MEETING

of

JOINT LEGISLATIVE TASK FORCE ON BIOTECHNOLOGY

"Discussion of bioremediation, with emphasis upon its potential for use with dredging spoils"

LOCATION: The Center For Agricultural Molecular Biology
Rutgers, The State University
New Brunswick, New Jersey

DATE: August 9, 1994
10:30 a.m.

MEMBERS OF TASK FORCE PRESENT:

Senator Robert W. Singer, Chairman
Senator John H. Ewing
Assemblywoman Joanna Gregory-Scocchi
Abraham Abuchowski, Ph.D.
Gordon Ramseier
Amy Factor
George Oram
Caryl Russo

ALSO PRESENT:

Walter C. Kowalski, III
Aide, Joint Legislative Task Force
On Biotechnology
Office of Legislative Services

Hearing Recorded and Transcribed by
The Office of Legislative Services, Public Information Office,
Hearing Unit, State House Annex, CN 068, Trenton, New Jersey 08625

ROBERT W. SINGER
Chairman
NICHOLAS R. FELICE
Vice-Chairman

New Jersey State Legislature
JOINT LEGISLATIVE TASK FORCE ON BIOTECHNOLOGY
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REVISED

TASK FORCE NOTICE

TO: MEMBERS OF THE JOINT LEGISLATIVE TASK FORCE ON BIOTECHNOLOGY

FROM: SENATOR ROBERT W. SINGER, CHAIRMAN

SUBJECT: **TASK FORCE MEETING - August 9, 1994**

The public may address comments and questions to Walter C. Kowalski, III, Task Force Aide, or make bill status and scheduling inquiries to Cynthia D. Petty, secretary, at (609) 984-0445.

The Joint Legislative Task Force on Biotechnology will meet on **Tuesday, August 9, 1994 at 10:30 AM at the *Center for Agricultural Molecular Biology (AgBiotech Center), Environmental and Natural Sciences Building, College Farm Road, Rutgers, The State University of New Jersey, Cook College, New Brunswick, New Jersey,*** to discuss bioremediation, with emphasis upon its potential for use with dredging spoils. In addition to presentations from scientists on bioremediation, the Task Force will also witness bioremediation experiments currently under way at the Center.

Testimony will be limited to invited guests.

<u>*DIRECTIONS TO THE AGBIOTECH CENTER:</u>

<u>FROM ROUTE 1 SOUTH:</u>

PASS JUNCTION OF ROUTE 1 SOUTH AND ROUTE 18 AND CONTINUE FOR ABOUT 1/2 MILE TO COLLEGE FARM ROAD EXIT. YOU WILL HAVE PASSED SEARS DEPARTMENT STORE ON RIGHT-HAND SIDE.

FOLLOW COLLEGE FARM ROAD PASSING A BARN ON THE LEFT. THE AGBIOTECH CENTER IS HOUSED IN THE FIRST LARGE BRICK BUILDING ON THE LEFT (Environmental and Natural Sciences Building, Room 352).

(OVER)

Assistive listening devices available upon 24 hours prior notice to the committee aide(s) listed above

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P E T E R R. D A Y, Ph.D.: Good morning, ladies and gentlemen. (feedback) Let me just adjust the volume control.

Ladies and gentlemen, I'm Peter Day, the Director of the AgBiotech Center. It's my pleasure to welcome the Biotechnology Task Force here this morning. Before I make a few introductory remarks, let me turn the microphone over to Senator Singer.

SENATOR ROBERT W. SINGER (Chairman): It's like passing the gavel, right? First of all, Peter, on behalf of the Task Force, I want to thank you for hosting this here today. There are some members coming in and out and, unfortunately, as it's being summertime, some are on vacation. I know Nick was sorry he couldn't be here, but he's in Alaska. Something tells me I'd rather be with him though, Peter, than here -- no insult to you. (laughter)

Let me just briefly state a little bit of the background of today's meeting. In my prior life in the Assembly, I Chaired a Committee called the Ocean Beach Protection Panel. In a number of hearings we had through those terrible days of pollution from New York and needles on our beaches -- and at that time, I was a shore legislator -- we were concerned about what was going to happen to our ocean and how we could clean it up.

One of the concerns we had was, certainly, dredge spoils, the possibility of building a containment island, and how we could work hand in hand with the Port Authority to solve that problem -- which, you know, has been renewed again, continuing the concern of a lot of people as to what's happening in dredge spoils. What are we doing with them; where can we dump them; what is happening?

The Biotech Task Force really deals with three areas. We've probably concentrated 90 percent of our concerns in dealing with the pharmaceutical aspect of biotechnology, which is the largest one -- the one that employs the most. But there are two other aspects to biotechnology. The second aspect is something that we haven't really touched that much on -- and something we will be -- and that's agriculture. I do Chair agriculture for the State Senate. That plays an important role in that particular part of our industry, and we will be dealing with that, also. But bioremediation is a very important aspect of it here, too. We are hoping that some of the concerns they have about dredge spoils, some of the problems we're dealing with, can be solved this way.

Therefore, we have -- and unfortunately, because of conflicts, not everyone else was able to be here -- invited some of the shore legislators to come here today to listen to this. This would be the beginning of it, not the end of it, and how, possibly, we might solve some of the concerns we have in New Jersey through this way.

Peter, I don't want to delay. I know the members who are here will be coming in and out, and I thank them for coming. But, on with the show.

DR. DAY: Thank you, Bob.

Let me say a few words about the-- Before I start to talk about the genesis of the meeting, let me welcome a few other important visitors who are not on the program. Dr. Jay Brandinger, the Executive Director of the New Jersey Commission on Science and Technology; Dr. Rod Sharp, who is Director of the Agriculture Experiment Station; Dr. Andy Rudczynski, who is from our Office of Grants and Contracts, and several other dignitaries here, who I may have overlooked mentioning. Welcome to you all.

The genesis of the meeting: Some weeks ago, Rod and I were down in Trenton trying to lend a helping hand -- which, in fact, turned out to be unnecessary -- to some legislation that would smooth the passage of biotechnology in New Jersey. I hope it has passed; I haven't heard that it has. I met Caryl Russo, and she mentioned the Task Force's interest in this area. I said, "Well, it's certainly a focus of our interest, here, at AgBiotech and at Rutgers, New Brunswick. Would you like us to do a dog and pony show for you?" She seemed quite enthusiastic, and the program that we have before you was set up at rather short notice -- I think within two or three weeks. We're delighted to have this opportunity.

Before we get down to the topic, I thought I would mention -- since I won't have another opportunity -- a little by way of background on the Center where you are now, which is, I hope, one of the gems in the crown of the Commission on Science and Technology of New Jersey. It's a Center which was established about seven years ago to apply biotechnology to agriculture in the broadest context. The Center has seven principle investigators, with an additional staff of about 60 other people, made up of post docs, technicians, and so on.

The building we're in at the moment is a temporary one. We will be moving in December, we hope, into Foran Hall, which is a new facility built with $20 million of funds from the last bond issue -- $17 million were applied to that center. We also received another $10 million of Federal money, through the USDA Facilities Program, and we will have 16 new laboratories. We hope to commission that building and dedicate it early in 1995. Three million of the $20 million was spent in the southern part of the State -- very wisely, I think, both from a scientific and a political point of view -- at the Rutgers Research and Development Center in Bridgeton. It's actually in the town of Upper Deerfield. There, the Center was upgraded, and new laboratories and containment greenhouses are in position.

Last Thursday, some of us went down there inspecting six field trials of genetically engineered materials. Two of them are Rutgers' trials of creeping bent grass, which is resistant to herbicides, and another of eggplant resistant to Colorado potato beetles. But more importantly, four of them are industry trials; two from American Cyanamid on potatoes and an engineered virus for controlling insect pests; one for the Upjohn Company, on squash that are resistant to viruses; and one from Monsanto, on soybeans resistant to their herbicide glyphosate.

These are really exciting, new developments. Let me just show you a slide of the turf grass, just so you can get a very brief idea of the sort of things that we do. (shows slides)

These are creeping bent grasses -- transgenic ones -- where a gene for resistance to the herbicide is being introduced by shooting pellets coated with DNA.

These are controls. The plants are being sprayed with the herbicide called bialaphos, and the controls have died. Now, that's fine in the greenhouse, but the real test comes in the field.

This is a test plot, hand-weeded because the plants were rather tender. Then, if you'll turn the lights off, please, Julie.

Here is herbicide being sprayed on the plant and here is our resistant grass with weeds killed round about. So herbicide is a first step, and there are a lot of other possibilities.

The AgBiotech thrusts that we're involved in, in both bioremediation, which is the focus of the meeting this morning-- You will hear from three of my colleagues; two of whom are microbiologists, a third is using plants to deal with bioremediation problems. We have a variety of other programs on virus resistance on the growth and development of plants, and we hope, soon, to add a thrust in livestock biotechnology.

Well, we have nine speakers this morning. Four of them are from the AgBiotech Center, and the other five are from other units and departments with whom we collaborate. One of them, David Carson, is from the campus across the river, and the other four are colleagues of ours from the Cook College campus.

So, without delaying things further, it's my pleasure now to introduce my colleague, Dr. Gerben Zylstra, from AgBiotech, who is going to talk about microbial degradation of aromatic compounds in marine sediments.

GERBEN J. ZYLSTRA, Ph.D.: Thank you, Peter.

Could I have the slides?

What I thought I would do this morning is first introduce what I do in my laboratory, and then go through a few experiments that we've just started recently in my lab in the last year, looking at degradation of different aromatic compounds in marine sediments. (shows slides)

In my laboratory, we've divided up into four different groups. The first group is looking at BTEX compounds, and their degradation by different, pure cultures of bacteria. BTEX compounds are normally components of gasoline and crude oil, and are a common contaminant around underground storage tanks that end up leaking.

We're also looking at polycyclic aromatic hydrocarbons, which are found a lot in marine sediments because they don't evaporate. They stick to dirt sediment, and they're also leftover waste from oil processing, as well as coal gasification plants from the early 1900s.

We're looking at the degradation of phthalates, which are plasticizers and used in the manufacture of plastics.

We're also looking at, recently, nitro compounds which are components not only in explosives, as you would expect, but also are biproducts of drug manufacturing from several different drug companies in this State.

Our approach in my laboratory is, basically, a microbial, genetic approach. What we've tried to do is go to the environment and isolate microbial strains that have the ability to degrade these different compounds. Then we try to figure out what biochemical reactions are involved in degrading these compounds by those bacteria. We try to figure out how those pathways are regulated, how they can be turned on and off by us by manipulating the environment, as well as in a shake flask or in an engineered system.

We also focus a lot on cloning the genes involved, because once you have the genes, there are a lot of things you can do with those genes; especially in the construction of novel or recombinant strains that may have enhanced abilities to degrade those compounds in the environment.

Because we're looking at so many different compounds, we try to focus our research on molecular biodiversity. Biodiversity, now, is a buzzword at all levels of government, because there is a lot of diversity in the biological world, and if we can understand that, perhaps, we can isolate better tools for doing what we want to do in bioremediation.

We're looking at several different, basic questions. The first is, what are the microbial capabilities for degradation of aromatic compounds? First of all, we try to find out what strains are there and what existing abilities are in the environment.

The other thing we can do is forced evolution. This is genetic engineering, but done in a natural state where we can mix different cultures together and then force them to exchange their genetic information in the laboratory, then producing natural recombinant strains which can be used in environmental applications with very little regulation.

This has been used a lot by several different groups to construct strains that can degrade very recalcitrant compounds where you cannot find existing abilities in the environment, but you can force evolution to produce those characteristics that you desire. Plus, because we're at an AgBiotech Center, we can do biotechnology-enhanced abilities with gene cloning and gene manipulation in the laboratory.

Then we're looking at how the genes are expressly regulated. We look at metabolism, which is the growth on a particular compound; cometabolism, which is growth on one compound, and degrading a second compound at the same time -- that's completely degrading it; cooxidation, which may not completely degrade a compound, but may convert it to another nontoxic substrain.

Then we're looking at how the genes evolve, by looking at what diversity there is in the environment and how that genetic diversity can tell us subspace recivicity, which is the ability to degrade a wide range of different compounds in the environment.

So one of the topics I wanted to touch on this morning is our polycyclic aromatic hydrocarbon degradation. Polycyclic compounds are just simple rings of carbons in either two rings, three rings, or four rings. As the number of rings increase, the ability to degrade that compound decreases. So a four-ring compound would be very difficult to degrade; a two-ring compound would be very easy to degrade. Once we get into five-ring compounds and six-ring compounds, those compounds become carcinogenic in experimental animals. So it's very important that we look at how we can get rid of these compounds in the environment.

We found that New Jersey is a very good source of organisms that can degrade these compounds. One site that we went to was the Passaic River -- which is up here in northern New Jersey -- and we isolated a number of strains that can degrade those different compounds. Napthalene is a two-ring compound; phenanthrene is a three-ring compound, and then other compounds that we looked at to try to characterize these isolates.

You can see here that all the strains grow on phenanthrene, the three-ring compound, and they have varied ability to grow on the two-ring compound, napthalene, and three-ring compound, anthracene. So there is some diversity in their ability to degrade these compounds.

But we wanted to look at genetic diversity. This is a simple, cellular blot, where, if the gene is the same, you'll get a band -- a dark band like this -- or if the gene is different, you'll get no band. So what we found in just this simple location -- the Passaic River -- using a probe that was identical to this strain here -- this 9816-4-- The probe finds itself, it finds three other strains, and we found that these three strains -- 38, 39, and 42 -- are different in their genetic makeup.

Now, further tests that are ongoing in the lab are showing that they are also different in their metabolism and their ability to degrade different compounds.

We cloned those genes from one of those organisms -- strain 39 -- and we did a reverse experiment, where we now looked at the original strain, then 38, 42, and 39. We found that these strains are different, also, because they do not hybridize, or partially hybridize.

Where here, as you can see, there are four bands -- actually five bands, sorry -- in this lane; then in the lane for 38, it's missing these two bands here. So just in this one location, we seem to have four different microorganisms that have different genetic capabilities for degrading these compounds.

Now, we wanted to apply this technique to the marine environment, and the question we wanted to ask was: Are the microorganisms in a marine environment different from those in terrestrial environments? There has already been some literature by people in Seattle showing that the organisms in the environment have similar genes to the ones that I just showed you, and there is some information from people at Boston showing that the genes are different.

We wanted to show whether the genes in, let's say, the isolates that we could get from the marine environment are the same or are different, then do more in-depth investigation and find out how they are different and what their capabilities are. So that covers the second one with the genes.

Then, we wanted to look at whether these (indiscernible) have any unusual capabilities.

The reason we went to the marine environment is because it's, obviously, very different from the terrestrial environment. The first obvious difference is that the marine environment is wet, whereas, in terrestrial environments, the organisms have to survive in soil in a more or less dry state. In the marine environment, it's obviously wet.

There is also high solidity, and this solidity can vary. You have temperatures ranging from refrigerator temperatures -- 4 degrees C, which is low -- to medium temperatures, in the 70s or 80s. There are low and high pressures, depending upon whether you are at the top or the bottom of the ocean. So there are different environmental niches where you can find different bacteria that have different abilities and different characteristics. So the potential exists for finding unique microorganisms in these sites.

We went to several different locations. We went to the east end of the Panama Canal, because I have a student from Panama who came up here on a fellowship -- a Fulbright Fellowship -- to work on the degradation of these compounds in marine environments, because there is a lot of contamination at the Panama Canal. We also went to the Arthur Kill region, here in New Jersey, and, in collaboration with the Marine Science Institute here on campus, we went to the Guaymas Basin, which is two kilometers down in the ocean -- so they had to go down in the Alvin Submarine and take these samples for us.

Now, we isolated a number of different bacteria. Some, you can see here, have different shapes -- and this one on the bottom shows very unusual branch rods and cocci. So we think of this as a microbacterium, which has been shown by other people to degrade the high-molecular weight PAHs -- the more toxic ones.

We showed that these different strains had different abilities to grow on the different polycyclic compounds. For instance, one strain could grow only on the three-ring compound, phenanthrene. This strain could grow on the two-ring compound and the three-ring compound. This strain, on the bottom -- 33 -- could grow on all the compounds that we tested, two-, three-, and four-rings.

So we have a variety of different strains to work with from the marine environment. What we've shown is that in these particular strains, the genes for the degradation of these polycyclics are different from the genes for the degradation of these polycyclics from terrestrial microorganisms. So we're in the process of cloning the genes from several of these organisms and analyzing them in more depth to see how they can be manipulated to enhance the ability to degrade these compounds in marine sediments.

Most importantly -- it was one particular strain -- we've shown that pyrene, the four-ring compound, can be degraded completely to innocuous products such as carbon dioxide. This is a simple graph showing that we get carbon dioxide produced when the strain is grown on pyrene.

I want to touch on one last thing; that is, the degradation of BTEX compounds. Like I said, these are found in crude oil and gasoline. These normally are not problems in the marine environment, because they evaporate quite readily. There are simple, single-ring compounds with methyl groups sticking off the sides.

We've isolated two strains, both of these are from the Guaymas Basin -- again, two kilometers down. This is because in that particular site, crude oil naturally seeps to the surface of the bottom of the ocean. So we hypothesized that we could find some bacteria there. We did, and we're in the process of showing that these bacteria are different, genetically, from the bacteria in the terrestrial environment.

So, to summarize what I've told you so far, and to tell you what we're going to do in the future: We've found that marine microorganisms can have similar or different genes for the degradation of these compounds. The potential exists that we can isolate new biodegradive processes from microorganisms in that environment. We're also working in my lab on biocatalytic processes. We're working on a contract with a company to screen some of these microorganisms for different capabilities for converting these different compounds to value-added intermediates. We're trying to understand the basic genetic and physiological properties of these organisms, so we can develop enhanced, rational bioremediative processes.

Thank you.

DR. DAY: Thank you very much, Gerben.

We have time for one or two questions, and I wonder if I could ask you one immediately?

Presumably, when the marine microorganisms come up with a dredge spoil onto soil, they're in an environment which is not hospitable?

DR. ZYLSTRA: Yes.

DR. DAY: So that would mean for biodegradation to occur in a situation where you have a spoil heap, you would have to establish a new microflora?

DR. ZYLSTRA: Right. We would have to work with the microorganisms in the marine environment that can tolerate those types of situations, which would probably be the best starting point, because they are then used to being in that particular sediment and being exposed to those compounds. But we could also probably screen our terrestrial organisms in those situations, as well.

DR. DAY: Are there any other questions?

Yes?

DR. ABUCHOWSKI: Is there any work on isolating the enzymes that degrade these compounds?

DR. ZYLSTRA: In the marine organisms, there has been no work that I know of. In the terrestrial organisms, there is a lot of work by myself and others isolating the different enzymes for, like, the first three or four stops in this process. We anticipate that the enzymes in the marine isolates will be similar but not identical. We'll be doing that in the future.

S T E V E N C O H E N: Do you find that the different indigenous organisms can coexist? Where you have multiple contaminants, you may need more than one indigenous microbe to do the job.

DR. DAY: Did everyone hear that question? (affirmative response) Okay.

DR. ZYLSTRA: In our situation, we normally work with pure cultures. Richard Bartha is really the person to ask about that. I'm sure he's going to touch on it in his talk, I hope. There is a lot of work done on manipulating the soil environment or the sediment environment, to get consortia -- or multiple organisms -- to work together. So, yes, there should be no problem with that, as long as there is not a push in one direction for one particular compound, or one particular population outcompeting the other population. But in my case, I do it with pure cultures, because they are easier to understand. In complex ones with multiple strains, it can get difficult to analyze.

DR. DAY: I think in the interest of trying to catch up on the schedule, we ought to move on.

Thank you very much, Gerben.

I'd like to next call on Gary Taghon, from our sister institute here at Cook, the Institute of Marine and Coastal Sciences. Gary's title is "Biological Processes Affecting Degradation of Contaminants in Marine Sediments."

G A R Y L. T A G H O N, Ph.D.: (shows slides) I'm going to be briefly overviewing research that we're conducting, with a variety of other investigators here at Rutgers, on the problem of in situ bioremediation of contaminated sediments and soils.

Obviously, our interest from Marine Sciences is on the marine end -- the sediments. For this particular project, we feel that one of the central questions that we need to answer is: How do the animals that normally live in marine sediments affect both the survival and the activity of contaminate degrading microorganisms?

We know that bacteria are really the ultimate agents responsible for the degradation of a variety of contaminants. But, we also know that there are many biological and ecological processes that, in nature, will affect the activity of bacteria, whether these bacteria are indigenous or ones that have been purposely introduced.

We think it's relevant to answer this question on three perspectives. First, as we all know, contaminants that enter marine waters tend to very rapidly partition, or become absorbed to particles, and accumulate in sediments. That's good from the viewpoint of removing them from the water. But it's bad from the viewpoint that, especially in areas where fine-grain sediments tend to accumulate, you can get high levels of contaminants, and then it becomes a problem.

There is a lot of information on the fates and degradations of contaminants from the types of laboratory studies that Dr. Zylstra was just mentioning -- many of these done with pure cultures of bacteria. However, it becomes quite difficult to extrapolate or extend those results into nature --

into field sediments -- because of the long-standing problem that's pervasive in science and engineering, not just in this field, of taking results from the laboratory and then applying them to the field. That's often the most difficult step to make, because you add multiple layers of complexity when you move from the lab to the field.

Finally, we know from a long history of basic research in marine ecology, that animals -- marine animals -- do affect, to a considerable extent, the activity of bacteria -- naturally occurring bacteria, in some instances, and the rates that they decompose -- the natural sources of organic matter. Therefore, it's quite logical to presume that these animals are going to also affect any sorts of bioremediation processes.

We feel that to understand how effective biodegradation or bioremediation is going to be, especially in situ bioremediation, that we need to have a much better understanding of these higher level biological and ecological processes that are going to affect bacterial activity.

So, what are some of these higher level processes? Briefly, we can think of them in two catagories, indirect effects of animals on bacteria, and direct effects. I should emphasize that there is no black and white division between indirect and direct; they often gray between each other. But just for discussion purposes, I'll group them this way.

So, indirect, just to denote that the animals are doing something directly to the sediment, and then that is indirectly affecting the activities of bacteria and, ultimately, the decomposition of organic compounds. The first one we know is just simple, physical mixing of sediments by the organisms, which is given a technical term, bioturbation. The analogy here is with earthworms in your garden. It has been known for centuries that the activities of earthworms, just by a simple, physical mixing of sediments, will increase soil fertility -- increase the decomposition of organic material in sediment. The same phenomena occur in marine sediments, as well.

The other thing that animals do to sediments, which indirectly affects bacteria, is that they often irrigate the sediment. They actively pump water across the sediment water interbase. This can increase the exchange of chemicals and other nutrients that the bacteria require.

Direct effects, short-circuiting the sediment is-- We know that bacterial growth and subsequent decomposition of organic matter can be stimulated by the presence of animals, simply by the recycling of -- limiting nutrients -- excretions, from the animals. However, it's not always a positive effect. In many cases, there might be either elimination or a severe reduction of either native or introduced bacteria, which is what you don't want to happen.

But there have been studies that have shown that introduced bacteria, in some circumstances, are rapidly eliminated from the system, probably due to either predation -- a variety of organisms eat bacteria -- or the creation of an unfavorable environment. For example, these kinds of physical mixing processes might be beneficial to one type of bacterial strain, but detrimental to another.

So these are all examples of the kinds of research that we're presently conducting here, in collaboration with a variety of other investigators, as I mentioned.

I just wanted to finish up with what, I think, are some of the unique opportunities here at Rutgers and its facilities. First, I feel that we do have unique laboratory facilities, in combination with the sea water laboratory -- where we have flow tanks, for the kinds of long-term studies that you need to conduct -- where you have intact benthic communities, that is, the sediments, the animals, the bacteria. We can then maintain these kinds of systems under natural conditions for a long term, under actual conditions to study the affects.

We also have that, in combination with state-of-the-art, analytical facilities and laboratories, both here on Cook and on Busch. I think in combination these two really make Rutgers, basically, a unique kind of facility that is unmatched anywhere in the world. I don't think that's hyperbole; it's just fact. We do have some very impressive facilities to conduct this kind of research. For example, natural outgrowths of this kind of study would be to look at remobilization of sediments and pollutants bound to sediments, and their transport, perhaps, away from the area where they were deposited.

As I mentioned previously, this is part of an interdisciplinary research effort, funded by the Advanced Research Project Agency and ONR that Dr. Dave Kosson and Lily Young are co-PIs on bioremediation of aromatic contaminant mixtures. I think that this is really a golden opportunity and a great example of moving from basic research to applied research on a topic that's of considerable interest with a great number of people.

So I wanted to stop there and ask for any questions.

DR. DAY: Thank you very much, Gary.

Are there questions, please?

SENATOR SINGER: Just one question, Peter. Have we done an analysis of exactly what is in the dredge spoils in New York Harbor?

DR. TAGHON: I defer to Fred Grassle, Director of the Institute.

J. FREDERICK GRASSLE, Ph.D.: Yes, they're analyzed for priority pollutants, not a complete analysis. There is a tremendous mixture of contaminants in the sediments: PCBs, hydrocarbons, dioxin, as you well know, a whole suite of metals. A broad mixture of compounds are at levels where they're in other areas that have been a source of concern.

DR. DAY: Other questions? (no response)

If not, thank you very much, Gary.

Our next speaker, Anne Frazer, is a member of Lily Young's group. Lily, unfortunately, is out of town for this meeting. Lily, Anne, and the group, work with a group of organisms that operate in anaerobic conditions, that is, with very little, or very limiting quantities of oxygen. Anne is going to talk about bioremediation of aromatic contamination in soil and sediments.

A N N E C. F R A Z E R, Ph.D.: (shows slides) Well, as Peter mentioned, I'm a member of Lily Young's research group in the AgBiotech Center, so I'm going to give you an overview today of the sorts of research that our group is involved in that deal with soils and sediments.

We have four postdoctoral scientists working in our group and, to add one more, a research technician, who kind of holds our group together -- an organization that's very valuable -- five graduate students, three undergraduate students. Our group is, perhaps, a little unusual in that we have three research faculty members, also, as part of our group. I'm one of them. The other two are Dr. Max Haggblom and Dr. Norberto Palleroni.

The general area that we are concerned with in Lily's group is the degradation or transformation of toxic compounds by bacteria that are derived from, isolated from, studied within, I guess, sediments, anaerobic digesters, and soil. Our emphasis, generally, is on processes that occur in oxygen depleted environments; that is environments that we refer to as anoxic or anaerobic.

We are very happy to be working much more closely with engineering colleagues, since Lily located to Rutgers approximately two years ago. You've already heard about one of these projects, which I'll talk to you briefly about a little more, that is, to develop and evaluate bioremediation approaches for contaminated groundwater here in New Jersey. The approaches that we are particularly exploring include using anaerobic bacterial processes for remediation.

I think there is one other thing I probably should mention or really emphasize, and, that is, the kinds of environments that become oxygen depleted include:

Soil, once it's waterlogged, because oxygen is rapidly used by a faculty of organisms that are present in the soil once it's depleted; then anaerobic conditions are established.

Sediments: there is an anaerobic layer in sediments, and once the oxygen is consumed there, then the anaerobic processes occur beneath. Digesters from municipal sewage plants: anaerobic digesters, the gastrointestinal tracts of animals, and those have been studied extensively.

Okay. We look at very diverse aspects then of the activities of bacteria on toxic compounds. We're interested in a number of different compounds, many of them similar to the ones that Gerben already spoke to you about. But in Lily's group, we have particularly emphasized anaerobic bacterial transformation of these compounds, both naturally occurring, toxic compounds or xenobiotics. Mostly, we have dealt with aromatic compounds, those that have carbon-ring structures.

We're also interested in the diverse anaerobic processes that are coupled to the transformation of these toxic compounds. Examples of these are where coupling is to the reduction of nitrate in anaerobic environments, or to sulfate, and to others that I'll talk about just briefly a little later.

We're also very interested in studying the different bacterial isolates that exhibit interesting or even typical transformation capabilities in these various environments. We've isolated several strains that are being studied in our own laboratory and in others.

This summarizes current activities and research that are ongoing in Lily's laboratory related to contaminated marine sediments. First of all, Lily is a member of a national research council committee on contaminated marine sediments. This committee has already done a good deal of its work and is now involved in writing a final report. Dr. Grassle is another member of this committee, and you've already heard a little from him.

There are three research projects presently being pursued in the laboratory that deal with marine sediments and groundwater. The first of these is the ARPA ONR Project. Many of the people who are speaking to you this morning are also involved in this large group project. Dave Kosson is the director of this effort. It is the bioremediation of aromatic contaminate mixtures in soils and sediments.

Lily Young's project of that is to study the affect of anaerobic microbial processes on aromatic contaminants. It does include this New Jersey groundwater remediation project, making use of anaerobic conditions, in this case, where nitrate reduction is coupled to degradation of the aromatic compounds.

A second project that has been ongoing for about a year or a year and a half now is focused on the role of anaerobic processes in the biodegradation of fuel components in esterine in sediments. There are two major aspects of this being looked at: One is the activities of anaerobs in sediments. Sediments are collected by coring -- taking a core sample into the sediment -- and then, in the laboratory under anaerobic conditions, that core is sectioned and the activities of various anaerobic processes -- nitrate reduction, sulfate reduction, iron oxide reduction, and methanogenesis -- are all studied. So we're interested in the history -- the previous contaminate history -- of the activities of microbes in these important processes. Secondly, we're looking at the capacity for the organisms in these samples to degrade fuel components.

The third project is diversity of anaerobic dehalogenation in esterine and marine sediments, this will begin shortly. We're going to be looking at the capacity of, again, marine sediment anaerobs to dechlorinate, to dehalogenate natural and xenobiotic compounds.

This is a map of the New York/New Jersey Harbor estuary area.

Is it in focus?

SENATOR SINGER: Yes.

DR. FRAZER: Okay. In our earlier work, we had taken sediment samples from the lower Hudson River and from the East River. The East River site that we used was a boat basin, so it was contaminated, you know, with some oil spill materials. We have studied these for some years -- their capacity to degrade many different types of toxic compounds, some of them petroleum derived -- and we have isolated organisms to study more intensively the degradation processes.

More recently, the study to look at sediments that have been impacted by petroleum spills has involved a sampling in three different sites: one in the Arthur Kill region, which is very heavily contaminated; also, on the lower Raritan River -- near Linden, actually -- it's also a petroleum-impacted site; then a pristine area upriver, at the Duke Island Park, near Bound Brook. As I said, those are ongoing studies right now and are yielding some very interesting degradation results.

Okay. I'll just summarize briefly then what it is that we've been looking at. Contrasting aerobic and anaerobic microbial degradation processes: In aerobic, oxygen is used in respiration, and the product of the reduction of oxygen is water. In anaerobic degradation systems, oxygen is absent and is not used. The bacteria, though, or different groups of bacteria, can use other inorganic compounds in respiration. There is a characteristic among different sites for different ones of these processes.

Denitrification is the conversion of nitrate to nitrogen gas, and this is something that is easy to study -- a process that is often found in waterlogged soils and anaerobic aquifers. Another process that has recently become very interesting is the use of oxidized iron to become reduced to ferrous iron.

Sulfate reducing bacteria have been studied for a long time. They're particularly important in marine sediments, but they're present in all anaerobic environments. We've been particularly looking at sulfate reducing bacteria in the Arthur Kill sediments and the ones in the lower Raritan. Then the last process is the use of carbon dioxide as a respiratory acceptor and the formation of methane gas.

Okay, I thought I would just briefly summarize the compounds of interest that we've looked at in our group: Naturally occurring toxic compounds released by various biological processes -- or natural processes -- for instance, during growth and metabolism, during the decay of biomass, biological degradation from natural oil seeps, and other occurrences of that sort.

Then, also, man-made or man-dispersed toxic compounds, including pesticides and fertilizers: These often include the chlorinated aromatic compounds, phenolic compounds, petrochemical hydrocarbons -- which have been mentioned already by Gerben -- including benzene, toluene, xylenes. Those are all ring compounds, and then there are straight chain alkanes. We have also done quite a bit of work, in years past, on polychlorinated biphenals, the PCBs.

We all know that to get the beautiful produce products pesticides and fertilizers are applied, and these are petrochemical intense processes for that reason.

Okay. In a little more detail then, the things that we have studied are derived from pesticide residues or PCB residues and include chlorobenzene, benzoates; wood preservatives include toxic compounds that are chlorphenols. Industrial wastes give rise to many products, including phenols, gasoline and petroleum, to the benzene, toluene, and the zyulenes, and industrial discharges of various kinds -- many pollutants including PCBs.

So these are the research interests of Lily Young and her group: To look at the anaerobic fate of environmental contaminants; to isolate and characterize novel anaerobic strains that perform important, or typical, degradation processes; to look at the elucidation of anaerobic biodegradative pathways, which is ongoing, but not included in any of the particular projects I spoke to you about earlier; and then recently, as part of an ARPA project, to collaborate with others on the treatment of contaminated soils by using microbial, anaerobic techniques.

Thank you.

DR. DAY: Anne, thank you very much for that account of the work.

Are there any questions?

Yes?

MR. McDONALD (Senate Majority staff): Once you've studied and identified certain strains of bacteria and confirmed that they do exist on some of the toxic substances, what happens then? What is the next step? What happens with the product of your research? If you've identified something that consumes and breaks down PCBs, what would be the next--

DR. FRAZER: Well, that example is particularly difficult. Usually, it's not a single organism that will break down PCBs, so we have focused, particularly -- and many others -- on the dechlorination activities. So I guess I would say the work of pure strains is mostly to better understand what occurs in the environment. In some cases, you can try to influence a process by adding organisms back, but it's probably more successful to try and enhance the activity inside two organisms to do the process. Usually, they're very complicated processes, so one organism couldn't do the job in the environment.

DR. DAY: Are there any other questions?

If not, thank you very much, Anne.

I'd now like to call on our colleague, David Kosson, a professor in the Chemical and Biochemical Engineering Department on the Busch Campus. David is going to talk about engineering scale-up and field application of bioremediation.

D A V I D S. K O S S O N, Ph.D.: (shows slides) Thank you, Peter, and good morning. What I'd like to talk about this morning is: How do we go from the organism, to the process, and actually out into the field, to carrying out a remediation program? I am in the Department of Chemical and Biochemical Engineering. Along with myself, we have five other faculty members who are actively involved in this area, as well as on the order of about 20 doctoral students, and five postdoctoral fellows.

Clearly, development of a bioremediation process is an interdisciplinary effort. There are various components that come from the various departments and activities on campus, and they all need to be tied together, ultimately, into a process to accomplish what we hope to achieve out in the field; that being, cleaning up a contaminated site that is terrestrial or marine sediments that have been dredged, or naturally in situ. What's clear, is that it's not only the contaminants that are necessary to understand the behavior of them and the bacteria as well -- we heard somewhat about the biochemistry and the microbiology this morning, as well as some of the marine macroforna that exist -- but also the risk assessment. What are our goals for remediation? What is the geology and the hydrogeology, and how do the contaminants behave in the system? All that has got to be tied together with the regulatory requirements and what the government agencies expect, as well as what the industrial capabilities and needs are at the particular site.

There are many components of a bioremediation application and how to develop it. The first, and one of the very important ones, is a risk assessment and site characterization -- what are the problems driving the need for remediation? Then, secondly, the characterization has to be fairly detailed.

This morning we heard the issue addressed that we know somewhat about the contaminant distribution in the marine sediments; however, that is necessary because that's driving your risk assessment. But that's not the only information you need. You need a lot of information regarding the chemical and physical nature of those sediments, as well as the natural environment that they are in or the modified environment that we may dredge and place them in, such as in a containment island. Normally, when we do site characterization at the first pass, it's only the contaminants, but that is insufficient information for developing a process and implementing it. There is a host of other information that is necessary.

Secondly, we need to know something about contaminant release and leaching behavior. That's important because of its potential for impacting groundwater or marine biota out at the site, but it's also important because that can control your rate of bioremediation and, ultimately, your bioavailability. To what extent can that organism remove that contaminant and degrade it? What will be the residual concentration, how long do we have to wait and, ultimately, how much will it cost us to carry out that process?

Mass transfer and thermodynamics are important because we have to get our organisms to the contaminants, or our contaminants to the organisms, on a timely basis. We have to understand how the hydraulics, the contaminant defusion, and the organism transport and survival behave out in the field. We have to understand the biodegradation pathways -- Gerben spoke some about that earlier this morning -- the biodegradation rates, and the bioavailability.

What can we realistically achieve? I want to emphasize that the organism is an important component, but it is also one of many components to having a fieldable, commercial process.

You want to model your contaminant behavior so you have a predictive design basis so you can predict how it will behave, so you don't get two years into a program and say, "I thought I would be done by now, but I still have another five years to go, and my cost estimates have escalated by ten-fold or more."

Finally, you want to go through process design and implementation. That usually involves, first, demonstration of the process at the laboratory bench scale; following that, a pilot demonstration out in the field; and then subsequently, scale-up to full remediation of the contaminated site or materials of interest.

You've heard several references to the ARPA -- which is the Advance Research Projects Agency -- and the Office of Naval Research, University Research Initiative, here at Rutgers. That is a five-year, interdisciplinary research program. It's funded at the level of slightly more than $5 million. Myself and Professor Lily Young serve as the Directors of that, and that has truly been an interdisciplinary effort, involving faculty from eight different areas and approximately ten faculty across the University, bringing together an appropriate team to meet the research objectives and, ultimately, being able to field processes.

This is particularly focused on development of bioremediation processes for removal of aromatic contaminant mixtures from soils and marine sediments, transferability from soils -- terrestrial environments to marine environments. How do we get from the nice, pure component where we found the organism that can degrade, to the real mixtures and contaminated materials that we have in the field, both mixtures of contaminants, as well as mixtures of biota, that being our macroforna and our microbial populations out in the field?

So what we're looking at is investigation of key individual processes. You heard some about that this morning. Other ones that you have not heard about yet are the transport and survival of organisms, and the behavior of the contaminants -- how they are transported, how you determine defusion rates, and, ultimately, what is your process design, and how quick and how costly will it be? That all gets tied together in overall process development.

We've been involved with a number of field development projects over, I guess, close to a decade now. Overall, we've worked with over a dozen field industrial sites and these two are two examples of projects that are in the field demonstration phase currently, as we speak. The first is an in situ bioremediation of a toluene contaminated site, using denitrifying bacteria.

Dr. Anne Fraser spoke a little bit about that work earlier when she was talking about particular groundwater remediation. This is dealing with remediating the contaminated soils and the overburden, as well as the contaminated groundwater at an actual industrial site. This is technology that is being developed and demonstrated out there -- not only can you actually remove the contamination, but can you control it so your drinking water standards are achieved at all times. Also, can you meet the regulatory objectives and can you accurately predict costs and time frames for that process?

A second one - a field pilot -- that we have ongoing right now, which is in conjunction with the Hazardous Substances Management Research Center, faculty from NJIT, and is sponsored under the United States Environmental Protection Agency's emerging technology program is: coupled pneumatic fracturing with in-situ bioremediation of, actually, a refinery contaminated site. Both these sites have mixtures, even though we're flagging the key contaminants there. This was actually at a gasoline blending site, not in New Jersey.

But coupling-- How do we remediate tight clays? Usually, you cannot get flow, but we have continuing leaching and groundwater contamination from that. In this particular process, we're coupling a technology developed by faculty up at NJIT -- pneumatic fracturing, which can open up the formation -- with biotechnology developed here at Rutgers that is using sequential electron acceptors -- or different types of bacterial processes -- in situ and how to control them so we can get both aerobic and anaerobic biodegradation at the actual fracture interfaces.

Finally, what I just wanted to comment on is, when we look at the scale-up of a remediation process, we have numerous stages that we go through. The first are the lab studies and site assessment. Clearly, I have to emphasize that it is more than just knowing what contaminants are there. They are spatially varied from location to location. They vary in time, as to what the actual conditions are, and how reducing, oxidizing, or the pH may be out at the site. You then go through a series of process designs and then into field implementation.

This is actually a picture from one of those ongoing pilot studies, right now, that we took late last week, where you can see the drums, and one of the students out in the field taking groundwater and vapor samples to assess the extent of remediation as it's ongoing.

Over the decade that we've been involved with this, we've been involved with numerous types of contaminant mixtures, in both aromatic contaminants and aromatic contaminants mixed with metal species. So however we can be of service to the State of New Jersey in the future, is most welcome.

Are there any questions? (feedback)

I've got to get rid of that feedback.

ASSEMBLYMAN STEVE CORODEMUS: (speaking off microphone) What is the scale of material -- volume of material -- that you're working with in either sediment or water out in the field?

DR. KOSSON: We've worked with some industrial sites that were up to 20 acres, or several hundred thousand cubic yards. We've done pilot scale demonstrations up to, I'd say, probably on the order of several hundred cubic yards. We've worked with sludge lagoons. We've worked with landfills and with landfill leachates. We're working now with some laboratory work in marine sediments -- similar types of processes. So we've gone from very fundamental work on how you measure the contaminant migration and leaching, to the field implementation. At that point, it would be turned over to a commercial venture to do the full-scale implementation.

Other questions?

Yes, ma'am?

MS. DiLORENZO (Assembly Majority staff): (speaking off microphone) Do you have any data yet from those pilot studies on the rate of breakdown?

DR. KOSSON: On the one that was a coupled pneumatic fracturing and biodegradation, we're in the process of completing the evaluation. We just did our final sampling after operating for eight months out in the field. We'll have that data available in publication form, I guess, in a month or two. The other site that we're working on right now is the groundwater and soil site that-- We've been in operation now for six weeks, and that's scheduled for completion this fall. On other sites, we have other information that we can certainly provide you with, if you would like.

MR. COVELLO (Assembly Minority staff): (speaking off microphone) What has been the extent of what you've been able to do on closed landfills for leaching and (indiscernible)?

DR. KOSSON: For leaching contamination what we've been looking at is, we've worked with a number of different types of leachates, some of which were primarily municipal mixed with industrial waste, which might be something similar to hazardous waste landfills. We've also dealt with strictly industrial landfill leachates, where you had a manufacturing company that took everything that was happening over decades, it went into the lagoon, and it leached out. We've been able to have very good success with a mixture of contaminants, being able to design a process that can sequentially deal with the different contaminants that are present and bring down, depending on the type of contamination, well in excess of 90 percent removal.

MR. COVELLO: Has EPA allowed you to do any studies or designs on Superfund sites, (indiscernible) on Superfund sites?

DR. KOSSON: Yes, they have. Actually, some of our studies have been on Superfund sites, some have been on CERCLA type sites. Some of them were on sites before they became Superfund sites and are now Superfund sites.

Okay, thank you.

DR. DAY: Thank you very much, David.

I'm going to introduce a change in the program. As you've all detected, we're running rather late, so we're going to cancel the laboratory visit. Some of my colleagues say one laboratory is just like another. (laughter) We're sorry you're going to miss these. Some of you who may be particularly interested, we could try to accommodate after the program. I would like to fit in two other speakers. The first of these I would like to call on now, that is, Steve Corodemus, who is Chairman of the Governor's Dredge Management Board (sic). He'd like to say a few words.

ASSEMBLYMAN CORODEMUS: Thank you, Peter.

I'd like to thank Senator Singer for the opportunity to be here to address this group and also to listen to the testimony from the various speakers.

As Peter said, I am the Chairman of the Governor's Dredge Material Management Team, and it's our short-term goal to find some resolution to the problem that is faced in the Newark area -- the New York/New Jersey Port Authority area. We, of course, are dealing with hundreds of thousands, if not millions, of cubic yards of contaminated dredge materials, and what you're talking about today is very important to me.

At the meeting of the Dredge Materials Management Team, I learned from one of the Team members, Dr. Angela Cristini, from Ramapo, thát the blue-claw crabs' -- from the Newark Bay -- bioaccumulation dioxin levels exceed what is considered safe for human consumption. There was a harbor estuary map up here just a second ago, and if you saw the Newark Bay area, right at the tip of the Kill Van Kull area is where her test site was. That's where the blue crabs were studied.

The bioaccumulation in these crabs is directly attributable to the dioxin levels in the sediments of the Newark Bay. I'd like to tangentially note that these crabs are being harvested by people; although there are signs warning them not to do that, they are there, and they are taking the crabs. They say they're not eating them, but they are. It's a real bad situation there.

These sediments are periodically dredged for navigational purposes and disposed of at the ocean -- the mud dump site, located six miles off of my legislative district in Sandy Hook. It's my hope that this Center for Agricultural Molecular Biology will provide the research capabilities needed to develop methods for removing contaminants, particularly the dioxins, from the dredge materials. It's very apparent to me, being sandwiched in an industrial corridor between New York, New Jersey, and Pennsylvania, with 127 miles of coastline and navigable rivers, that the equation spells trouble.

In addition, I've received many letters and phone calls from individuals and companies who are developing new technologies to remove contaminants from dredge materials, but have no independent scientific evaluation for their technologies. I think that the AgBiotech Center, in cooperation with other departments here at Rutgers, could provide the necessary evaluation of these technologies and provide the information necessary to the Dredge Materials Team. There are some very credible people out there with some very innovative ideas, and there are a lot of people out there with snake oil that they are trying to sell us. So I'm hoping that this Center here will be able to filter between those, so we can make some progress.

I am cosponsoring legislation -- Assembly Bill No. 1637 -- which is the companion bill to Senator Singer's. It's critically important that this legislation be enacted so that New Jersey will be in the forefront of this biotechnology. The financial assistance programs will enable this University and private industry to collaborate on important research that will bring economic opportunities for thousands of New Jersey residents. It will also foster environmental remediation research that New Jersey truly needs.

There is a real exigency in the work that I am doing, because the location of the dredge materials and their toxicity will have a direct impact on the viability of the Port. The Port provides thousands of jobs, and is a transportation hub for all of New Jersey and the greater northeastern area. It's a very delicate balance. We're trying to keep the environment clean and jobs in place. That's why I'm looking forward with great anticipation to the success of this program -- the legislation.

I'd like to commend Senator Singer for his foresight in impaneling this team and my colleagues and team members for working so hard on this.

If there are any questions, I'd be glad to answer them. If not, thank you very much.

DR. DAY: Steve, thank you for that interesting challenge. I think we could manage the bioremediation of snake oil quite effectively, and I look forward to hearing more about those problems in the near future. (laughter)

I'd now like to call on Dr. Mike DeLuca, who is the Associate Director of the Institute for Marine and Coastal Sciences (sic). Mike has been intimately involved in several meetings dealing with these issues that have been designed specifically to try to formulate some policies. Now, he very kindly agreed to summarize the present state of affairs, on very short notice, I might say.

MICHAEL P. DeLUCA: Thanks, Peter.

About 10 minutes ago, I was involved in a meeting similar to this, talking about shore protection -- another contentious issue for New Jersey. What I'd like to do is just summarize very briefly some of the data gathering that the Institute of Marine and Coastal Sciences and other groups here at Rutgers -- including the AgBiotech Center and some other academic institutions, including SUNY Stony Brook -- have been doing for about two years now, to try and take some steps forward with respect to issues related to dredging. Then I'd like to take a moment or two to describe the dredge management forum, which has been taking place for about a year.

About two years ago, we conducted the first in a series of international conferences on remediation technology. The first meeting focused entirely on bioremediation and, in fact, there was some strong participation from the AgBiotech Center at that meeting. We had experts from all over the country, in fact, from all over the world, attend this meeting: from Canada, Europe, and in particular, the Netherlands, where there is a lot of innovative work taking place.

We took stock in what was going on around the world and how it might be applied to the New York/New Jersey harbor situation. We learned that, certainly, bioremediation is not a panacea. It's not the magic bullet, so to speak, that's going to resolve the issues related to dredging. However, there are some innovative techniques out there that can be used to clean up specific contaminants. Most of them are designed to a specific contaminant. There is no one process that is designed to clean up a range of contaminants, organics, heavy metals, and the dioxin that has been in the news quite a bit. So we have that summarized in a report here. I have a copy that I can leave here.

We had some of, I think, the best talent in the world looking at this issue for us. We also identified a few other things that have to be done in addition to remediation technology if we're ever to get a handle on managing dredge material in the harbor.

First and foremost is a survey of the sediments in the harbor; we're lacking that. We need that road map to tell us where the hot spots are, where the sources of contaminants are, and where the sinks of these contaminants are. Without that, we're not going to be able to effectively manage dredging activities in the harbor. We've conducted two conferences since that first one on bioremediation, and in each conference that was the number one gap that needs to be filled if we're ever to get a handle on this.

The other, I guess, major point that came out of these conferences-- The other two focused on remediation as well, but physical and chemical remediation technology. The other major point that came out of these conferences is that there is no one solution. We have to really pursue a range of strategies, again, if we're going to be able to effectively deal with this. That includes dredging technology, as well as disposal options.

We're using technology to dredge this material that has been in place for 50, 60, 70, 80 years now. There have been a lot of developments that have taken place within that period of time that can reduce the dispersal of contaminants associated with the dredging activity and with reinplacement on the sea floor, say at the mud dump site or in subaqueous borrow pits or, ultimately, some upland disposal or containment islands.

There is a lot of innovative technology that we just took a fresh look at back in June, again, assembling a variety of scientists, engineers, policy makers, and environmental groups from around the world focusing on dredging technology. In fact, there is a lot of technology out there that will help to conduct this survey of the sources and sinks of this material much more efficiently. We can actually use some of these acoustic survey techniques to distinguish lenses of contaminants within this system, and it's very valuable information that can be used to manage this much better.

We have each of these conferences summarized; the reports are available. I have many copies back at the Institute, if you care to stop by before you leave, and we can provide you with that information. The last conference has not been summarized yet; it was just in June of this year. That summary, at least on a draft basis, should be available very shortly.

The other, in which I'm a participant, is with this Dredge Management Forum, which was created about a year ago by the EPA and the Corps to focus a lot of the various groups who are involved in this discussion on related dredge issues. There are six subgroups. I have to refer to this document, because I can't keep them all straight. I just participate in one.

There is one on containment facilities that deals with subaqueous borrow pits, trying to identify upland disposal areas, and looking at containment islands as a disposal alternative. Containment islands, by the way, are used rather successfully by a number of other ports throughout the U.S. and throughout the world and are something that we really need to look at as one of the long-term strategies for dealing with contaminated dredge material.

A lot of people point to the Baltimore Harbor situation as one illustration of the success of how containment islands can be used to store and manage large quantities of dredge material. Unfortunately, in Baltimore they did use it to store what is considered Category 1, -- Class 1, or clean -- dredge material, and they filled up their containment island rather quickly. Now they're in the process of setting another one. It takes about 10 years to site one of those facilities, so it is very important that we do communicate and use the best information available when we're looking at these issues.

The second subgroup is dealing with the siting of decontamination facilities, and that group is looking at identifying sites for potential pilot scale remediation facilities.

There is one that deals with the closure of the existing mud dump site. That has received a lot of press attention, most recently, with the introduction of a straw proposal by the EPA which seeks to extend the life of the mud dump. That will be the topic of discussion tomorrow at the next meeting of the Dredge Management Forum in New York.

There is also a new ocean disposal site work group, and that is seeking to site an area to receive Category 1 material -- clean ocean sediment.

Then, there is a group that I participate in-- Oops, I'm sorry, there is one more which is dealing with dredging transport and disposal alternatives. That is reviewing dredging technologies that are available now, or that might become available in the near future.

Then there is a decontamination technology work group. I've been participating in that group for about a year now. It's gotten off to a rather slow start, primarily due to some contracting difficulties. The money was provided by the-- Well, it came in a House Merchant Marine and Fisheries Committee, was passed to the EPA, it passed at the Corps, and now, it's being passed, once again, to a consortium of institutions led by Brookhaven National Lab.

There are several million dollars available to select the most promising remediation technologies -- biological, physical, and/or chemical -- that are at the bench scale now, but need to be tested out at a pilot scale. We've been struggling for about a year to come up with the selection criteria for identifying these most promising techniques. Most recently, we put together a request for proposals, which, I believe, is out on the streets now. We should be in a position to begin selecting projects in the next few months. It will take at least a year and a half to two years for this effort to run its course and for us to put together a treatment screen.

Again, we'll be looking at specific techniques that are geared to specific contaminants. That is the job of this work group -- this subcommittee -- to put together a treatment train, a train of technologies that could be used to effectively remediate a variety of contaminants that are found in the New York/New Jersey Harbor estuary. We will be using sediments from three areas: Newtown Creek, Newark Bay, and the Arthur Kill, in this project.

The pilot scale will be on the order of several hundred cubic yards, and, as with the current permitees -- who are stalled in their effort to receive permits for dredging -- we, too, must go through a permit process to site the remediation programs. We're looking for some suitable sites now. There had been, actually, some sites volunteered by people who would like us to use their sediments in the process. But we should know more in another month from now. We should be able to at least be in a position to begin reviewing some of these technologies.

I think I'll just stop right there, Peter. That's a very brief overview of the Dredge Management Forum and some of the conferences that have been sponsored through Rutgers and other institutions recently.

DR. DAY: Thank you very much, Mike.

Are there any questions of Mike.

Yes, Steve.

ASSEMBLYMAN CORODEMUS: (speaking from audience) Mike, could you give us a brief idea of the type of technologies that you'll be looking at in the next year or two, in your particular subcommittee?

MR. DeLUCA: The decontamination? I can't say at this point, because the request for proposals is out on the street, and I just don't know what's going to come in. I would think that some individuals, who think they have some promising techniques, might be concerned about revealing their technology, if, indeed, it's subject to some public scrutiny. There are some patent and royalty concerns that some groups may have. We're still wrestling with that public versus private ownership of the technology.

DR. DAY: Yes, Rod.

W. R O D S H A R P, Ph.D.: (speaking from audience) Mike, don't you think this kind of goes hand in hand with one thing that has been discussed here in New Jersey, the possibility of having incubator, Group 1, or high tech companies-- After all, here in New Jersey, we are positioned to become the model for the whole nation on the environment. It would be really wonderful-- I know Senator Singer has been working on this, and a number of others, to really make this happen. There is this J&J facility on Route 1, which would allow inventors to court the venture capital people and get up and running. What is happening here is, we're losing this technology in the State of New Jersey. We can clearly continue leading and become the crown jewel in the environment. We're talking about a $600 billion industry that will be in place by the year 2000, and we can be the home for the blue chip companies in this industry. The science is here, but we need a place to encourage these new companies that can capture this technology and make it happen here in New Jersey.

MR. DeLUCA: Yes, I agree. I think New Jersey is a microcosm, in many respects, in several disciplinary areas. Certainly, with respect to dredging, where we're facing problems now that will be faced by other port communities around the United States in the very near future, there is a lot of novel technology out there. I mentioned just a couple related to mitigating dispersal of contaminants and acoustic methods to survey contaminants in situ. There is a lot of technology out there, and, I think, with a little bit of stimulus, could provide us with some answers.

Again, there is no one answer, but there is a range of things that we need to do over the next 10 or 15 years to manage dredging. Certainly, the Institute is on record as saying that there is no ideal solution presently but to continue using the mud dump site. I don't think it needs to be used for a long period of time, but while we're continuing to use it, we have to begin developing some of these other alternatives, such as the use of subaqueous borrow pits, which might be on the order of two to three years to get in place. Remediation technology might be further along than that, in terms of developing an effective treatment train to deal with a range of contaminants. Then, of course, there has to be some long-term solution that can deal with the best quantity of contaminated sediments that we have. I think containment islands merit some discussion there.

DR. DAY: Laura.

L A U R A R. M E A G H E R, Ph.D.: Just following up on the incubation idea-- In addition to physical incubators for the small companies that are starting new technologies, you may have been talking to some companies that really feel the need for almost a regulatory incubator -- some way by which they can try out and demonstrate their new technologies in a little bit larger scale than research, but still not pretending to officially take on a job to clean something up.

MR. DeLUCA: Yes, that's important. I mentioned earlier that one of the difficulties that we face in scaling up some of these remediation technologies is finding a site to do it. We need to go through a permit process for that, as well. If we could have a "skunk works," so to speak, that is already sited and permitted and bring in, or focus, all this technology at that site using sediments from the harbor estuary -- not from some place else, but sediments that contain the full range or full suite of contaminants that we're dealing with -- I think that would be a major leg up for entrepreneurs, because that's more than half the battle, just siting and meeting permit requirements.

SENATOR SINGER: Just one question: You mentioned about the mapping. Is that going on right now?

MR. DeLUCA: No. We have several proposals that have been on the table for a couple of years now. We've tried to shop them around to various agencies. It's ready to go; we don't benefit from this at all. It's a USGS proposal to use side scan sonar technology and some cores to groundtruth the sonar images, to find out exactly what the extent and concentration of these contaminants are through the system.

SENATOR SINGER: What is the estimated cost of this study? Do you know?

MR. DeLUCA: I believe it's about $700,000 over two years. It's only stretched over two years because we felt it was more advantageous to seek a smaller amount on a per year basis. But we just learned in June that there are some new techniques now -- new acoustic techniques -- that might reduce that figure.

SENATOR SINGER: So you need the funding sources, also?

MR. DeLUCA: We need a funding source, right. The proposal is ready to go, and I think everyone knows the traditional -- well, not traditional, but the best way to do it is using side scan, perhaps complemented by some of these newer acoustic approaches. There has to be some sort of, I guess, leadership, some decision-making authority to say, "Go with it." I guess I'm impressed most by the amorphous nature of this discussion that has been taking place for years. It just continues on and on and on, and they just don't seem to be making any progress. I think there has to be some entity charged with that. I have a few ideas on that, but maybe that's another time.

DR. DAY: Thank you very much, Mike.

Let me say that in the interest of time, I'm not proposing to call a break, but there is some human engineering, I know, involved in that. There are a couple of rest rooms just outside those two doors. Please take a break if you feel the need.

We have four more presentations. What I also propose is that we'll feel more of mind, after the fourth presentation, before we go out to see some experiments in progress in the greenhouse. I don't want to cancel that, because it also gives us an opportunity to place some lunch out on the table. So, bear with us, four more short presentations, the greenhouse trip, and then something to eat.

The next speaker is Professor Richard Bartha from our Biochemistry and Microbiology Department. Richard's topic is the bioremediation of xenobiotic pollutants in soil and air.

R I C H A R D B A R T H A, Ph.D.: Excuse me, this microphone doesn't work.

DR. DAY: It does, I've got a new battery for it.

Can you use that?

DR. BARTHA: Thank you.

I came to Rutgers almost exactly 30 years ago, and since, the focus of my research has been biodegradation bioremediation. It would certainly be a long and boring list to recount what we did in this field. I would just like to cite two little highlights which show that we made some impact on the field.

The standard techniques for biodegradation measurement in soil in the EPA, the FDA, and also European economic community procedures-- The biometer flask was developed in our laboratory by me and my former boss, Dr. Pramer. Another little tidbit is that the so-called olephilic fertilizer prototype -- which has been used in the form of Inipol to clean up the Exxon Valdez spill -- was also developed in our laboratory by a graduate student, Ronald Atles.

I want to show you not a lot of technical detail, but just two brief examples of the type of work we are doing. We are basically taking an ecological approach by looking at natural system soil sediments, sea water, etc., mixing pollutants in them, and trying to identify the environmental factors which are limiting the biodegradation. Once we have identified these factors, we try to do something about them. This is our bioremediation effort. Hydrocarbons take care-- Liquid hydrocarbons take care of over 40 percent of U.S. energy needs, and currently this amounts to something like 3.5 billion metric tons per annum -- per year -- of use. This huge volume makes it inevitable that some spills and losses take place during storage and transportation.

If you could dim the lights a little bit? (shows slides)

Oil-polluted soil looks kind of nasty. It is also, of course, poisonous to plants, animals, etc.

UNIDENTIFIED MEMBER OF AUDIENCE: Do you want me to borrow that? (referring to control for slide projector)

DR. BARTHA: Yes, please. There are too many buttons. (laughter)

We have done research on bioremediation of oil-polluted soil on several scales, initially in the laboratory and small systems like this.

Next slide, please.

Later, in so-called lysimeters, which are about one-cubic-yard containments of soil, which we intentionally contaminated with various field products and then applied various bioremediation measures.

This is the structure of such a lysimeter. It's a concrete cube in which we have contaminated soils, some drainage layer, and a drainage spout.

Next slide, please.

Finally, we have come back to the pilot-scale, field bioremediation of oil-polluted soil, as illustrated here.

Next slide, please.

Here you see some data on bioremediation of diesel oil. The upper curve is biodegradation of untreated soil contaminated with about 5 percent of diesel oil. This work was done in intermediate lysimeter scale experiments. When we apply bioremediation, which consists of applying fertilizer, liming the soil to control pH, and turning the soil for mixing and aeration, this is referred to as land treatment or land farming. It's a very simple practice. It essentially takes care of the oxygen needs, fertilizer needs, and mineral nutrient needs of the organisms. Just by manipulating these two factors, as you see, we can considerably speed up the process.

Whenever we conduct bioremediation work, we often run into the questions: Are you sure that this and this pollutant were biodegraded? But how do you know that everything harmful was taken care of? Therefore, to answer these questions we like to couple our measurements with state-of-the-art chemical and instrumental techniques. We like to couple these also with some toxicity measurements.

One toxicity measurement, which we can easily do in the laboratory and which is quite accepted by the regulatory community, is a sort of microtox test. It uses light-emitting bacterium. To make the story as simple as I can put it, you add pollutants in various concentrations to this bacterium, and the toxicity is expressed in a reduction of light emission by this bacterium. Now, if we apply these techniques together with -- to monitor the bioremediation, what you see in the untreated soil is the toxicity is remaining pretty steady. The so-called EC_{50} is a microtox measurement process which works the same way as the lethal dose 50, so the low curve shows high toxicity, and the high curve shows low toxicity. This is a little bit confusing. Anyway, in the untreated soil, toxicity persists to the end of the experiment. In the treated soil, there is a brief, little peak of toxicity and, eventually, the toxicity returns to the level of the uncontaminated soil, which is indicated here.

This is showing more common bioassay. There are two flats here, which four weeks prior were contaminated with jet fuel. Bioremediation has been applied to this soil, not to this soil (indicating on slide) and four weeks later they have been planted with soybean seedlings. As you see, these are very stunted from the toxicity of the residual oil, while here the seedlings grow normally. Okay, that was my example about soil bioremediation.

The next one about air seems to be a big jump from soil, but actually there is a connection. With the tightening of the environmental regulations -- the 1990 additions to the Clean Air Act -- we have to be increasingly careful during bioremediation not to release volatile compounds into the air. Other contamination sources for the air are, of course, various industries, which manage solvents and other volatile compounds.

We have done, during the last four years, extensive research on using biofiltration and bioscrubbing, to remove volatile, organic compounds from air. Here is a diagram of such a devise, which we use. The heart of the system is this porous column on which we immobilize selected microorganisms. This column is kept wet, and is actually being leached continuously by a cycle of water, which is pumped through a pH control unit. The pH control is particularly important if we work with chlorinated solvents, such as chlorobenzene, dichlorobenzene, because during the degradation they release hydrochloric acid, which very quickly poisons the column unless we have such a neutralization and washing system.

Now, through this column we pump air, which, because it is an experimental set-up, we artificially contaminate with a solvent. We purify by bubbling the air through a solvent trap. The other air stream goes through water and partially moisturizes this air stream. The air streams are combined, and we measure the solvent concentration at this stage by gas chromatography. We have flow meters; we know the flow of air in terms of cubic meter per hour. The air passes through the column, the bacteria degrades the organic contaminant, and we verify this by, again, sampling the air stream at the exit. We can also make on-column measurements to measure the activity in various parts of the column.

Next slide, please.

This is just -- not a diagram, but a live scrubbing column and shows a relatively small laboratory to keep it in scale.

Next slide, please.

Here are some actual data: Removal of a chlorobenzene from air, and if the removal is effective, then we remove 100 percent of the chlorobenzene. This occurs, as you see, in our column which is biologically active and inoculated with the appropriate organisms. In a column which is an abiotic control -- which is not inoculated with the appropriate organisms -- there is a very brief, initial removal by physical absorption, but very quickly the removal becomes zero. We pump out as much contaminant as we pumped in.

Here is an intermediate situation where we have a biologically-active column, but with no pH control. As you see, initially, removal is good, but very quickly the column gets poisoned by hydrochloric acid and becomes inactive. We can design such biofiltration systems for a variety of volatile pollutants.

There is a connection of my presentation to -- this is marine dredge spoils. Obviously, once a dredge spoil is on land, it can be worked with techniques very similar to land farming, as we do for soil. If there is concern about volatile pollutants, again, we can do this land treatment in containments from where the air can be exhausted through biofilters and, in this way, purified.

Thank you.

DR. DAY: Thank you very much, Richard.

Are there questions?

Yes, please.

S T E V E N   L U D M E R E R: (speaking from audience) What kind of pressure drop do you see across the biofilter?

DR. BARTHA: Relatively little, about one to two millimeters of mercury per meter.

MR. LUDMERER: Could it be used then inside a building, in an indoor environment?

DR. BARTHA: Yes. You mean to exhaust the air from a building?

MR. LUDMERER: To clean the air within a building, with an (indiscernible) factor.

DR. BARTHA: Yes, yes, it could be done.

DR. DAY: Other questions? (no response)

Thank you very much, Richard.

It's my pleasure to introduce the next speaker, Professor Peter Strom, who is a very close neighbor. He works on the floor below us, in the Department of Environmental Science. Peter is going to talk about rational applications of biological treatment and biotechnology to bioremediation.

P E T E R   F.   S T R O M, Ph.D.: Thank you. (shows slides)

I'm going to talk briefly about some classical biological treatment to put bioremediation, which is a relatively new application, into a context. Although bioremediation itself to soils and, particularly, to sediments is a relatively new idea, biological treatment in general has been widely used for a long period of time.

Virtually all domestic waste waters and most organic industrial waste waters have been treated biologically for many years, using processes like activated sludge, invented in the early 1900s; trickling filters, invented in the 1890s; and RBCs, or rotated biological contact, is a new process developed in the '60s. Liquid organic sludges for many years have been treated either through anarobic digestion, or beginning especially in the '70s, through aerobic digestion. Solid phase, or dewatered organic sludges and solid waste, of course, for many years have been composted more or less effectively depending on the situation.

Just as another historical note, our Department of Environmental Sciences was actually created by the Legislature in 1920. We believe it was the first environmental science department in the world and was created in response to the biological treatment needs of the State. So this is not, by any means, a new technology, although the particular application is new. I was not here when it was created in 1920. (laughter)

SENATOR SINGER: Senator Ewing was though. He claims he signed the bill. (laughter)

DR. STROM: The basic principle involved in this biological treatment is a process known as acclimation. The idea has been used for many years. You would take a new waste that needed to be treated, go through an acclimation procedure, and develop a process that would then work. Without going into any real detail, there was, at one time, a ubiquity principle which is now, like many principles, not considered 100 percent true any more. But the idea was that just about all bacteria are found just about every place, so whenever you wanted to start a process, the bacteria you needed would be there.

You would go through an enrichment procedure, in which those bacteria that could grow on a particular waste would grow. They're basically using the waste or the contaminants as a food supply. There are strong selective pressures that are then involved and a natural evolution that occurs in these systems. There is genetic rearrangement or sort of a natural genetic engineering which occurs, involving plasma, some chromosomes, and the genes contained there.

These systems involve relatively rapid growth, so that over the course of several days, there are many generations of bacteria which occur and go through a very rapid evolutionary process, provided that you give the organisms adequate environmental conditions to work under. They don't have to be optimum, but they have to be adequate or acceptable conditions. The results of this process are that highly adapted populations and, actually, unique organisms develop in these systems and communities -- unique and highly adapted communities, also -- providing treatment that gets almost 100 percent of all chemicals and degrades them to very high levels, at 90 percent, usually 99 percent or more biodegradable compounds are degraded. Now, that's almost all organics.

As an example: You start up a new industrial waste treatment facility; after about a month, you're getting effective treatment in these systems. Okay? There is no particular start-up necessary. They just let the waste start flowing into the tank, and the treatment will naturally develop in about a month. It gets better over the course of the next several months, but it's already at the level where it can meet permit requirements in one month.

The applicability of this to bioremediation-- Many of these treatment processes can be used in other applications. For example, we could modify conventional treatment such as activated sludge and use it to treat contaminated waters as opposed to waste waters, but there are differences when we try to do this. It's not a quick one, and there is some need to modify these systems.

More relevant, perhaps, is with things like contaminated soil or sediments, the process that we use for solid waste or sludges could potentially be modified to treat contaminated soils or sediments, but there are differences. Sediment, even when it's highly contaminated, is not the same thing as sludge or municipal solid waste, and there will be some need to modify these processes.

There have also been some innovative methods developed, things like soil slurry reactors, which are still somewhat in the experimental stage. These may be very applicable to sediments. One of the problems with soil slurries is that you need to add the water to get the soil wet, and you then need to get the water out later, so you can dispose of or reuse the final material. With sediments, of course, the water is already there, so that requirement wouldn't be necessary. They may have to be dewatered anyway, so it's not an added step.

In summary, there are proven technologies, but they may need to be modified. There also may be newer, innovative technologies that are applicable to these materials. The need is to provide the proper conditions for the microorganisms and, especially, to do this cost-effectively. That's really what it comes down to. One of the parts of doing it cost-effectively is where you build a capacity -- a treatment capacity -- you want that capacity to be fully utilized. It's very expensive to build a facility that is only used for a few days, then sits idle for a longer period of time, and then it's, again, used for a few days. So one of the needs would be to match the supply of sediment to the capacity that is built. That may involve storage, or it may involve changes in the way dredging is done.

Now, one of the things that I used as a qualifier before was, "almost all organics," and, of course, there are some exceptions. We now get into a somewhat more experimental area. There are a number of organics that cannot be treated using this traditional approach. PCBs, for example, are not available to microorganisms as a food supply; therefore, we cannot use the acclimation and enrichment procedure which I mentioned.

Yet, there is the possibility that bioremediation might be used for these materials. There is a process called cometabolism, which was briefly mentioned earlier, in which the biodegradation of a compound occurs even though it's not used as a food source -- the organism grows on something else.

What's happening is that the enzymes involved make a mistake. The compound is similar enough to some compound that they can utilize that they mistakenly partially change that compound. They biotransform it in some way, but they get no benefit from that.

Without going into the actual examples there, just at the bottom (indicating on slide) we cannot enrich the cometabolism, and there is no benefit to the organism. In fact, cometabolism actually hurts the organism, because it's wasting its time doing something that's not useful to it, although it may be useful to us. Now, on the other hand, cometabolism is potentially an extremely valuable tool. It would be nice if we had some way of utilizing that for bioremediation.

There are amazing possibilities if this could be utilized. There are microorganisms, for example, that can transform metals. Metals, of course, are one of the hardest things to deal with because they're not biodegradable, but they can be transformed biologically to less toxic forms that could be solubilized or precipitated out microbially. So there are a lot of possibilities here. Some of these enzymes are known, and in some cases, the genes are actually already available.

The problem with this is that it probably will involve the need for some type of genetic engineering. The problem with genetically engineered microorganisms, up to now, has been that they will not survive in the environment. There is a lot of fear of GEMs getting out into the environment, spreading, and causing all kinds of problems. In a practical sense though, the problem with GEMs is that when you put them out into the environment they die; it's not that they live forever and take over.

Something that might be a little easier to interpret-- Imagine taking a handful of some terrific new wheat strain and throwing it out into the jungle in the

Brazilian Amazon. You don't really expect to be able to bake bread from that next month. But what would happen to the wheat seeds? Well, they get eaten. That's exactly what happens to GEMs when you throw them out into the environment. The microbial environment is also a jungle of sorts. There is really little hope of these laboratory-pampered organisms surviving in this situation, but there may be techniques to overcome that.

This is something that is on the research level at this point. There is, in fact, a patent pending for this, and there have been several publications showing the potential for this. It's not something that we can apply to dredge spoils this month, certainly, but it may be something coming down the road in a couple of years.

The technique referred to is one that we've named, "field application vectors." The idea here is to create a place for the organism to grow in the environment. If you're going to plant wheat, you first clear the field, you add some nitrogen fertilizer, and you do those sorts of things. You give it a chance. That's actually what we're trying to do, create a niche for the genetically engineered organism.

These field application vectors involve combining a host bacteria with some special food that only that bacteria can use -- that other bacteria in the environment, for the most part, cannot use. Then, engineering the organism by putting some desirable trait, such as PCB degradation, into the organism. This work, by the way, was initially funded by the Commission on Science and Technology and also by the DEP.

The approach involves finding an organism -- we've been successful doing that -- inserting genes -- which we've been successful in doing also, with the help of Gerben Zylstra and also help from Envirogen in New Jersey -- then we add the engineered organism and the specialized food source. The food source we're using, actually, is a detergent, one that has USDA approval for application of pesticides, so it is one that is already considered acceptable to add to the environment in reasonable amounts. When we do that, we've been able to demonstrate growth.

The environment we're working with, of course, at this point, is a flask. I'm not talking about going out and spraying agricultural fields at this point. But within the environment of a flask, we've been able to show, I think for the first time, growth of genetically engineered microorganisms in a real soil. They're able to compete with the native organisms for a limited period of time, and we've been able to get PCB degradation, as one example. We're also working with an organism now that will give us TCE degradation -- trichlorethelene degradation. This may open up the possibility of using cometabolism as another method. It also may give us a possibility of bringing levels of contaminants down to lower levels than has been possible in the past.

That's it. Thank you.

DR. DAY: Thank you, Peter.

Are there questions? (no response)

Thank you very much for a very clear description of your work.

The next speaker is a colleague of mine, Dr. Ilya Raskin, of the AgBiotech Center, who is going to describe an interesting new technology in his paper entitled, "Phytoremediation and Rhizofiltration." Listen up, because you'll have practical examples of this when we visit the greenhouse in a minute.

I L Y A R A S K I N, Ph.D.: Thank you very much, Peter. My name is Ilya Raskin. What I will do today is talk about a new technology which is being developed here at AgBiotech, something we're very excited about, and something which we really hope can solve some of the problems in existence in New Jersey. (shows slides)

What I will talk about is something called phytoremediation. This is a word we made up here, together with Laura Meagher, in 1990. What we believe it defines is really a novel use of plants, because we can focus this a little bit to many conventional uses of plants. I'm not saying this is for food -- for fiber, construction, chemicals, pharmaceuticals, landscaping, decoration, and restoration. What we've been really seeing in the last four years is a new area of plant uses being developed and that we call phytoremediation. Phyto is for plants; remediation, you all know what that is.

What I will talk about today is about phytoremediation of heavy metals. We define phytoremediation in a new class of environmental remediation. You know that heavy metals is a particularly important problem in New Jersey, and this is a problem which conventional microbial bioremediation has real difficulties in solving, because as you have already heard, microbes cannot degrade metals.

I'll briefly mention just three subsets of this technology on which we are working simultaneously. First is phytoextraction. This is for soils contaminated with heavy metals.

Phytoextraction: We define it as the use of metal-accumulating plants which can transport -- concentrate metals from the soil in the roots and in above ground shoots, things you can harvest.

Rhizofiltration is the use of plants to absorb concentrated, precipitate toxic metals from pollutants. Our first screens to be used for anything from groundwater to industrial effluents, and phytostimulization, which is a more temporary solution which, nevertheless, can be used for eliminating the bioviability of toxic metals in soils.

We have to compete with a lot of engineering approaches, because really, at this point, the only solution which is being utilized for remediation of contaminated sites with metals -- sites contaminated with metals -- is what is called removal and burial methods, where you take the soil, put it in the drums, and ship it to the states which will still accept it. That approach costs about $1 million per acre, if you assume 50-centimeter-deep contamination. This is very expensive, and we really cannot afford that.

Well, if you really look at the plant from an engineering point of view, the plant is a soil-driven concentrator, which took 360 million years to build. That's the time plants have been evolving to do just that, to concentrate elements from the environment -- test and optimize. So we already have this inherent ability of plants to concentrate elements from the environment.

What I will talk to you about is, we know about separate groups of plants which are grown in metal-rich, natural soils -- which are very rich in metals -- which are called hyperaccumulators. Our book collaborator, Dr. Alan Baker, from Sheffield, has been collecting those plants for a very, very long time. Those are plants mainly belonging to the family of mustards, or brassica, and they have an usually high ability to accumulate and concentrate metals from the environment.

So why do we want to use plants to accumulate, concentrate, and remove metals from the soil? There are really three simple reasons. It can be calculated that in the average field of rye, you have 300 million miles of roots per hectare. This is an enormous length. You can collect, conservatively, 15 tons of biomass per hectare, and it may cost you $1000 to do that. Just to put things in perspective, this is larger than the diameter of the earth's orbit, this number here, and this is very cheap to do. Engineers, as far as I know, cannot build anything of that sort today.

SENATOR EWING: What's a hectare? How big is a hectare?

DR. RASKIN: Two acres -- roughly two acres.

Just to give you an idea of the numbers we are looking at, this is a five-year, toxic metal cleanup cost, just for the U.S. There are lots of sites, and New Jersey, I guess, has an unfortunate fame of sharing a big number of all those sites. The total market for metals and organics for five-year cleanup is $34 billion -- just metals alone, $7 billion, and New Jersey has the lion's share of those sites.

DR. ABUCHOWSKI: That's the cost of cleanup or the value of the metals?

DR. RASKIN: No, that's the cost of cleanup.

DR. ABUCHOWSKI: Oh, okay.

DR. RASKIN: Very conservative, because a lot of those players here don't really want to accept the liability which is really, probably, theirs.

So just briefly, this is a schematic of what we call phytoextraction of metals in the soil. These are rhinonucleads, those particularly, which are brassica rhinonucleads. Our approach was to really look at the crop and crop-related relatives of those little mustards which I talked to you about, which grow natural in metal-contaminated soils and can concentrate those metals. But we looked at the crop-related species hoping that they retained some of those genes, some of those traits, which were inherited from their predecessors. We screened at least 50 different plant species, and we've identified Brassica juncea, or Indian mustard, as the best metal hyperaccumulator in the harvestable part. This plant is not grown in the United States. It is usually grown in India.

Then we went back to the actions of Indian mustard. We've identified one specific culture of our Indian mustard, which we were able, at least in the greenhouse and laboratory experiments, to concentrate lead up to 3.5 percent dry weight of the shoot and about 10 percent of its root weight. If you ash that, you come up with ash which has about 50 percent lead, and this is a much richer source of lead than lead ore, so the possibility of reclaiming is in there.

This is a slide taken in India during our trip there. The plant can be grown to about 18 to 20 tons per hectare, biomass. It's a very tall plant and can be easily grown in New Jersey.

The next concept is rhizofiltration. This is when we pass the solution of metal-contaminated water through the roots -- hydroponically grown roots of terrestrial plants. Again, we use Brassica juncea here, or sunflower. The roots can very efficiently absorb metal through water, really providing a very, very cheap biosorb, or biofilter, for removing those metals. We can do that in the lab.

This is a prototype of the rhizofiltration system as we see that. The polluted water comes here, filtered through the roots, then clean water is here as an effluent. We can do it with lead; we can do the chromate; we can do it with nickel; and we can do it with zinc. We have demonstrated that. We can take very highly polluted water and, literally, remove the metal using the roots of those selected plants below the detection.

SENATOR EWING: How long does it take?

DR. RASKIN: This is a very good question. Directly, it's a function of root mass, and it's a function of metal concentration. If we use enough roots there, we can really-- For example, if we start with 300 parts per million of lead, we can remove it to below .1 part per million in two or three hours, in that system.

This is a laboratory system we're using, a prototype. These are Brassica juncea roots. You put the solution here, it's a filter layer so you don't add any nutrients here, and they do remove it.

Next one, please.

SENATOR EWING: How long do the plants last?

DR. RASKIN: Well, again, it depends on how much metal is in there, but certainly, you can cultivate plants hydroponically for the whole life cycle. So, again, it would depend on the initial level -- how toxic that solution is. You don't really need to have a very healthy plant to do that, because you don't really care about the agronomy of this. All we care about is that the roots remove the metal.

Phytostabilization: From what I've said to you before, you know that roots can absorb metals, and actually then prevent -- by absorbing those metals -- the leaching of those metals into the groundwater after the rain, for example, which can really stabilize a lot of metals and reduce their bioviability -- reduce the human toxicity.

A lot of people ask what we're going to do with the plants when we harvest them -- that metal-rich plant residue. Basically, they would use it to try to reduce the biomass by composting, combusting, ashing, or just drying. Then either you can bury the highly-enriched plant residue containing metals, or -- what we're really hoping to do -- you can give it to someone, or even sell it to someone, to reclaim the metal. This is the only way really to prevent just taking metal and shipping it to the other side. This is, I hope, the only technology which eventually allows reclamation of some lands and reclaiming the metal from it.

I want to show you this is becoming a reality. Because we're very much interested in, certainly, the mechanism -- the scientific part of that -- but we want really to see the use of this technology. Here is what's happening this year in New Jersey. This is very close to Liberty State Park, a site heavily contaminated with chromate. Dr. Michael Blaylock, from Orlando and Dr. Slavik Dushenkov, with the help of the DEP; ICF Kieser (phonetic spelling), and PPG, are doing the field test.

Here is just another angle of Michael Blaylock transplanting the seedlings of our Brassica juncea. Those plants are now about waist high there.

This is another test site. There are two of them actually, in Trenton, urban gardening. People are trying to garden in Trenton. This is a very good program. People are getting involved. The community is getting involved. The problem is not only heavy metals, they also provide for us a very good test site. This is Trenton; this is our group setting up the field trials there. It's nothing interesting, sort of, marking an obligation.

This is one of the oldest houses in the East Brunswick area, circa 1845. Many, many layers of lead containing paint were on the surface of this house, scraped along the drip line, and the soil around the foundation really has very high levels of lead, but not with our Brassica juncea growing around the foundation.

Now, we move outside of New Jersey. Some of you may recognize this structure here. This is the Unit 4 of the Chernobyl nuclear reactor, in the sarcophagus here. This is Dr. Dushenkov from our laboratory. Unfortunately, five or six years ago, this enormous area was contaminated, which provides, certainly, an urgent need for soil remediation and a very good test site for us, because all the metals are labeled. We, in collaboration with scientists from Kiev, are involved in a field trial in Chernobyl.

May I have the next slide, please?

Those are our little Brassicas growing in the field about 15 kilometers from the reactor. This is Dr. Sorochensky from the Kiev Plant Biology Institute evaluating the field trials.

This is a layman view of our market for the future. (laughter)

DR. DAY: Thank you very much, Ilya.

Are there questions?

SENATOR EWING: Who developed the plant? Are there just certain types of plants, or did you develop it?

DR. RASKIN: Well, we selected them here. We looked at many different genotypes, and we selected one particular line of Brassica juncea, and now we're in the process of optimizing this through conventional methods and things like biochemistry and biotechnology, to further increase its ability to accumulate metals. We're also working together with several scientists to develop soil amendments which will make metal more available to the plant. It's a very interdisciplinary approach we're trying to build here.

MR. COVELLO: I actually have a question about what you've been doing in Liberty State Park. That's a fairly big-sized project, and you have other contaminants that I don't believe are metal-based. I know the major one is asbestos from the railroad facilities that used to be there. How long would it take to actually do something the size of that Park?

DR. RASKIN: As long as it takes to-- Planting-wise, it's not a problem. We have good economical practices to certainly plant the whole Midwest in corn and soybeans. I mean, we can certainly do the Liberty Park. However, if you really do the calculations based on the amount of metal in the plant, I told you 3.5 percent -- let's say we can do 1 percent. Let's say we can do three croppings a year, because we don't have to wait till seeds are set, we can harvest earlier. We can remove half a ton per season. That's a very optimistic assumption, certainly, based on the laboratory data. It may not be that easy in the field.

MR. COHEN: How deep do your roots typically grow?

DR. RASKIN: We assume about 50 centimeters deep. Again, this is something which is not going to solve all our problems. It will be applicable to a small market of large areas of low levels of contamination and possibly in conjunction with the other methods everybody here before me talked about, like bioremediation, if you have organics there. Although, I should mention that plant roots are probably the best means of delivering microorganisms to the soil.

MR McDONALD: Have you done any work with water hyacinths? I understand that--

DR. RASKIN: We have not done any work with water hyacinths; however, we've talked extensively with people who did work with water hyacinths, and I think we have a better system.

MR. McDONALD: Is there any potential for that technology being brought to clean up our water here?

DR. RASKIN: Yes, we certainly are hoping that, and we are now in the pilot phase. The problem with water hyacinths is your surface to volume ratio of the roots is very small. The plant is very small; it's almost impossible to dry. There are assorted other problems with that, and it's not as efficient.

MS. RUSSO: I just have one question. You mentioned the DEPE was working with you. Have you been having much success working with them and getting your field permits?

DR. RASKIN: Yes, I think we've had some success, but I think Laura Meagher, who has been really intimately involved in setting all this up, can address that much better. She really has been instrumental in putting this together.

SENATOR EWING: Do you think in Chernobyl, are they going to use this over there?

DR. RASKIN: We don't know. We're just in the first year, because we have to learn how to walk before we can run, and that is what is happening now. It's the first small step.

SENATOR EWING: But they're cooperating with you?

DR. RASKIN: Yes, very closely.

DR. DAY: Ilya, would you like to mention what you expect to show them in the greenhouse.

DR. RASKIN: Well, actually, this was put in there without me knowing that much, because we don't have that many things in the greenhouse right now. There is a little bit of things, because mostly people are involved with field trials right now, and they are actually in the field. I would be happy to take you over there, but it will take too much time.

SENATOR EWING: When you harvest them, how long do you wait for them to harvest?

DR. RASKIN: How long do we wait? We're still evaluating that.

SENATOR EWING: What?

DR. RASKIN: We're still evaluating how long you have to wait, but we assume a month or so.

SENATOR EWING: Because they can only absorb so much, and then it stops absorption?

DR. RASKIN: That's right.

DR. DAY: Thank you very much, Ilya.

The last talk of the morning is from Laura Meagher. Laura has been mentioned a number of times this morning. She has been an extremely valuable colleague of ours at AgBiotech. From the 1st of July, she moved from AgBiotech to join Rod Sharpe in Martin Hall, a move which widens her sphere of influence, and where I'm sure she is going to continue to look after our fortunes here at AgBiotech and help us. Laura is going to talk about technology transfer and strategic plans for bioremediation in New Jersey, a subject that's very close to her heart, because she has played such an important role in coordinating our biotech efforts in bioremediation at Rutgers, New Brunswick.

Laura.

DR. MEAGHER: Thank you. It's very good to see all of you here today, paying attention directly to bioremediation. I've worked in all the different sectors of biotechnology, but in some ways I think environmental biotechnology is one of the most exciting. That may be because it's young. Compared to, say, the pharmaceutical industry and biotechnology, which is exciting because it's getting more into the market, bioremediation is new as a science, it's new as a technology, and it's new as an industry. So it's growing right now and that's kind of exciting.

I think all of you know that we're facing a tremendous cleanup problem in this country. Whether it's dredging, whether it's Superfund sites, whatever it is, the costs are in hundreds and hundreds and hundreds of billions of dollars, and we just can't afford that. That's the reason that the EPA, the DOD, the DUE, and other major agencies are so proactively encouraging alternative technologies, innovative technologies like bioremediation. It's not because they like the nifty science; it's because we can't afford the cleanup bill unless we come up with some cost-effective alternatives. That's why there is so much interest in bioremediation, why it's a growing subsector, as are some of the other innovative technologies.

It isn't a panacea. It's not going to clean up everything, but it does have a lot of potential. Our challenge now is to explore where that potential is and how to address it. My bias is that the way you address -- really achieve -- the potential of a new technology is by the combined efforts of people from academia, industry, and government. I'll probably be mentioning that later, too.

The AgBiotech Center, the Institute of Marine and Coastal Sciences, and other units in the University, you've heard were really pushing forward the technical frontier of bioremediation. But we're also very committed to the technology transfer side of things, to developing an industry. We have a very deep commitment to that, and I'll be talking about that dimension.

I'll talk about several different levels. Individual technology transfer on the part of individual researchers; providing education to people in industry and government;

helping a start up company; what I call community building -- bringing together people from industry, university, and government in the State -- State-level policy recommendations and national-level policy activity, positioning New Jersey nationally. So I think all of these activities, if you add them up, can go a good way towards helping us to really facilitate this growing subsector of the economy here in New Jersey.

At the individual level, you've heard, many of our individual researchers conduct research that is funded by companies -- Envirogen, we have Paul Togna, a good colleague of ours here from Envirogen. We have one of our-- Pete Strom mentioned the innovative partnership from the commission that helps people work with Envirogen here at the University. We also have people that less formally, but very importantly, talk with their colleagues in industry. That kind of informal technology transfer is really critical, and I think our folks do a good job on that.

We also sometimes help companies simply through consulting. That's not directly funded research, but, for instance, Lily Young is working with a company that's doing cleanups here in New Jersey. That's important, that kind of consulting. On the center level, more than the individual level, the AgBiotech Center-- I think one of our proudest early moments of technology transfer was when we made it possible for Envirogen to rent laboratory space. Now, we were brand new and we had empty laboratory space. That is impossible for us to imagine now, because we're crowded beyond belief. But in the early days, we had empty space. We managed to persuade the University that the walls weren't going to come tumbling down if we allowed a company to share our space, and really the start of a lot of good collegial relationships began.

Ilya got interested in cleaning up metals with plants by talking with colleagues who were here with Envirogen. We benefitted, but the company benefitted. When they came they had a president, two vice presidents, and a research director. By having space here, they could hire scientists, they could start to conduct feasibility studies for potential clients, and they could, sort of, demonstrate to investors that they really, truly, were real; they existed, and they were worth investing in. They've thanked us publicly many times, but I think that's a creative kind of help to a company at a crucial stage in its development that we were really glad to give. I think that helps the State, because the company now has 100 employees. So we like to think we made a contribution there.

There is a natural avenue of technology transfer from the University, and that's education. In a study I did -- I'll mention later -- between '90 and '92, primarily from Rutgers, we put out 75 Ph.D.s in bioremediation-related areas, and about that many in masters and bachelor-level people. That's an important kind of technology transfer.

We're also involved in continuing professional education, so that when people in companies feel they have to start learning about this new technology, or people in government feel they have to know whether they can approve or not approve it, when it's useful, when it's not useful, they've got a foundation. That kind of education is an ongoing technology transfer.

I think that sort of outreach is related to the dimension I want to talk a little bit about, and that's building a bioremediation community in the State. Over and over in all different kinds of biotechnology, when I've been involved, it's when you really get people together -- they get to know each other long term; they start to share ideas; they talk about a problem they ran up against, and somebody else maybe has the solution -- that's when really good technology transfers happen. So we've taken it as our charge to develop that kind of community.

We've had a grant from DEP -- no longer DEPE, right -- Division of Science and Research, Bob Mueller is here, a colleague. We were able to hold a variety of seminars and to hold some regional workshops -- there are some reports from them. We did one on pollution prevention and biological approaches and, to my surprise, I got people from industry across the country to come as speakers -- people who had started using biological approaches to prevent pollution. Nobody had ever brought them together before. They were having a great time talking to each other. So we were able to provide some cutting edge information and analysis of trends here to our people in New Jersey and the region, and in the meantime, they were getting to know each other. We also did another workshop on bioscrubbing of gases -- Richard talked about some of that -- and biodegradation of plastics. So we keep trying to explore some of these newer areas.

Along with helping to build the industry in the State, I think we're really very interested in helping to put together policy that helps to build industry in this State. So I put together-- I think you have copies -- at least the Task Force does -- of an inventory we put together of the different players in bioremediation -- industry players, academic and government, probably so they could find each other, partly so we could see what we had, and we've got a lot of expertise. We really have a lot of expertise in this area in the State. The inventory is a way, really, of helping to put together the people who have the expertise with people who have problems.

While we did that -- this was, again, funded by the Division of Science and Research at DEP -- I conducted a survey of the people who responded, as to what the obstacles were for bioremediation, how the bioremediation industry could grow in this State. I think I'll just skim over a few highlights. You've got an executive summary and some of the key recommendations.

I'll just go briefly through a quick profile of our industry here. About 64 people responded, which is pretty good, actually. There were more people who we wrote to, but 64 is good. Half of those were from the private sector, almost half from academia, and a few from government. People were allowed to have more than one affiliation, but 31 chalked themselves up as primarily interested in research, 15 in consulting, 15 in field application, 10 in development, 5 as potentially responsibile parties -- the ones who have the cleanup problems -- and 4 in regulatory activity. I think that emphasis on research and development illustrates what is happening nationally, as well as here. It's a young technology, even the industry has to conduct research.

Work in bioremediation in the State is healthily heterogeneous. We provide people with a healthy heterogeneity of compounds to work on. The 10 compounds receiving the most attention were BTX, PAHs, chlorinated solvents, gasoline, PCBs, metals, mixed waste, pesticides, PCP, creosote, and TNT. If you really want to be a Pollyanna, we're a wonderful laboratory here for people looking into bioremediation. There are a lot of different treatment types. Whether it's bioscrubbing or whatever the different treatment types being explored in this State, a lot of interest was expressed in pollution prevention through biological approaches. I think that's important.

People did show-- I admit it, I asked questions. Maybe they were leading questions, but people did show a lively interest in participating in these sorts of events: networking events, different kinds of programs, workshops, and seminars. The reasons that they cited were: to gain technical information, to keep abreast of trends in the area, to network, and to present their own work.

Most of the people -- 80 percent -- expressed a very strong interest in technology transfer and in establishing collaborations with other sectors. Whatever sector they were in, they were primarily interested in working with the others. Only 90 percent of those responding saw that the role of the University -- many of them had participated in our events -- was a useful one in expediting this community building and expediting collaborations.

As far as the obstacles people saw, they saw Federal and State regulations as the key obstacles. That's usually true for innovative technologies. Sometimes they saw the research or knowledge base that's available as an obstacle, something that needed work. Public perception was mixed; some people saw it as a negative, some people saw it as a positive. We run into that a lot in bioremediation. It's kind of natural, kind of benign, and we certainly hate toxic waste. On the other hand, we're usually talking about germs here, so you get a mix of public perception, but a lot of people did see it as actually a positive.

I asked about current corporation commitment to bioremediation from the industry respondents. About half of them described it as high, others medium, a few were low -- five -- and exploratory were eight. That range of people, when asked if they expected the level of corporate commitment to stay the same or go up, most of them said they expected it to go up significantly. So there is a strong interest, and we're catching, again, a snapshot of an early stage.

More than 36 sites -- this was in '92/'93, so I'm sure there are more now -- have been treated by bioremediation in New Jersey. Just one more thing out of the profile, many of the companies responding -- I think this is typical -- are small. They're not dedicated solely to bioremediation, with the exception of a few -- or almost the only one, that's Envirogen. But the small ones are maybe a little bit more entrepreneurial, willing to try out this niche. We also had companies that were engineering and consulting firms. They wanted to have bioremediation as one part of their repertoire, so they would have a diversified portfolio of treatments they can bring to bear. Then some of the people who responded -- as some of the people who come to our programs -- are the companies with the cleanup problems.

So I think in the short summary of the profiles, there is a healthy level of involvement here by different kinds of companies. There is potential for real technology transfer, especially because we're relatively finite, the proximity is here. There is a high level of attention being paid to the really tough chemicals, like PCBs. We've certainly got them here, in a way that can lead our industry into developing that niche. I mean, tackling that tougher compound gives you a more specific niche.

Also, I think this interest in pollution prevention, that's a relatively open niche. I'm Cochair of the National Subcommittee on Pollution Prevention of the Bioremediation Action Committee of the EPA. There aren't a lot of full force players in that yet, and there is a lot of potential to use biological in treatment of industrial waste before it goes out and pollutes anything. So I think, again, that's a potential market niche for us here in New Jersey.

I'm going to run through-- I wrote out a set of recommendations. There are about 25; I picked about six of my favorites, so I'll run through some recommendations I made to the State, because I think we've made a beginning by pulling people together. Our individual scientists have made excellent beginnings by pushing the technology, and the companies are beginning to explore new niches. I think if we work together, New Jersey really could be a leader in this new, growing subsector of the economy.

Okay, really quick, a couple of my favorite recommendations; these are from the survey. These are not just mine, these are things I extracted from the survey. One is to support informational conferences, continuing professional education, and courses for people in industry and for people in State government. If they're going to be proactive and help to facilitate new technologies, they've got to know how to evaluate things. They don't want to be irresponsible; they want to be informed. If they're informed, they may be able to be more helpful as the companies go through the regulatory hoops. Supporting regulatory personnel so they can go to these short courses and become informed, is very important.

When there are compounds that are special interest, either because it's a new niche -- a big problem in New Jersey -- or when there is a particular phase like sediments, we may need to pull together brainstorming workshops. We may need to develop priorities and actually have some money for funding research and development in those areas.

Formulating a strategic plan to push pollution prevention with biology, I think, is going to be very important. We have language in our statutes-- I'm not the legal expert, thank goodness, but there apparently is a complex situation where the language in New Jersey's definition of pollution prevention doesn't exactly include bioremediation. It doesn't quite include these biological approaches, and somehow, whatever brownie points companies can get for preventing pollution, they should be able to get if they are using biological approaches. That's going to be important as an incentive.

Continuing series of events like brainstorming, seminars, workshops, to share information and bring people together, I think, will be important as we continue to build our community. DSR's funding was very generous. It won't last forever, but it has been very helpful so far. At the State level it might be useful for people in government -- and some industry people -- to really look at what regulations pertain to bioremediation, put it all together so the process can be streamlined, someone can know where they go when. Clearly articulating that process could help a lot, especially the small companies that don't have 15 regulatory experts on their staffs.

Developing calls for proposals with useful amounts of funding in areas of science relevant to bioremediation: I couldn't not say that, but I think it's true, particularly if you get the industry people, the academics, and the government people together to sort out what the priorities are. I think, then you've got a chance of detecting things in the real world with that sort of funding.

Finally, for the State to continue to develop a comprehensive strategic plan for encouraging the development of bioremediation in the State. We can position ourselves nationally: We've got people who are on national committees; we've run national workshops. We can continue to build ourselves nationally not just academically, but as far as the industry. But it's going to take a lot of different kinds of people working together, and a comprehensive, strategic plan could help us to do that. I think we've got a real chance for leadership here in this State. So that's the end.

Any questions? (no response)

Okay. You have these recommendations and an executive summary.

DR. DAY: Can you identify the documents for us?

DR. MEAGHER: They all look alike. We were very pleased with our cover, but that means that everything looks alike. The one that says, "Bioremediation in New Jersey." With my name on it, is the executive summary and the set of recommendations. It's kind of thin, maybe the thinnest one you've got. There is also, "Bioremediation and Pollution

Control," that's the report of our workshop where we pulled in the national experts, much to their surprise. We also have one on bioscrubbing of gases. That is another report of a workshop. Our plastics biodegradation is not quite printed up yet, but we do have that if you're interested in that. The big fat one is the inventory. Then, there is the dark green one, the more printed-up version.

Thank you. Carol is right on top of it, she's finding all these-- (witness handed material by associate)

That is the national conference we held. The DEPE, at that point, the Office of Naval Research, the Department of Energy, Environment Canada, and I think somebody else, helped to fund that. We pulled together experts from across the country, and our team here were the organizers. We got people to really sort out how you get from the lab to the field. There are some definitions in that of bioremediation, what the challenges are of getting from academic research out into the real world. That may be your most useful synopsis of what's going on.

DR. DAY: Well, thank you very much, Laura. I apologize to you, members of the audience and the Task Force, for, in a sense, beating you to a pulp intellectually. (laughter) It has been a tough, demanding morning and I admire your intestinal fortitude. It's about to be rewarded by lunch. (laughter)

I've checked with Dr. Raskin about the greenhouse. He tells me that there isn't very much to show you there. So those of you who do want to see it, you're very welcome to after lunch. But we will now have some sandwiches and soft drinks, and we can have a general discussion while we're munching.

What a pleasure it was to have you visit us today. We hope that the networking we've continued to establish here with the Biotechnology Task Force will prove fruitful in the future. You know us now, you know what we're doing, and we're here ready, willing, and able to help in any way we can.

Thank you. (applause)

(MEETING CONCLUDED)