or 150 years of "perpetual care." There is a need for shallow land burial sites for some of the less toxic, less hazardous, or moderate, half-life, low-level radioactive wastes.

JOHN A. D. COOPER
President
Association of American Medical Colleges

I would like to start by observing that when I left the research laboratory, I thought I would be rid of issues surrounding the disposal of radioactive wastes. My participation today makes it appear that I am going to be involved with this the rest of my professional life. We haven't made a lot of progress since I started a radioisotope laboratory in 1948 and devoted a lot of effort trying to get rid of the wastes that we were generating.

I served as a member of the Atomic Energy Commission Committee on Institutional Licensure from 1956 to 1959, licensing institutions to work with radioisotopes. The problems facing us then in using these materials are still with us and have increased substantially in the intervening years as radioisotopes have become a more essential and critical part of our biomedical research effort and the diagnosis and treatment of disease.

We were very pleased with the recommendations of the commission to give exemptions to certain kinds of wastes that are generated in biomedical research: liquid scintillation vial contents and animals used in experiments.

We would like to recommend that consideration be given to extending those exceptions to other kinds of paraphernalia that one uses in conducting research experiments. I mean disposable material such as gloves and paper products that become contaminated at levels below 0.05 microcurie per gram during the experiment. From the radioactivity standpoint, they are no different from levels in the carcasses or the vials.

In addition, very often one takes parts of the carcass, such as livers or spleens, and body fluids, such as urine and blood, as a part of the experiment. We would like to suggest examining whether these materials could also be included in the exemption. They do not differ from the carcasses in the content of radioactivity or the types of materials that are involved.

The third area about which we are concerned is other solutions that arise from many experiments involving radioisotopes: for example, from chromatography, where one deals with fairly large amounts of solutions with very low radioactivity content. One samples out of column chromatography 1-milliliter fractions of the effluent of the columns and counts it using liquid scintillation. The vials and their contents are exempt, but the rest of the effluent from the column chromatography is not. This effluent contains extremely low radioactive levels. We would like to raise the possibility of including all of the effluent from this type of column chromatography in the exemption.

If we could get these included in the very forward-looking proposal by the commission, we could further reduce the amount of waste for which we are going to have to find disposal sites, sites that it has been pointed out are becoming more and more difficult to find and more and more expensive to use.

The fourth area that I think deserves serious consideration is the problem of finding burial sites for materials containing radioactivity, not because of radioactivity, but because today it is not very easy to develop burial sites for any kinds of chemical wastes.

We are concerned about whether we can continue to handle the problem with only one burial site available, and that one in a precarious situation; whether we can develop an adequate number of sites, particularly if we don't reduce further the volume of materials that are not exempt.

A fifth area about which we are concerned is not the carbon-14, tritium, and sulfur-35 we have been discussing, but materials that arise from medical diagnosis and/or therapy. We are using more and more short-life radioisotopes in medical procedures because they greatly enhance our ability to diagnose and treat disease. These generate large amounts of wastes, usually of very short half-life isotopes.

It is quite true, as Dr. Davis has said, that we can store these for 10 half-lives, but we are running into problems in finding the places to store the volumes of solutions involved. We would like to raise the question of whether there is something that can be done in working with the commission and other agencies to find places to store these wastes for the short periods of time required; space is simply no longer available in the hospital or medical center.

The last point I would like to make is one Dr. Davis has pointed out--that in segregating wastes by types, it is going to be possible for us to reduce the amount of waste we have to take out of the institution to burial sites. This is going to require a change in behavior of the group that is involved with the collection and disposition of wastes. To change this behavior, we must have an extensive program for education of personnel.

It is going to take time and effort to introduce a new way of operating into a system that has been functioning in a different mode for a long time. For this reason, we are concerned about education and training and the time that is going to be required to adapt to the new system of segregating wastes. Frankly, some of the funds we are going to save in reducing the volume of our waste will be taken up by instituting the segregation procedure.

The recommendations the commission has made have been excellent. We do see their action as an interest in clarifying the problems, particularly for very low-level waste, which should never have been of much concern to us or the public. We hope that there will be continuing consideration of how we can extend the exemption to other wastes that contain such low levels of radioactivity that they contribute essentially nothing to the radiation doses received by the general population. But if this can be accomplished, we still face serious problems in obtaining permission from OSHA and others to get rid of these materials by incineration, burning, or combustion, even though they are classified as nonradioactive. We have made some progress, but we have a very long way to go, particularly in view of the increasing importance of some of these isotopes to biomedical research and medical diagnosis and therapy.

JOSEPH SILVA, JR.
Professor of Medicine
University of Michigan Medical School

Some of the newer regulations that pertain to generation of biomedical wastes have great interest to the American Federation for Clinical Research. We are composed of 10,000 clinical investigators and probably account for the generation of much of the problem, and that is scintillation vials and the fluid contained therein.

I have served as a focal point within our Federation for discussions related to disposal of the waste we generate; and once again, we are only talking about low-level wastes. I think the speakers this morning highlighted the importance of these technologies. For the nonphysicians in the audience, I can relate that much of the major advances today, either at the lab bench or at the patient's bedside, could not come into an accounting without this technology. It winds its way through all types of research, ranging from immunology to cancer.

In terms of the practical approach to the problems, the Federation has been looking at several measures, and they all have to be applied at a variety of different levels. We find difficulties with the storage of scintillation vials. Most laboratories are quite small, and our research space is shrinking.

If we can't get the scintillation vials out of our laboratory, they simply overrun our workspace. We may have accidents related to spillage of the material or to the flammable hazard. Much of our activity is directed at removing these wastes from the laboratory so that our own personnel are not involved in manipulating the materials any further than from the scintillation counter.

Some centers now demand that the researcher "break down" the vial, pour out the scintillation fluid into a central void volume, and then close the cap up and throw it into a central canister or drum. This is a very time-consuming procedure. Many clinical laboratories are generating 500-plus scintillation vials per week, and it really does increase the cost of research grants and all the other efforts that Dr. Yalow addressed.

With respect to other things that should be looked at, I agree with John Cooper. I think we need to see an expansion here in the materials that can be disposed of by normal means. He addressed the fact that in many of our experimentations we work with column effluents or irrigations of a cell system or degeneration of a waste product from animals, and these are clearly very low-level wastes and could be disposed of by the usual method.

In my own laboratory, for every 1 milliliter of scintillation fluid that we generate that is contaminated with low-level radioactive waste, we may generate 10 or 15 other milliliters that are used in irrigating cell systems or from column chromatography. In that same vein, I think the plastics and the benchmats, and all the plastic disposals that contribute to the actual spacing in the drums, could be eliminated by the usual disposal methods.

Before I left to attend this Forum, I went by my laboratory and removed the top of one of my disposal drums. Clearly much of the material in there was related to plastics and benchmats and things of this sort that are very bulky in size; there was an incredibly small amount of radioactive material contained therein.

Most of our investigators indicate that compaction or dehydration or concentration are really not going to be feasible because they are going to make demands on the clinical lab to separate the various products or, even more, will create a hierarchy in the university that will involve high personnel costs to maintain a separate group of people who will dispose and manipulate the product.

We really believe that the major way to go is incineration at a local level, particularly for those products that contain the organic carriers, the aromatic hydrocarbons, and so forth, in which we perform our scintillation counts. So we look to incineration or combustion as the way of the future.

DISCUSSION

RICHARD DISALVO, Radiation Specialist, Johnston Laboratories: Dr. Davis, you didn't mention the alternatives for the uses of radioactive materials: to use materials either under an exemption--in other words, exempt quantities of radioactive materials--or under a general license, which is authorized by the regulations, for certain in vitro diagnostic products.

Another area I would like you to address if you could is that there are 26 states that are agreement states and therefore promulgate their own regulations separate from the NRC regulations. The city of New York also is an agreement city and has its own separate regulations, so that in many instances it really doesn't matter what the NRC does regarding waste disposal and licensing regulations.

DAVIS: Let me address the agreement state matter first. Perhaps I said it too rapidly, but in my introductory remarks I mentioned those activities under our jurisdiction, and that is my code word for those things that come under NRC licensing and not those things that come under agreement state licensing.

Of course, in the agreement state program the NRC makes periodic determinations of compatibility of the state's program with the NRC's program. Basically this compatibility with regard to the regulatory requirements has been that the states' protective measures, their restrictive measures, must be compatible with those of the NRC.

However, for NRC regulations that might be viewed, as this particular aspect is, as some relaxation, judgment will have to be exercised about compatibility. The states are aware of this, of course, and I am sure will give some consideration to it in deciding how they desire to go.

With regard to exempt quantities, as I understand the requirements, wastes from exempt quantities are also exempt. If you use radioactive material under an exemption, that exemption includes exemption to Part 20 if it so states, and if it does so state, then the requirements of Part 20 for disposal would not apply and it could be disposed of in normal waste channels.

LAURISTON TAYLOR: I would like to make a brief comment expressing my appreciation to the Academy for the privilege of being at this meeting today and enabling me to spend some 6 hours or so at the Foggy Bottom altitude as compared to where I have to spend most of my life, at 427 feet, 6 inches, in Bethesda, where my radiation exposure levels are considerably higher, in fact higher than most of those we are talking about today.

I would like to have the panel return to the question of incineration; and I would like to hear some more about the problems associated with burial at sea.

Burial at sea is being done by a number of countries under circumstances that are considered, as far as I am aware, to be reasonable. As far as land burial, landfill, there has been some discussion, but let's bear in mind that on the average in this country, 1 square mile of earth 1 foot thick contains the following radioactive material: 1 gram of radium, 7 tons of uranium, and 14 tons of thorium. I doubt if you could put that much per square mile 1 foot thick in any landfill around. Actually I think, if I have done my arithmetic correctly, it is 2 million tons or something of that sort.

There are problems, and I think this should be discussed a little also. We have two kinds of basic political problems in this country: one is a national situation, the other is a state situation. It seems to me that one of the big impediments we have to the solution of this problem is built around states' rights.

Somewhere along the line we have to make up our mind as to whether we are going to have a country built up like a collection of Middle European states that all have their own laws and spend the rest of their time squabbling with each other or whether we are going to have a country that survives in spite of the energy situations that we have.

I think these are all tied together, and, without asking a specific question, I would like to hear some discussion of where our waste problems lie outside of the technical area.

LINDSEY: Well, perhaps I could address that. I don't think I am going to get into the states' rights issue, however. Maybe it is more of a local issue.

Regardless of the type of waste disposal facility, we find in North Carolina, and I suspect it is true in many other states, that many of our people will agree that we need these facilities, that we have got to manage these wastes somehow. But the feeling is, "Don't put it in my backyard, put it somewhere else." This is the basic issue, whether it is a burial site, an incineration facility, or some other type.

What I think any state faces, or the national government faces, it we preter to approach this from a national standpoint, is how indeed do we solve the problem of locating these facilities within communities? They can be held up in courts, as anyone who has dealt with location ot facilities of this nature knows. It is taking years, several years, to locate these facilities, and then in many instances, even after spending literally millions of dollars, we have to back away and go somewhere else.

We don't have any answers to this necessarily in North Carolina. All I can tell you is what we are trying to do about it, which is one ot the reasons we have this task force on waste management.

We believe that we must deal with the locational problem by getting a number ot people across the state involved, not just as individuals, although individuals are important, but also as representatives of organizations, environmental groups, county commissioners, associations, municipalities--i.e., people who are leaders in many respects. As they weigh the benefits from research and industrial activity associated with these wastes against the risks associated with their proper managment, we think we can develop with our people a set of procedures to follow to ensure equitable and technically sound steps to take in locating facilities, again with strong local participation. This will be followed by whatever legislative action is necessary to legitimize the procedure. Then, if this procedure is followed in locating any facility, local opposition to the location of that facility will be minimized.

When I say procedure, let me give an analogy that I sometimes use to try to get across what I mean. Suppose those ot us on the panel decided that we're going to sit here and talk but that one of us must go after coffee for all of us. We might draw straws to decide who has the burden of going after the coffee and bringing it back for the rest of us. This means that someone must do something that all ot the rest of us are going to enjoy, i.e., that one person bears a burden that benefits all of us. Likewise, we believe that some procedures must be agreed upon (just as we would agree upon drawing straws to decide who goes for the coffee) as to what it will take to locate a facility within a community.

Along with the procedure, however, we believe that there is logic in some sort of compensatory arrangements. After all, you are asking a community to take something that no one else wants, and whether there is any actual adverse effect on the community or not, there is at least a perceived adverse effect, e.g., land values may go down or people may desire extra monitoring or health care to ensure that no adverse health effects result.

It can be contended that there ought to be some compensatory arrangements. Compensation can be in the form of a surcharge or a waste management tax upon the generators of the waste as it is brought to the facility. (Back to the coffee analogy, other members of the panel could agree to pay for the cottee of the individual going after it.) Funds generated can be used to offset the cost of extra monitoring, fire protection, or other measures to ensure the health and safety of people in the community where the facility is located.

For example, there are concerns that people have, and no matter how much we talk about it, there will still be some of these concerns. We believe that it may be advantageous for some communities to think in terms of an additional health center right in their midst to monitor the health of people if they are going to worry about the facility. If they are worried about other aspects of the danger, they may think of having an extra fire station, or whatever other things that the community wants that will be to their advantage and will tend to offset the perceived disadvantages of that facility.

These are examples of how we hope to proceed. We don't know for sure whether they will work, but at least we do think it is necessary to achieve much more significant public participation at the local level in what we are seeking to do, rather than decide ourselves in Raleigh what we want to do and then go out and try to sell somebody on it.

We think we must get the participation of the people who are involved, lay out the facts, the costs, the benefits, and so on, and ask them to help us decide how to solve these waste problems.

SHERMAN GEE, Naval Surface Weapons Center: Dr. Davis, you have summarized a number of current options for disposal of radioactive wastes. I wonder if there are additional options that are in the R&D stage at this time that look promising. For example, I have heard that there are investigations going on into the use of ultraviolet radiation for reducing the radioactive contamination. I wonder if you could say anything about some of these other techniques.

DAVIS: I am afraid that I cannot deal with those in detail. The NRC staff tries to stay abreast of these new developments. Sometimes we get somewhat excited about them, and sometimes we do not. I imagine in the near term, however, that we will examine the options that now exist with some modification: for example, the one that I have heard the most comment about relates to extending the "de minimus" quantity is the term used, although perhaps not quite properly. I am sorry, I really can't speak to your question.

BRINER: I think threading through the discussion today there has been some evidence of a light at the end of the tunnel, dim though it may be. On the other hand, I don't think there is anyone in this room who would be willing to swear that it is not a freight train coming toward us at about 70 miles per hour. Let's just say that there are some bright signs on the horizon.

But from my own perspective, we are far from out of the soup. Dr. Nelp, and I was happy that he did it, mentioned interstate compacts and their possibilities in his remarks. He also indicated that the ultimate fate of the Hanford site is still somewhat up in the air with regard to other than biomedical waste.

It is also clear to me that in the foreseeable future the probability of ever taking care of the total biomedical low-level radioactive waste problem without the use of some shallow land disposal facilities is literally impossible.

Now, the compact situation that Dr. Nelp mentioned brings to mind something that I am not at all sure that everyone in this room quite understands. Everyone I have ever spoken with, every group in the public or private sector, says yes, compacts are fine, we are all for them. But when you get around to attempting to establish compacts with exclusionary powers--this is to say that nonmember states of that compact are not welcome here--then you run into interstate commerce violations, federal laws of commerce that seem to contraindicate this.

In the current session of Congress, the Senate passed a bill (S2189) relating to interstate compacts. At one time or another there were several other bills in the House that kind of coalesced into two, with no passage in sight.

My first question for the panel is: Is it your consensus that perhaps some encouragement might be provided to the Congress of the United States, perhaps by the Academy or perhaps by this Forum, to proceed with all possible dispatch to enact federal legislation that would legalize once and for all the establishment of regional compacts for low-level radioactive waste with exclusionary powers?

NELP: My answer to your question is yes. I think that there are several routes to this. Federal legislation is one way, and if it were passed speedily and properly I think that would be very useful.

As you well know, the other route is through the governors' associations, in which the governors, getting back to states' rights concepts, at least feel that they have borne the major responsibility for this situation and, as a matter of fact, they would like to implement further change through their own bodies. Perhaps that will have to come to a blending of interests.

The other group is the President's Radiation Policy Council, which--now you can see how the bureaucracy works--also has a subcommittee for this type of activity, and who is preempting whom isn't quite clear.

So yes, I think this body and this Forum could amplify the importance of getting the show on the road. And I might say that the initiative should have a complementary effect in this regard, that is, closing the site in the state of Washington, which is sort of a provincial, states' rights act of defiance by some people but a very good thing by the majority of people who voted the issue in. I think that will help at least focus on the issue, the need for regionalization.

BRINER: I think the need for regionalization also is emphasized by the fact that there are now only three states in the country that have been handling the total low-level waste problems of the nation for at least 15 years, perhaps a little longer with regard to one or two of those states.

The question I would like to direct probably again to the whole panel is simply this. Is it appropriate or even desirable to seek a solution to the biomedical low-level radioactive waste disposal problem to the exclusion of low-level--and I emphasize low-level--radioactive waste producers who are outside the biomedical umbrella in view of the overall economics of the situation?

ALBERTY: Who would like to respond to that?

NELP: I will respond very briefly. I think it is very appropriate to show leadership if you can, and if we can show leadership in a solution, even though it may be somewhat exclusive and doesn't include everyone, I would hope that through consideration, hopefully some action, we could provide a mechanism or pattern for other people to follow in response. So in that sense I think it is very appropriate.

BRINER: What is it going to do to the economics of our burial or disposal of waste?

NELP: Well, what I perceive will happen is, for instance, if you take a low-level waste disposal site like the Hanford site in the State of Washington, which I am most familiar with, where much of the biomedical waste goes, if we are effective in doing things like combusting and incinerating and careful management, I think that we can cut down our volume considerably and probably cut down the volume that is buried in that site from 30 percent of the total site volume maybe down to 5 percent or less. I think we are always going to have some.

Economically I don't think combustion as an alternative is any more expensive than what we are currently doing. What will happen at the site if they lose not only the out-of-state business but more of our biomedical business? To keep that site open it is going to cost more to bury the smaller amount that we have, I think.

Now, maybe you have looked at this issue, Quentin.

LINDSEY: We believe that we must consider the whole low-level radioactive waste picture. As I said earlier, we have nuclear power plants that generate low-level radioactive waste. We have forms of low-level radioactive waste other than scintillation vials and carcasses.

As a state, we can't deal with just a part of the problem and tell the other folks "go solve your own problem." Second, the economics of it are such that for those low-level radioactive wastes that must be buried in a landfill, the cost per unit of waste does decline until a rather large volume per year is reached. Hence, there are economies of scale.

If my understanding of the economics of the operation of the Barnwell, South Carolina, facility are correct, they are concerned also with the economics of the situation. If they restrict the disposal of radioactive waste at Barnwell just to what South Carolina generates, their problem is similar to what has been discussed before with respect to Hanford: the costs become astronomically high. On the other hand, they don't want to become the disposal facility for the whole country, or even half of the country.

So I think we must address the problem comprehensively, both the various types of waste and the geographic location of these facilities through compact--and we are very much interested in the compact arrangement--so that we have located across the country adequate facilities within reasonable distance.

I would also add only parenthetically that we think consideration of regional facilities in the hazardous toxic waste area as well is something that we have got to consider more seriously than we have up to this point, for essentially the same reason.

JAMES SMITH, Director of Nuclear Medicine Service, Veterans Administration: I would like to take up the question about the oceanic disposal of radioactive waste. There was a conference on this in Washington recently. It has been hoped that from 1990 onwards the ocean might become the repository for radioactive wastes. There are certain attractive features to this. The red clay that forms part of the abyssal shelf is highly suitable because red clay tends to heal fractures that might occur from earth tremors, and even the crystalline matrix of red clay may trap any radioactive materials that would escape from the canisters that are sunk into it.

It has been suggested that such canisters be sunk 50 to 100 meters below the clay surface, either by projecting them as darts or by digging trenches and burying them. It sounds very attractive except that the London Dumping Conference in 1975 forbade the disposal of all radioactive materials even into territorial waters, to say nothing of international waters, and Scandinavia has recently come out against the burial of all radioactive materials in the sea.

Now, the London Dumping Conference of 1975 did not forbid the oceanic disposal of low-level radioactive wastes, but from everything we know about low-level radioactive waste and other methods of disposition, it would seem extraordinarily expensive to pursue the oceanic disposal for low-level radioactive wastes only.

Both Britain and the United States are very eager to have the stipulations of the London Dumping Conference amended, but it seems highly unlikely that they will be able to do so. In this problem as in all others, the international lawyers will profit more from this than anybody else.

UNIDENTIFIED: So far today I haven't heard one alternative that I think really should be mentioned about what we can do at the present time. I have not heard anyone talk about the possibility of interim emergency storage sites for waste. If we have another shutdown, if Washington State shuts down and Nevada gets involved in one of these political situations and they shut down, we are going to badly need, I think, in this country a place for each state to take care of some of its own local waste to cover us until we can get some of these other things resolved.

I don't know how the rest of the panel feels about it, but I think this is something the states should be asked to do.

COOPER: We have been very concerned about this. Biomedical research would just come to a halt, but in the medical area that would be absolutely impossible. We must find, we must have available ways to dispose of whatever we have to dispose of in this route, and I hope we can continue to look and reduce the number of things we have to dispose of in this way.

But we certainly will need a standby somewhere unless we are going to shut down a considerable amount of the activity of our hospitals and of the research laboratories.

MIGNON C. SMITH, Alanet News: Does anyone on the panel know if the Hanford site was a hazard to Congressman Mike McCormack, who was just defeated? And do you have any specific suggestions, even more so than you have been naming, on how elected officials should deal with this problem?

NELP: Mike McCormack was a congressman, a Democrat who was not reelected. Mike also happens to be a very competent scientist who has a background in radiation, radiochemistry, and radiophysics, so he was a very understanding representative of that group.

I would really hesitate to comment on your question in the political sense. Was his advocacy in relationship to or his understanding of nuclear matters instrumental in not being reelected? I would say that most of the people in his district are very understanding. I was at Washington State University recently and was talking about some of these issues with students. One said, "Don't worry about me, Dr. Nelp; I'm from the Tri-Cities area, the Hanford area, and I'm pro-nuke." What that means is that the people there have grown up understanding more of the realistic aspects of these things.

You had a second part to the question: How do elected officials deal with this? Very carefully.

I think Dr. Yalow will remember that at the congressional hearings we discussed all the issues that we have discussed today in some form, and finally it came down to what is the main issue regarding the problems that we face in implementing regionalization in waste disposal? I think there wasn't a person, political or scientific, in that room who did not agree that these are largely political issues, or exclusively political issues as opposed to health issues at the present time.

So for me to advise how politicians would deal with it, I do mean in a sense very carefully, but I think more openly, and I think we in the scientific field have to push ourselves into the political arena as best we can to try to implement understanding and potential courses of action.

EDWARD L. GERSHEY, Rockefeller University: I have two sets of questions. I would like to direct the first to Dr. Davis. I would like to point out that I clearly see the relevance of Dr. DiSalvo and Dr. Taylor's comments that small research institutions will not reap the full benefits of the NRC-proposed rule change unless, of course, the states and cities in which they are located comply.

The question is: Advocated by the NRC in the background description is a very strong case for local incineration, and I wondered what limits would you concur with being incinerated locally, for one; and two, what about aqueous solutions that are radioactive that would exceed the 5-curie-per-year, perhaps an extra, say, second 5-curie amount, which would not be permissible to put down sewers?

DAVIS: How about giving them to me one at a time. What was the first one, again?

HERSHEY: I just wondered about incineration. It is advocated by the NRC as a method of on-site, for example, removal of low radioactive waste. How much can be incinerated?

DAVIS: We have a guide that we send out to people who are thinking about applying for approval for incineration. Basically the limits are based on the release of gaseous effluent, and those limits are specified in the regulations. That is one of the considerations when we examine or evaluate an incinerator for approval.

I might add here that of those incinerators that have been approved, there may be an incinerator that is running exclusively for radioactive waste, but I don't recall one. Generally they are incinerators that are used for other purposes that are also approved for the incineration of radioactive material.

GERSHEY: There is a strong reticence, though, on the part of New York State, or in particular New York City, to grant permission for incineration even though the panel established that, if all of the wastes from the biomedical community were incinerated, it probably would be within the guidelines that you referred to.

DAVIS: If you are asking what would the NRC do with New York City--is this the question?

GERSHEY: Well, it would be awfully nice to hear your view on that question.

DAVIS: Nothing. We have set up in our regulations an option of incineration, and the state, of course, can consider that option as they see fit. As I mentioned earlier, we look for the states to be compatible in those areas that place lower limits. But if we take a regulatory action that leads to something that appears to be less restrictive, then it is a matter of judgment as to whether that is a compatibility matter or not.

COOPER: I would just like to extend that question before he asks his second, if I could. It isn't quite clear to me. Here we have a proposal in which certain scintillation vials and animal carcasses are exempt. Now, if they are exempt, is there a prohibition on any incineration of those two items?

I mean the exemption sort of, I would say, indicates that there is no foreseeable health hazard or anything. Can't you just incinerate those? I am leaving off OSHA and all the other problems we have got.

DAVIS: So leaving off all the other problems, if in fact the regulation becomes effective, then that material, the scintillation vials and the carcasses, under the conditions expressed in the regulation can be treated as nonradioactive. In addition, there is a portion of the regulations that permits particular approval of incineration for other purposes.

COOPER: This could be carried out in a regular incinerator if you get by OSHA and all the other problems that plague us. But aside from that, as far as the commission goes those are nonradioactive wastes, so to speak, and there are no limits.

LINDSEY: I'm thinking primarily about the Resource Conservation and Recovery Act requirements in terms of how to properly dispose of the chemical waste, toluene, contained in scintillation vials. Also, it depends on how you incinerate. There are types of furnaces that do not adequately incinerate, and you may find air emissions or other types of emissions that will violate either state or federal regulations in other areas.

In other words, if the waste is no longer controlled by NRC, then I think the standards of good environmental management, plus the concerns of the local community where you may locate facilities, dictate that you be very cautious about how you incinerate or otherwise dispose of these items.

COOPER: As I understand it, under this we are going to peel back one layer, but there are multiple layers underneath that we have to confront to carry out our business.

GERSHEY: Dr. Davis, do you have any suggestions or recommendations for what one can do with aqueous liquids, let's say, containing tritium and carbon-14 that exceed the 5 curies that the proposal would make permissible to put down the sewer, say an additional 5 curies per year? What are the methods for local removal?

DAVIS: As a first act, if you were under the NRC jurisdiction, I would apply to the NRC and build a case for perhaps some special consideration for a larger annual quantity.

GERSHEY: May I address the second set of questions to Mr. Broseus as a representative of a large generator of low radioactive waste. It has been said that since much of our research is funded by the NIH and they take credit for inventions and products made thereof, perhaps we should send our waste back to the NIH.

The question is: How is your waste distributed in percentages, in terms of dry wastes and liquid wastes, and how do you actually deal with it in numbers locally? What percentage is incinerated, etc.?

BROSEUS: I am sorry I don't have very exact numbers on what the actual volumes are going to our incinerator. As I was preparing for today, I looked more at the volume reductions that one could realize. Off the top of my head I would estimate that probably 50 percent or more of our dry waste goes to the incinerator, some of it immediately because it is very low-level stuff like benchtop covers and so on, other after storage for decay till it gets down to reasonable levels.

GERSHEY: How do you handle your aqueous fluids, which I presume contain probably 98 or 99 percent of the radioactivity that you deal with?

BROSEUS: Well, as an example, we get in about 70 curies per year of tritium. It is our biggest single amount of radioactive material. But we have a tendency to see most of that activity coming in in large activity amounts and small volumes. The key to handling it is segregation, solidification, and shipping it for burial right now.

GERSHEY: Would the NIH welcome receiving combustible items from university campuses where they support the research? Would you be able to handle that?

BROSEUS: That is not a question that I can make a policy statement on at my level, but I doubt that it would be a reasonable way to go.

I might, while I have the floor, go back to a question raised by Dr. Taylor; we were talking about incineration earlier and there was a question in that area that I think deserves amplification. He asked a question on what the impediments are to implementing alternatives.

The chief impediments I see for incineration are primarily political. If you have to install an incinerator, you are going to have to deal with the local community in getting an incinerator going. The other primary problem right now is an operational one, and that is deciding what the incinerator is to use and the method to burn or incinerate your materials.

Let us go back to disposal of liquid scintillation vials. There are two ways to burn their contents. One is with a "bona fide" incinerator that will meet RCRA regulations (whatever they are) with respect to disposal of toxic chemical wastes; the other method is to feed the liquid into oil-fired boilers. As I understand RCRA, in the case where one is dealing with certain organics, if these are used as fuels then they do not come under the RCRA regulations. However if one burns such materials in an incinerator, with heat recovery, the primary purpose of burning is not to use the materials as a fuel; then RCRA regulations for hazardous material disposal apply. These are two disposal alternatives that should be kept in mind. I understand that there are two institutions that are crushing vials and feeding the liquid scintillation fluids into oil-fired boilers now.

DANIEL BRANNEGAN, Pfizer, Inc.: I have just two questions for Dr. Davis. What happens now with the proposed rule that we all agree is so enlightened?

DAVIS: Today, I believe, is the last day for comments on that "wonderful" rule. As far as I know, the staff has not evaluated the comments, which will be screened and evaluated; then there will be a judgment made as to whether it should be an effective rule.

As I mentioned, there is apparently a fair amount of optimism expressed by the people who generate biomedical waste for this rule, but we should not assume that it is 100 percent guaranteed that it will be an effective rule. We still must go through the process.

BRANNEGAN: You don't have any prognosis?

DAVIS: No, I don't. I haven't seen the comments.

BRANNEGAN: My second question may go all the way back to Leland Cooley. I have in my notes that what we are talking about is 6 to 8 or 10 curies per year of waste, and there have been a couple of figures that just recently were pointed to 60 to 70 curies per year at one institution.

Being a chemist by training, I worry about material balance and wonder if we are not worrying about a very insignificant portion that has a larger underlying problem. In fact, do we use 10 curies per year and is our material balance 10 that we have to worry about disposing of, or am I correct that it is significantly more than 10, and a lot of it is going away somewhere that I haven't heard yet?

YALOW: It is the difference between scintillation vials that they were talking about and the concentrated materials that Broseus was talking about that is disposed, either where permitted through the sanitary sewage, if it is water soluble, or impacted and sent to disposal sites. This is where the differences in the numbers are coming from.

In other words, there are different types of material you have to get rid of. The scintillation vials have, give or take, about 10 curies of tritium and 1 curie of carbon. But there is much more in the way of carbon and tritium that come into these institutions. A certain amount of this, up to what will be the 5-curie level for tritium and the 1-curie level for carbon, can be disposed of in each institution through the sanitary sewage, according to certain regulations that are being met.

Then in addition there are very high levels that may come into some institutions, a fraction of which is used and the rest is compacted and otherwise insolubilized and returned to burial sites, and that accounts for the differences that people are talking about.

I think we have gotten into this bind because we have accepted irrational regulations as long as they did not cost us very much. When we accepted these irrational regulations, the uninformed among us thought that they were rational and therefore developed--I think the TMI word is--a mindset that these levels were in fact dangerous.

I would like Dr. Davis to comment on some of these regulations that I would consider irrational. For instance, until now there has been a 1-curie limit per institution for disposal of radioactive materials.

This is 1 curie whether it is a small, local hospital, the NIH, or Harvard. There is no distinction made between institutions with respect to this disposal. I wonder what the rationale is for that.

The second rationale I would like to examine is the fact that if I were in the Cancer Institute treating one patient with thyroid cancer a month receiving 100 millicuries of radioactive iodine, the intake of these patients would be 1,200 millicuries. They are likely to put out a curie of iodine-131 in their urine, which they can dispose of into any toilet in that institution without any recordkeeping; whereas if I were to collect this in my laboratory to measure it and determine what is being excreted, I would not then be permitted to dispose of it.

I could go on and cite other such regulations that we have accepted willingly over the years that have created the mindset that these things are dangerous, and I would like to ask if there is anybody within the NRC or any agency that attempts to develop a scientifically sound approach to disposal of radioisotopes?

DAVIS: I dislike being called irrational, but basically, as I am sure you are aware, the regulations try to span a whole nation of use, so consequently they are not generally patterned by the amount of material a particular institution happens to get or compared with another institution. So consequently they tilt toward conservatism.

We always have had in our regulations the opportunity for institutions that believe they deserve a special consideration to apply for that special consideration, and we hope that we have dealt nationally with these applications--which, by the way, are not too many. In other words, most institutions accept what the regulations say. But we hope that we deal with the special applications in a most rational method.

With regard to other problems in this particular area, Part 20, which is the regulation that we mostly live under, is old. I believe early this year we announced in the Federal Register that we would be reviewing Part 20, and now we are in the process of doing so. I would welcome your very rational comments on Part 20.

P. KYO PARK, Ocean Dumping Program, National Oceanic and Atmospheric Administration: Five months ago I did go to a dumpsite off-island where radioactive wastes are ocean-dumped. I saw one Dutch ship coming by and throwing about 100 canisters overboard. This year's estimate is that about 55,000 curies of those canisters will be dumped off-island. It is about 400 miles offshore from the island.

If one canister is $100 from New York to Hanford, the break-even for a dump ship is about $200,000 from shore to, let's say, this nuclear energy agency dumpsite. This means 2,000 canisters. Probably this kind of rationale is used for the dumping of radioactive wastes in Europe. So even from the United States this is economically feasible based on what the present practice is.

Now, being an oceanographer, I am concerned. Let's say that you dump, out of sight, out of mind, and it is 5 kilometers deep, 2 to 3 miles deep, and we know very little of the basic ecosystem. Since we are the center of the universe, we are only going to worry about those doses coming to us.

Let's say that the 1 milligram could be the minimum concentration that we could receive. Then we have to study the dosimetry of the deep-sea ecosystem and then its route to come back to us. Those two are very difficult tasks.

Several months ago I advocated at Georgetown University Law School that thinking all of those things is great, but let's start to design a 6,000-meter submersible so we have a way to go after establishing a scientific basis. There I was told that it takes 5 years to design one submersible. But even though the dumping is going on, I believe we should try, and I am still advocating that we should keep improving our instrumentation, including a submersible, so that we may be able to study more intelligently when the bottom of the ocean is used as a dumpsite.

And if you ask me whether or not I advocate the dumping, I decline to comment; but since I am working for the ocean dumping program for the U.S. Congress, I would like to state that I have to establish as much scientific basis as I can. My budget gives about $3 million a year, but this encompasses all the waste, including sewage sludge. So I have budgeted virtually nothing for radioactive waste at present.

ARTHOR J. SOLARI, University of Michigan: This question is for Dr. Davis of the NRC. You asked for a logical basis, perhaps, for the regulations and the like. There have been several articles on the cost of saving a life in various fields of endeavor from radiation safety, automobile safety, flight safety, and what have you. It has an appeal in the sense that it becomes now a mechanical judgment: that is, Where do you save the most lives for your dollar? And there is no sort of value judgment at all except that, you know, the life of a professor has the same worth as the life of a minority individual or the life of a child, and so forth.

So it seems to me that the one way you can get a more logical approach to your regulations is to see how much do you get for the money that you force people to spend. I would like your comments on taking an approach like that, not only just for the NRC, but essentially for all the bureaucracies, both large and small.

DAVIS: I don't disagree that in the area of radiation safety we perhaps operate further out in the margin than in many areas of safety. What you suggest does have, I guess, the ring of understandability so that it could be explained. However, at the NRC we see ourselves basically as the advocate of all the people concerning radiation safety, and I am not certain that many of our constituency, if we had one, would be interested in seeing a dollar value placed on radiation protection matters.

We try to look not at any one single aspect of radiation protection but exercise a professional and hopefully rational judgment on radiation protection.

ALBERTY: I think I want to now bring this session to a close. It is not the objective of an Academy Forum to reach conclusions, but the chairman does have an opportunity to make a couple of summary remarks, so I would like to make a couple of very personal observations.

I think we are dealing here with a kind of waste that is very large in magnitude, some billion cubic feet per year. It is a volume of waste that has been growing rapidly. Someone estimates it has grown over 60 percent since 1975. And it is a waste from an area of research that is producing very important practical applications at the present time and holds a tremendous potential for the advance of medicine in the future.

I am sorry we didn't have more opportunity to talk about this because radiocarbon, tritium, iodine, and other isotopes are being used and are a necessary part of the way in which biological sciences are making their advances at the present time.

When we begin to discuss the potential hazards, we run into a very serious problem in trying to talk about them because of the huge range of magnitudes of radioactivity. I am really sympathetic with our American Indian colleague who says there are problems of language, because I think there are problems of language even in English.

To emphasize this I want to quote from an editorial in Science magazine: "Radioactivity continues to present formidable barriers to the understanding of the subject. It is not unusual for the discussions of waste disposal to involve units as small as picocuries and as large as hundreds of megacuries. This is a range of 20 orders of magnitude, a spread of values totally without precedent so far as the public and so far as most scientists are concerned. Members of the public and their elected officials may not understand the enormous difference between picocuries and megacuries."

Let me just say that as a chemist I have had the problem of trying to help students understand how big Avogadro's number is, 6×10^{23}, and I won't give some of those lectures to you. But I just want to make the point that when you have that kind of a range, there are really qualitative differences that are extremely difficult to comprehend.

With respect to the options for the future, I see the need for lots of work on the part of many of us. Of the methods for disposal that we have talked about, with respect to disposal in the sewer there are certainly opportunities for disposal of things by diluting them beyond the point where they can be of any conceivable harm to anybody, and I don't think we have taken full advantage of that.

With respect to burial, I think there are very distinct limits as to what we can expect to bury. We cannot continue to take up more and more land for simply burying things. There are perhaps some things we can't find other solutions to, so burial will have to be used for a method of disposal. But it certainly should not be thought of as almost the only method, which is the way we have been operating.

We do need more sites, and we need better distributed sites. Certainly trucking all of this material across the country has its own disadvantages, which we have not had an opportunity to talk about. I think there has been an emphasis today on the development of short-term storage or emergency storage. Laboratories are not good places to store things; universities and hospitals are not good places to store things like this; but storage itself has some uses.

With respect to incineration, it has really not been used very much, but it certainly seems to be a promising method. The analogies to burning wood, I think, were very well taken. The quantities of radioactivity involved in the two things are really not very different.

I think we have some promising new proposals for amendments in regulations. Certainly below some point it is not worth considering certain types of isotopes as a hazard to health and they certainly can be exempted below some levels from very expensive regulations.

I have learned a lot today. I hope you have learned some new things today, no matter how experienced you have been in this field. I hope that we can find other methods of interacting with the public, as we hope we have done today; there is certainly much more to do.