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"Toxic Chemicals in the Environment"

William E. Cooper

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Portland State University

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[*voices recorded before the lecture starts: HOST and COOPER discussing the setup of the microphone, and which college COOPER is from*]

HOST: Good afternoon. For those that may have not been here this morning, I still need to indicate that the Portland chapter of Sigma Xi is sponsoring a series of lectures on the general topic "Earth Resources Limited," and our speaker this morning was Bill Cooper, and this afternoon it's also Bill Cooper from Michigan State University—an outstanding ecologist involved with a lot of national affairs in all sorts of ways, but as a scientist, primarily. And this afternoon's lecture is on "Toxic Chemicals in the Environment." Bill Cooper.

BILL COOPER: We touched between 11 and 12 this morning in our discussion, briefly, on some of the aspects, but I want to kinda back off and systematically approach the topic of that problem of, that proportion of, that aspect of an ecosystem management dealing with what economists call "residual management"; what, often times, environmentalists call "pollution." It's the discharge of thermal and chemical, you know, residual materials, left over from either the direct production of goods, or once commodity goes in the marketplace and you utilize it as a consumer, what happens to it after it leaves your use. Now, the reason I chose the topic of toxic materials is if I had to name *one area* that I personally think that in the next 10 to 15 to 20 years is gonna constitute the most difficult, and yet important, area of environmental issues that we have not yet learned to come to grips with, it's the area of toxic materials. I can lay this out for you either in terms of a theoretical kind of presentation, in terms of the thermodynamics, and the kinetics, and so forth; the transport and fates and effects of toxic chemicals, or I could illustrate it for you by walking you through a couple of case studies, and I've chosen to do the latter. I think often times it's more informative if you can wrap your message that you want as an ecologist up in some kind of physical case that people have read about—they've seen, they've experienced—so they can identify with it. You can still get the same points across and do it in a very real, and ostensibly, accurate sense.

The few case studies I'll show you… [*recording is muffled for approximately 15 seconds, picking up only the a few words and the sound of the speaker's voice until 03:00*] …made a movie called *The Poisoning of Michigan* that was shown all over the Midwest and the East Coast. We had quite a total traumatizing effect on the state of Michigan, and it was a fairly accurate movie. That's the one case study. It happens to be a fire retardant that accidentally got directly injected into animal feed in the dairy industry in Michigan, and prior to our catching it, it diffused its way through the state. And that happened in 1973, and right now it's sitting in the Supreme Court in Michigan and it's just as hot, politically, as it ever was; in fact, it's even hotter now than it was five years ago. It's an environmental episode that's long from over, and it's gone from the realm of hard science into the realm of the social hysteria, and I'll illustrate some points, I think, from that point of view.

The second case study I wanted to choose was one which has a very different set of properties to it. It's the Kepone incident in Virginia. If you remember, again, it's one that you might have seen on *60 Minutes*, read about, it's the insecticide that was dumped intentionally into the James River. We have 100,000 pounds of it sitting there now. It's one that Life Sciences… a lot of people got hurt when it first happened. A number of workers got sterilized, a permanent injury in terms of human health effects. It's one that, locally, the people in Virginia believe has gone away because they haven't read about it. It's one of these cases where, you know, when it's first in front of ya, everybody's concerned, and as soon as the exposure, in terms of publc media, goes away, people somehow assume that… [*recording is muffled and speaker's voice is barely audible for about 10 seconds, until 04:37*]… so there seems to be an inverse relationship between the attention of the individuals and the actual nature of the project. I didn't—I wanna—I picked these two state case studies by [*sighing*] really as illustrative examples. Virginia and Michigan are *not* dumb states; we don't have necessarily irresponsible industry. These happen to be just two situations where the accidents, or in this case, in one case an accident, in the other case intentional dumping—was of such a magnitude that you couldn't afford to ignore what happened; that's the only thing unique about it. The only thing unique about it is that people were forced to look at it and try to understand what happened.

This kind of thing goes on everyday in smaller scales. Oregon is no different than the other states. I'll guarantee you if you went out and forcibly went through and looked at all your industrial waste haulers, the total chemical mass balance… if you went and looked at the number of toxic materials sold in the watershed, okay, in the municipality of Portland, and tracked those things chemically as to what happens, they went to the market and where they eventually ended up, you would find these case studies in hundreds of them. Simultaneously. I can walk you through some of the other ones we have going in Michigan. We have been stung pretty bad so now we're diligently looking and we're finding this stuff all over the place. Virginia's doing the same doggone thing. And so, I've picked case studies that I think are typical; they're blips in a learning curve. One of the questions that you can ask yourself is whether or not we've learned anything from it, or does each state have to go through one of these experiences before they actually face up to the issue in front of 'em? If so, it's gonna be a very costly and traumatic learning experience, I'll guarantee you. That's gonna be a very, very inefficient and costly way for education, if you gotta personally walk through one of these yourselves.

Now, if we back off for a minute, what I'd like to do, we'll look at the toxic materials problem in a more generic sense. I'll just kinda set out an academic foundation for this thing. Basically, it really comes down to the fact that we, about 19… in the 1940's, the war years. To a great degree, we had the invention of synthetic chemistry to a great… you know, the major industrial use of synthetic chemistry. We had many of our kinds of inputs in terms of both organic products and inorganic products like natural rubber, and like tin and so forth. The imports were blocked from us in World War II, and so when we couldn't guarantee flows of iron and flows of natural rubber, we made synthetic rubber and we went to plastics. We went to various different kinds of alternative substitutes to resources you'd find in the natural world and that you'd find in the world. So we substituted man-made synthetic compounds for things that were naturally developed or naturally, you know, deposited in terms of your own accessibility, in terms of natural compounds. Now, we really had a choice there. You could say, "Well, fine, if we gotta make synthetic fibers…" you know, seat covers, clothes, you name it. If you look around this room, probably 80% of the compounds in this room are man-made compounds, they aren't natural organics at all, they aren't wood fibers, they aren't cotton fibers; they're things that are essentially made as polymers of carbon-type compounds. Myself included, but most of us either haven't had organic chemistry or rapidly forgot it 'cause it was taught to us in a very uninspiring fashion, in my particular case; what we're really doing is we're going back and learning our organic chemistry in a very, very painful way, 'cause when we talk about organic chemistry, meaning: organic complexes, synthetic molecules, polymers made taking carbon as the basic store for the building blocks… [*recording is muffled for a few seconds until 07:51*] …you put these together in different configurations, okay? And you're really only limited by the amount your imagination and how many different ways you can hook things up, which gives you tremendous diversity of which you can go on and make different alternative chemical structures, each one with different biochemical properties. You put these together in different ways and they act differently; they have different toxicologies, they move through the environment at different rates of speed, they break down more or less rapidly, they might or might not accumulate in biological food chains and cause other kinds of public health effects. So there's tremendous, you know, different implications of hooking organic compounds up in various ways.

The reason that we went to carbon as the basic structure to build on is, first of all, we can make polymers—we can hook 'em in long chains—and, also, carbon was cheap. Carbon was cheap 'cause most of these carbon compounds came as secondary by-products from the petroleum industry. When you refine gasoline and all the petroleum products left over, a lot of 'em went into plastics, they went in synthetic fibers, they went into antibiotics, they went into food additives, and into a *tremendous* diversity of synthetic organic compounds. So carbon was amenable to these kinds of multi-structured systems, and it also was a very cheap compound. On the other hand, if you think about it, the mere fact that we took the same basic building block carbon that you're made out of… [*recording device is muffled and picks up a phrase from another recording (minute 9 of Michael Arbib,"Participation and alienation in large democracies") before returning to COOPER*] Stop and think of what would happen if we decided, well, we shouldn't use carbon, we'll use silicone. We'll make silicone compounds—polymers of silicone which is a very common element; which is much, much less biologically active. Whether we would still have the same class of environmental toxicology problems that we do with chlorinated hydrocarbons and the things we'll talk about today. The point is we didn't do it, we pretty much built the *whole* synthetic chemical industry on a carbon-based molecule which, essentially, is the same basic structure that you use biochemically.

Now, to go the next step and look at the structure of organic compounds, basically up to about mid-1940's, the organic chemist was pretty much… [*drawing*]—I'm not much of an artist here—pretty much dependent on hooking things up in two-dimensional ways; you could make various kinds of organic compounds, okay, by essentially laying your tinker toys out on a two-dimensional tabletop, and it very much constrained their options. In the mid-1940s, some chemists developed something they called "cubane." For the first time, there was a major breakthrough in organic chemistry. They made a cube-shaped compound [*drawing*] like that, and it was really unique; there's no compound like that in nature. Far as I know, there's no cubic organic compound, these are totally man-made, okay? And now, stop and think of the configurations—the number of permutations and combinations—of products a chemist could make when he could hook things up in three dimensions. You know, just conceptually, you can go almost any way you want, now, can't you? If I take that same thing called cubane—that same compound called cubane—and modify it just slightly, where I… [*drawing*] let me get this thing right… and I put something like that, and I put and O2 on it—oxygen—and I put somethin' like that, and I put two chlorines, that's Kepone! If I put a chlorine in each one of these intersections, okay, I have this little organic compound we're gonna talk about.

That particular compound, Kepone, which was the insecticide that was dumped into the James River, is one of the most toxic compounds I personally have ever worked with. It will kill fish in parts per trillion, a spot in the James River's bioassay. It'll cause cancer; in bladder… liver cancer in mice in parts per billion, okay? It's a compound that was made to be very stable. This thing was made in fuming sulfuric acid and it was washed in a very strong hydroxide so during the production and purification procedure, it was exposed to a very strong reduction—very strong oxidation—which means it's very resistant to any chemical breakdown, all right? It's a cube-shaped compound with 10 chlorines on it. Chlorines are one of the halogens. Halogens are chlorine, bromine, fluorine, and iodine. Chlorine com… halogens like this have single electrons acceptance. They have a very strong affinity for electrons, and if you know anything about your biochemistry, that's the way your electron transport system operates biochemically; it's passing electrons around your body. And so the halogens is a class of elements—very biologically reactive yet oftentimes in a negative sense, in terms of public health and terms of effects, and so this essentially represents a class of compounds, not just Kepone itself. We can talk about Kepone as a chlorinated hydrocarbon. When I talk about PBB, it's a brominated hydrocarbon. Rather than having chlorine hooks outta this thing, it's got bromine hooked onto it. Remember the aerosols? Your ozone controversy? That was a fluorinated… fluorocarbons 11 and 12 are refrigerants that they're using. Again, it's a fluorine attached to the hydrocarbon molecule. I have not yet, myself, run into a major environmental problem with iodine compounds. I'm sure they're there, the logic says they have to be… I had not… I just don't know of one myself that essentially has yet made a major catastrophe or major social issue.

But we're talking about, then, a whole class of compounds where essentially you take off a hydrogen and stick on a halogen. These things are very toxic from that point of view, and are very stable. To actually break this compound down thermally, you have to burn it at about 2700 degrees for 8 seconds duration. We did this at Monsanto. It broke down about 85% of it, the other 15% went out the smoke stack. So here we built a compound that is known toxic; it's… this was used in ant traps; this is the insecticide. You know those little ant traps you buy, you put around your house? This was the powder that's in that thing, okay? It's built as an insecticide; it's built to be chemically very, very stable. It's very toxic and essentially persists in the environment for long period of time; it's got a, what we call a "half life" that is almost infinite. If you put that stuff out—look at it—you put a pound out there, 10,000 years from now that same pound's gonna be sittin' there, okay? The pure fact that the way we made that compound, we made it almost indestructible, at least for anything that you'd find out there in the natural environment.

Now, Kepone is an extreme case. The properties of Kepone make it extremely bad actor. It's one that you probably could've looked at during the manufacturing process and then say, "No damn way we're going to build that thing." But when they didn't, nobody was concerned about that, all right? But that's… I picked the one extreme. PBB is nowhere near as *toxic* and nowhere near as stable as Kepone. Here's my other example I'm gonna give you. Now, if you actually look at the statistics of this kind of thing, then the numbers change all the time and there can be a rough idea about the nature of the problem you're dealing with. EPA estimates there's about 2 million different species of synthetic compounds right now in your marketplace. If you went out there and went up and down the shop—supermarket—or went up and down the clothing store or hardware store, and started writing down every different species of organic compound that's currently licensed and marketed in this country, there's something over 2 million of 'em. The National Cancer Institute, at least the last testament I saw, estimated probably 72,000 of 'em are potentially carcinogenic. We know the detailed information on probably a dozen. If you ask me, "How many of these compounds can we actually go out and predict where they're gonna go in the environment? How long are they gonna last? Where are they gonna build up?" We'll probably have that data on about a dozen of those 72,000, to give you some idea about the estimate of the magnitude once you get into this ball game of trying to find out what you're dealing with and what you're not dealing with.

The chemical industries maintain a computer bank that they log in their new experimental chemicals. That doesn't mean they're gonna get on the market; they're the ones that they're just generating to look at. They add about—by their own estimates a couple weeks ago—about 6,000 compounds a week, is the rate with which our research chemists dealing with industry and the federal government, and the universities now, are generating new kinds of organic compounds. They're gonna to have to be, you know, in one way or the other, tested, investigated, explored.

Now, up to very recently, the mode of operating in this country was to take a compound like this and put it in the market, to a great degree. There were only essentially three classes of compounds that were regulated: Food and Drug had all the food and drug, EPA had pesticides, and I believe the Treasury had tobacco and alcohol, okay? And those are the only classes of compounds that were regulated. All others, basically, you'd go out and put 'em on the market, and you tried 'em out empirically. Now, if you got a compound and had a usefulness and somebody wanted to pay for it, you had a right to market it, and there was almost no regulations on those. Now, as a result of two incidences, both PBB and Kepone—that's one of the reasons I picked these two case studies—that we had an act signed into law—federal law now in this country—called the Toxic Materials Act, the Toxic Substances Act. I don't know how many of you have ever read it, but if you want to take it as a case study and to illustrate, you know, to get people used to reading some of that stuff, it's a classic one to take. It is probably the most—I think, anyway—the most awesome piece of environmental legislation ever passed. It's gonna affect almost every industry in this country, and basically the act says this: the act says that "the administrator of the EPA has a right and responsibility for any compound both existing and new"—so it's retroactive. It's every compound existing in the marketplace today plus any new one that comes along—"to essentially require from the industry, if there's a reasonable doubt about its safeness, evidence that will prove that the compound is safe before they're allowed to market it." It gives the administrator of the EPA the authority to stop the production and sale of any chemicals that's not in those first three classes. So every industrial solvent, every plastic, every fiber, you know, you know the names. Stop and think about it. How many industries? Everything from dry cleaning fluids, okay? All the way down through to what you add in your clothes for fire retardants fall under this act. It's as *broad* as anything could possibly get, and the most interesting aspect of that thing is up 'til now, we've operated under the assumption that an industry can do something and is innocent until proven guilty—I mean, that's the way our system operates. Now we have a law that says, "No, we'll assume it's guilty, as the burden of proof is on the industry to prove the compound safe."

Now, stop. I don't know how many of you have ever had statistics 101? Stop and think of the scientific method. Do you know how the scientific method operates? Do you ever go out and prove a hypothesis true? You always set up a null hypothesis as a false statement, okay? And you don't ever prove it true, but you try to disprove it. You say, "There's nothing there," okay? There is no effect and you don't ever prove it is, you just fail to find a certain effect over and over and over again. If you test that long enough or hard enough under an array of different environmental conditions and you reluctantly say, "Well, maybe, maybe it is true. Maybe there's no effect," but you never prove that, do ya? Now, here we got the law of the land that has turned the whole scientific method just backwards, mmkay? And you say, "Well, how the heck can you get into this? How can we have a piece of legislation that affects, I don't know, 80—90% of the industries in this country, improving people's lifestyles, built on a logic that seems just backwards?" Well, these two case studies were the two situations that forced that through Congress. That piece of legislation was tied up, effectively lobbied against for six years. Kepone and PBB both broke the same summer and the impact—*60 Minutes* and all the publicity and all stuff that happened—that thing went sailing on through Congress; they had to do something and they passed that act. Now, I'm not speaking against it, I'm just trying to lay out… so you can judge yourself whether or not you think that kind of response to that kind of crisis is an adequate thing. But let me back off now and walk you through the two case studies to give you the specifics of it, and we'll come back and talk about some of the general properties.

The first one I wanna walk you through is the Kepone situation. The Kepone, again, is this little species I got drawn right here. If you look at… I don't know how many of you know the East Coast, but that's the East shore, okay? Here's the Chesapeake Bay, there's the James River, and it comes up and you got the York River, and there's another—can't remember the name of that one—then there's the Potomac River, Washington D.C. is right here, okay? And Maryland's up here. That's the Chesapeake Bay. Chesapeake Bay is—[*breaking from lecture*] can you all see that? Close enough? [*resuming*] Chesapeake Bay is in a marine situation like the Great Lakes is in the freshwater. It is the largest marine estuary other than Hudson Bay in the world, and if you know anything about marine productivity, you realize the fact that most of the production of the ocean takes place within the continental shelf—within the shore, you know, the boundary areas of the shore—because you have essentially a lot of nutrients washing down from erosion and so forth and freshwater is in the land; you have shallow waters that are warm, and you have sunlight that penetrates to the bottom, and so the bulk of the fish production, the bulk of the plant production in the ocean takes place within the continental shelf within these estuaries. These are the major breeding grounds and major nursery grounds for young oysters, young clams, young fish, young crabs, and everything else. In the East Coast, our continental shelf goes out about 200 miles.

On the West Coast, yours is very short. The estuaries in the East Coast are far more important to marine productivity; yours are all truncated because of that fault line, and you're going to the bottom real fast. But in the East Coast, we have a long continental shelf and that's where the bulk of that activity is. So, again, this is a non-trivial environmental resource. There's a little plant right here, Hopewell, on the James River, just down from Richmond, and if you've seen the *60 Minutes* program, this was a little two-bit operation, and I mean that actually. It was a chemical company that opened up in an old Phillips gasoline station in the little town of Hopewell, and they took this filling station and they modified it into a production process. Kepone was made by Allied Chemical. Allied Chemical was a big industrial firm in this country, operating out of Baltimore. It operated a plant here in Hopewell up 'til late 19… early—mid-1960s, okay? And it became apparent that Kepone was going to be highly regulated by the government because of its toxicology. They wanted to use that plant for something else, and so two of the people that work for Allied spun off as Life Sciences and set up their own little business. These were two Ph.D. chemists, all right? They had a very unique contract—they show you the actual thing you get into when you deal with this—with a parent corporation, and there was a parent corporation: Allied. They had a contract where Allied gave them all the raw materials for nothing, and Allied was the sole source contact of buying back the Kepone once it was made, okay? But yet, institutionally and legally, it was a free independent corporation, so if you sued Life Sciences, you couldn't sue Allied, so they were absolutely clean—you know, free—from any kind of potential liabilities, but yet they had this kind of legal contract with Life Sciences.

Now, one of the problems in dealing with toxic materials is that—remember we talked about anticipating environmental problems—when I'm dealing with radioactive waste, when I'm dealing with heavy metals, when I dealing with thermal effluent, we at least have the option to set up monitoring systems where you can go out and try to determine whether or not accidents have taken place. I can hire a, potentially, a technician—a Bachelor of Science, chemistry degree-type individual—put 'em into the laboratory with standard chemical technology, standard equipment, and I can monitor for mercury. I cannot monitor for lead. I can monitor for radioactivity; I can, you know, give 'em a thermometer, have 'em measure temperature. The problem is you don't monitor for organic compounds of this nature.

To give you some idea of the magnitude of the effort it takes to go out and determine whether or not you have Kepone in your body, okay? Let me walk you through some examples. You have probably seven to eight parts per million PCBs—that's that polychlorinated biphenyl I talked about this morning. Now, the FDA regulations say that the action level was five, which means if we were a society of cannibals, none of you could be put on the market; you're all unfit for human consumption, okay? Now, if you found that very abrasive and didn't believe it, let me walk you through what it would take for me to actually make that determination on you. These organic compounds—some of them are polar and some of them are nonpolar, that's the structure of the compound—they take different kinds of activity to extract it from your body, to get it out of your body where I can measure how much I got, all right? These things are basically… most of them lipophilic, that we call this, "fat soluble." You've got to take some kind of solvent, then you gotta put 'em in solution and something, okay? And different compounds have different solvents. And it's the solvent I would use to extract Kepone will not extract DDT. The solvent technique I use to extract Kepone from oysters will not work on human beings; had to develop a different ki… a different technique for humans than I do for oysters. That is, to really define, to refine a technology, you just extract this stuff to work with it. I really have to know what the compound is and I have to develop a different technique for each bloody piece of tissue I'm gonna work with. So what I do is I put you in a whirring blender and I grind you all up, make a mush outta ya, okay? And then I use some kind of a solvent to extract that organic compound. Now, the problem is two. One is some things don't get extracted; better use the right solvent. In the other case, you can get many of them coming out together. Remember I mentioned this morning that much of our stuff on DDT that we talked about turns out to be a bum rap that was PCBs? They both came out together with the same extraction techniques, and it was about, well, was the early 1960s before we learned to separate the two. So a lot of things we thought were one turned out to be masked; the other was hidden along with it.

So you got both classes of problems. So you bring the stuff out and then what you do is you have to somehow refine it, clean it up, and you run it through some kind of a gas analyzer. We use—what we're now using is a capillary gas chromatograph. What they do is they put it in a little dish and they flame it real hot, make a gas out of it, and shoot it down a long glass tube and each compound goes a different distance, all right? Depending on the size of the molecule and its polarity, some of 'em only travel short distance and stop, others go a long distance. And what you get, then, is a graph where this is retention time, all right? The bloody thing looks like a porcupine, like this, okay? This is what a sample, for instance, from an oyster from the Chesapeake will look like. We got these last month. One of those spikes is Kepone. One of those spikes might be DDT. One of those spikes might be PCBs. A typical oyster sample for the Chesapeake has about 520 spikes in it. We know what probably a dozen of those compounds are, we can identify. The other 500-510 compounds are the environmental crises of the future. We know they're there. We know that every one of those, by the way, every one of those spikes is a man-made, synthetic, halogenated hydrocarbon. There's not a natural organic in that particular technique, and won't come out with that technique. So these are all *existing*, you know, chemicals out there in the environment.

We have been doing the same thing with human milk in Michigan since PBB, monitoring as a service to women, 'cause they wanna know whether they should breastfeed their kids. We get somewhere around 300 to 320 spikes in a typical sample of milk from people in Michigan. To essentially take one of these spikes that you don't know and make it into a known, to do the kind of research chemistry it takes to extract it, identify it, purify it, it'd cost about $10,000 per spike, mmkay? Now, that's the cost it would take. It takes about 18 hours of bench chemistry for you to do one oyster sample, mmkay? Once you know what you're looking for. Costs about $10,000 just to get it 'til you know what it is. Now, that's a magnitude of the time and effort it takes a Ph.D. organic chemist to do the research, and it almost takes a Ph.D. physicist just to get the machines working, mmkay?

Now, there isn't any state or local community that can afford to go out and monitor your environment for organic contaminants with that kind of technology, can they? I mean, yeah, we've now geared ourselves up to look for PBB in Michigan; that's about all we can do. We know the rest are there, there's no way we can go out and monitor it. So this is one of the reasons I put this class of problems as kind of high in a priority of social conflict, because almost by definition, it's gonna be crisis reaction. We aren't gonna know we have the problem until we see a localized effect. There isn't a *single* environmental episode that I know of that we anticipated ahead of time. Every one that I personally know of like Kepone, methylmercury: cats were dancing in circles, PBB: cattle, their hooves were growing up, Kepone: the workers got the shakes. The first indication was their effect on people or animals out in the environment and then we scrambled like hell to try to find out what it was, how far it went, how long it's been there, who got hurt; and that is the most difficult kind of decision-making. And one of the most difficult things is in that early stage of a crisis when all you've got is the shakes, or all you got is cattle that are knock-kneed, and people demanding to know what's going on, that's where the decision-maker is most vulnerable and that's where, if I had to name one major thing we gotta learn how to do, is how to discipline a society during the early phases of one of these things so you don't overreact. 'Cause there isn't, you know, isn't any point in going out and beating on the governor or beating on the director of agriculture and demanding that your environmental officers tell you what's going on—they don't not [*do not*] know, and there isn't anyway to find out, at least not in the short run.

Now, what happened with the Kepone situation is exactly that. There was a worker here at the plant… that the symptoms of Kepone toxicology is you get shakes. If you saw that 60-minute program, the guy couldn't even put a screwdriver into the head of a screw, his hand was shaking so badly. You get peripheral vision, your eyes don't focus. This guy went into his local general practitioners—his doctor—in Hopewell, a small little town in south Virginia; 'course they didn't know anything about Kepone. The first couple times they went in, they gave him a tranquilizer and sent him home. They said, you know, they did the normal kind of diagnostic, medical diagnostic tests, nothing showed up! They didn't see anything. "Well, it must be stress. You must be overworked, okay?" And literally, they sent him home, told him to take a couple days off and rest and they came back, and of course as they came back and picked up the same symptoms right again. And eventually, this guy, about the third time, met up with a Taiwanese intern, one of these young, aggressive guys that was gonna make sure it was done right, and he had enough sense to essentially take a blood sample and sent it to the toxicology, the community disease center there in Atlanta, Georgia [*Center for Disease Control or CDC*], and had enough sense to ask the guy, "Well, what are you making in that little plant?" He said, "Well, Kepone." Well, they didn't know what Kepone was, but he passed it along and these guys did analysis and found about 7 parts per million in the blood. Now this was actually in the blood of the worker, and if you know anything about physiology, that's a very high level. That's not in the fat, that's actively circulating in your blood system; 7 parts per million is very high.

So, immediately, they call up the state of Virginia, they shut down the plant, the various occupational health safety people and MDs and so forth went and looked around in this little garage. You walked into this place, there were 30 workers in there. The Kepone dust was so thick in the air you could hardly see across the room. It was up to 6, 8 inches in the corners, just sittin' there, just Kepone dust, and people had no protective gear, they had no face masks, they had no protective clothing at all; and this was not 1820, this was four years ago, okay? I mean, it's not as if somehow we're back in the 1800s and we don't know any better, all right? Everybody in that room had the shakes in some form. They immediately, you know, shut down the plant, they begin to follow this stuff out, 'course these people went home and they took the Kepone home and dust in their clothes with 'em and their family, their houses were contaminated. The contamination was less 'cause the intensity was less, so the human health problems didn't show up, but you could measure it there. They looked at the air samples; EPA ran one of these dust collectors over the city of Hopewell. The dust was about 10% by weight Kepone in the air in that dust collector. They went out and they sampled the soil around the plant and of course they would take these things out and bag it, and they were kind of sloppy about it and they'd bust a bag and it'd fall on the ground, and there were… percent by weight Kepone in the ground around the plant itself, all right? You know, cause the further they looked, the more they found. They then immediately began to worry about aquatic discharges and they got a hold of the town of Hopewell and it turned out that these people—remember I mentioned this morning that the municipal hookup, the industrial hookup and municipal plants? They'd initially hooked up the sewage treatment plant in little Hopewell and completely killed all the bacteria in the plant—wiped it right out, okay? And the engineer fired it back up and figured out it must be this garage, and his solution to the problem, they gave him a permit to dump directly into the James River.

Well, know, here's some sanitation engineer working in a small town of Hopewell, what the hell does he know about Kepone, organic compounds. You shouldn't expect him to be a synthetic organic chemist. No, you know, he said, "Well, whatever it was, we'll just, you know… you haven't got very much, we'll just do it that way," and of course immediately then they began to worry about what happened in the aquatics, 'cause this was a direct discharge right into the James River. 'Course the company meeting when this happened, the workers, you know, these guys were permanently sterile, all 30 of 'em; they were between 25 and 30 or 35 years of age. They went back through the medical records in terms of births over the last 10 years of that plant and it was something like only three births of all the workers and their families in something like 10 years and only one of them was normal, which was very low, percentage-wise, OK, it might be just luck of the draw; on the other hand, there's a good indication it wasn't.

So immediately these people wanted, you know, to sue somebody, but, you know in Hopewell, little town… little Life Sciences declared bankruptcy. Again, it's a typical thing that you find you got a small undercapitalized industry—they've got nothin' to lose! They got no capital investment in a plant so immediately they declare bankruptcy, and the law allows them to flee, you know, clean and green. Absolutely. And, of course the workers wanna sue Allied, which is the big corporation, and they said, “Look, you guys don’t work for us. You’re an independent operation.” Okay? So the only person left to pick up the difference was the state of Virginia which is not… you know, the whole budget wouldn’t pay for this thing. So the federal government eventually is gonna get stuck with the bill on this, and most of the situation we’ve run into where this happens is it's not a great big corporation; sometimes it is, [but] many times it’s these small little independent operations that are so small they’re cutting corners.

Now as it turns out, as a result of crapping this stuff out in the James River, instead of monitoring oysters and blue crabs and bluefish and so forth in the James River, these people dumped 100,000 pounds of it, okay? Over about a year-and-a-half period. That’s 10% of their total production, and if you saw that *60 Minutes* program where these two guys said, “Gee, we’re sorry, we didn’t know it was toxic.” With all due respect, they’re both Ph.D. chemists and working on the toxicology of that compound for about 20 years, at least 15 years, all right? Now, the question, then, comes, to what do you do? We have in the James River now—if you look at this and blow it up—up until 6 months ago, we were hoping that the Kepone would stay in the James River. Now, here’s what you call a “salt wedge.” If you look at a tidal river, if this is the ocean going that way, all right, the fresh water flows along the surface ‘cause it's lighter than salt water, and rides out over the top of an estuary like this and the salt water then, what happens is there is a diffusion upwards of salt water, and it causes a vector that causes salt water to flow upward. So in the Chesapeake Bay, fresh water flows on across the top and salt water flows upstream across the bottom. And there was a zone which they call a zone of… essentially, negative or neutral transport; it’s a deposition zone of particles of silt and so forth. Kepone adheres to small soil particles, and as it’s carried down the river, these things are deposited because of this counter-current flow in the zone. So if you looked at the river, the Kepone was distributed like that. Now if you take 100,000 pounds of Kepone and you take the toxicology—the FDA standards right now are 3/10ths of a part per million—that any fish above 3/10s of a part per million you can’t commercially put into state commerce, and you take that and multiply it times the number of pound of fish it would take if that 100,000 pounds were uniformly distributed, okay? And not only is it capable of completely contaminating the whole Chesapeake Bay, but if you really distribute uniformly, the whole Atlantic Ocean in terms of getting the fish in the Atlantic Ocean above the action level of the FDA.

So we're talking about, now, a situation where what do you do? Here you’ve got a compound that is stable as the devil, it’s toxic, we’ve done the toxicology of it and normally what they will do in analyzing toxicology—you might ask the question of how does the FDA come up with the number 3/10ths of a part per million? It’s a very interesting one to look at. The *basic* problem of course is what they need to do is determine what level of fish could you eat… well, I’m saying, what amount of fish could you eat for each level of Kepone in the fish, so you don't exceed your body tolerance, your ability to process that compound or at least tolerate it. So what you first have to do is decide what's the toxicology of Kepone. Now, to do toxicology, obviously, you'd want to do it on human beings; we can't do it that way. The next best model would be monkeys, at least they're primates. With the cost of monkeys, you can't do that either. So basically what they use are carcinogenic prone strains of white mice, highly inbred strains of white mice, that are sensitive to certain kinds of pathologies, and they use these as supposedly very sensitive indicators [of] the toxicology of this compound.

Now, there are two levels of screening for toxicology. One is… no, you can't go out… we did it with Kepone with mice, but they've also done it with other mammal type things as well; but when you first get in with this, you're not really sure what you should spend your money on; it takes a lot of time and money to go out and test for one of these compounds. They have what they call the AIMS test. The AIMS test is a quick and dirty look of solution that uses bacteria, and what it really is doing is one of the theories of cancer is that it's a mutation—a genetic mutation—that initiates, okay, a biochemical event, and it's a latency period because there are controls on that gene that don't allow it to be expressed, and sometime in the future, then, there is a genetic shift in the body that releases that expression and cancer's expressed. Now, the latency period can be anywhere from 8 to 40 years. So the question is, how do you test for carcinogenic material if you don't expect it to show up for a 40-year period? Well, you obviously can't test for that directly, can ya? So you gotta test for it in an indirect fashion.

Well, the AIMS test is one of the ways to do that. What it is if you take a bacteria that cannot grow in a growth media, you put it on, [*claps*] it dies every time, so you expose that bacteria to your mutagen, right? Your mutagenic material, and if it then mutates to the point that you get a little plaque, that's what the AIMS test is. And for certain kinds of compounds, it's about 95% efficient; that you really don't know it's carcinogenic, but at least you know it's mutagenic and that it's potentially a carcinogen. Then if you find that it's mutagenic then you test it with white mice, spend a hell of a lot of time, and money and effort. And during that period of time, of course, the decision-maker doesn't know whether he's got himself something that's good or bad, does he? And that's that time lag in decision-making that you can't help—it's built into the science of the system.

Now, when this thing first broke, and this information came out, they really didn't have very good standards. The EPA set—and FDA set—the level at 1/10th of a part per million. The fish had more than that. The governor was faced with a decision. He shut down the bluefish, crabs, and oysters in the whole Chesapeake Bay, and that's just like our salmon—that's a hundreds of a million dollar annual budget. I mean, you know, that's a water-oriented economy; the watermen in the Chesapeake make their living off that bay, and it’s a *tremendous* economic impact that you’re shuttin’ that thing down. But the governor was very reluctant to do that, and he did two things: he first said, “Well, let's hold up the information. There’s no point in sending this stuff out ‘cause we don’t know what it means yet,” and put up a moratorium on the release of this information to the public and said, “Guys, we will protect the public by putting more inspectors” […] on the fisheries—“we will hire, you know, a lot more meat inspectors for the Department of Agriculture and we’ll monitor this fish, and if we find any contaminated fish, we’ll take it off the market,” all right? You might think well, that's a good trade-off. Well, the problem is think about the time lag in terms of monitoring this compound—remember I walked you through the technique of doing it? You go out, you collect fish off the market—the FDA does not monitor anything in the environment, all of your food quality monitoring is market basket sampling. All the FDA sampling for food quality—so they go to the store, they go to the fish market, and they take a sample off the shelf. They don't do it when it's out in the environment, mmkay? And by the time it’s there—if it’s a fresh fish, it isn’t gonna stay very long on the market, is it? They take the added sample of fish, they’d send it to a biochemical lab, it’d take about 48 to 72 hours to get the samples back—sometimes as many as five days. By then, by the time you got the information, those fish were already eaten or rotten, okay? So obviously that system didn't work and blew up in their face, and became a real social issue.

They re-analyzed the numbers that they were doing. The FDA set the level initially at 1/10th of a part per million, and let me tell you how they get that number. They did the toxicology and they got it down in the parts per million when the stuff was not causing cancer was passing urine in… a protein in the urine which means something was going on. So they didn't find a zero safe level, all right? But what they decided to do, they put a margin of error of a thousand—they find that number and they divide it by 1000. It’s the same way an engineer would put a, you know, 15% margin of error on the stress of a bridge, just to make sure his calculations were robust; this is same thing biochemically, and they usually use a factor of either a hundred or a thousand—set the number three decimal places over [to] the left, okay? And then what you got—that’s a toxicology level—that’s the ambient level of your blood that’s safe, then you have to decide: well, what’s the level in the fish that associates with that? So you have to decide how much fish do you eat? And it turns out, the average fish consumption in the United States is 19 grams a week, it’s a 145-pound man in Des Moines, Iowa, okay? And so the FDA takes that calculation and looks at what level of Kepone in the fish would it take if you ate 19 grams a week, so that your body level will not exceed 1/10 of a part per million, mmkay? And it turned out to be that the fish in the bay were over that level and would not be legally sold. The state went back and re-analyzed it, and of course the watermen don't eat 19 grams, they eat a hell of a lot more than that, but the FDA also assumed that Kepone will be in all the food, not just fish: dairy, poultry, beef, and everything else, and so if you make the various—‘scuse me—

readjustments in terms of concentration, the estimate come out to be 3/10ths of a part per million—the fish had .29, okay? Just below it, and they opened the fisheries back up.

That was a year-and-a-half ago. Unfortunately… remember I mentioned the salt wedge? That salt wedge kept that Kepone right there in a fairly narrow band. Last year, we had a drought on the East Coast and that salt/freshwater interface moved upstream about 20 miles and the samples we've taken for the last, oh, 6-7 months, looks as if that wedge is moving downstream now. It's gone through the barrier. I'll go back and look at my James River, give you a bit more on the biology of it. Right here, the Kepone wedge is about right there, and now it's beginning to move. That position right there is where all the seed oysters from the whole Chesapeake Bay come from. I don't know whether… how many of you ever been in the East Coast, but oysters out in the East Coast are a delicacy, they're like the abalone out here, okay? And they fish farm oysters by—this happens to be just the right salinity and right velocity, right sediment—oysters throw their spat out in the open ocean. They have to settle out, they have to get a very high percent survivorship right here and the way the oyster farmers work, they come down they collect the young spats, here, and they move them up to other places in the bay, and two years later they come and harvest the oysters; it's a two-year fishery.

But the total reproduction of the whole oyster fishery in the Chesapeake comes right there. Every female blue crab in the Chesapeake Bay spawns right here. Blue crab also is a marine delicacy in the East Coast. What happens is they ride that salt wedge upstream, the young larvae do, and mature up in the upper rivers and bays and in the whole Chesapeake. The females, when they get ready to mature, *walk* all the way down here, and that's the total breeding ground for all the blue crabs in Chesapeake Bay. Remember I talked about the salmon migrating from salt to fresh water? And they holed up in these estuaries? All of the bluefish, all of the flounder, all of the spot, all the striped bass that migrate into the Chesapeake from the ocean on their migratory runs stop and spend three to four to five weeks right here in the bay, making this physiological shift. If you had to find a place to which you would not want to inject a load of toxic materials into a critical ecosystem, you couldn't find a worse ecosystem and a more unfortunate position than what you have right now.

The governor of Virginia, now, has got about eight to nine months to make a decision. What does he do? It's very easy to say, "Well, we'll go out and we'll sue 'em, we'll put 'em in jail." That ain't gonna help Chesapeake Bay, is it? From a scientific point of view, you know, the question is, what kind of mitigating options do you have? *All* of 'em are extremely expensive. The Army Corps of Engineers, for instance, has investigated the feasibility of dredging. They love to dredge—they got all kinds of boats, all kinds of machines, all kinds of people, okay? To dredge the James River right here, [*pointing on a map*] right here, it's about two and a half miles wide, here it's about four and a half miles wide. About 8 feet deep; big, wide, shallow. To dredge that Kepone—of course it'd be mixed with the winds, be mixed with the tidal currents, be mixed with the worms and crabs and so forth that chew up the mud, okay? So it's essentially infiltrated a couple feet of sediments. The spoil site would be about 30 square miles, about 8 feet tall. The estimate, even if you found a place to put it—and someone would have to write an environmental impact statement on that and nobody would want to live next to it, okay?—the estimate on that was about 3 *billion* dollars—that's B, billion, okay? Another alternative was to dam off the James River here and here, divert the James River into the York, which would completely destroy the lower James and essentially just dam it off and isolate it. The estimate of that, if you don't consider the fact that all the Norfolk, okay, and Newport News Navy yards are all right in here—all your major shipbuilding and your big Navy ports are all between those two barriers—just the project itself, the estimate was somewhere around 9 billion dollars. Another proposal was to impregnate a resin, okay? Some kind of an organic resin as an absorber to Kepone—something that would absorb Kepone with more infinity that the sentiments would themselves—and impregnate it with metal filings, put it out there, come back around with a big magnet and pick them up. See if you can't retrieve it. Unfortunately, there's not enough resin made in the world to do it. The estimate of that was about 13 billion dollars.

And I'm not being facetious; these are actually the kind of things they're talkin' about, okay? As far as I know, nobody has a technically and economically feasible alternative I know of right now. The governor is faced with a rather *difficult* decision. I used to say that, up 'til this situation came along, I couldn't think of an example where an environmental toxicant caused major ecological disruption, the same way that [...] did, this morning that I talked about. Here is the exception. The Kepone apparently is toxic enough that we're now monitoring blue crabs and spot in the lower James River, and the populations seem to be going to zero. In most cases with environmental toxicants, it didn't kill ecology, it just pre-empted your use of it. The PCBs don't kill my salmon, you just can't consume 'em, okay? And up 'til recently, we thought the same situation with Kepone: that we set our environmental standards for health purposes and they're so rigorous that we never did see ecological damage. Here's a case where, apparently, what it looks like, is it's intense enough and toxic enough that it's destroying the fauna and flora in the lower James River. Now, but even that is not entirely an ubiquitous thing; for instance, the two species of catfish that live in the James River… *side by side*, two species of catfish! One of 'em accumulates Kepone in high concentration, the other's got none in it at all, and they sleep side by side and eat the same food. They have some different biochemical thing that apparently they're urinating it out or processing it in some form so one of 'em you can eat, and one of 'em you can't touch, okay? One of 'em's loaded, one of 'em isn't.

Now, where this goes… I don't know yet. If you talk to the people in the lower Chesapeake, they think the problem's gone away; they haven't read about it in the paper for the last six years—well, the last six months, year and a half, alright? We made a big splash, everybody was concerned. The problem is *more* difficult now than it was before. I guess one of the questions you could struggle with in terms of your policy issues is whether or not you should release that information to the public and generate the crisis all over again. When this thing hit, all right, *initially*, the only contaminated seafood was right here in the James River, okay? The oysters, the blue crabs, the stripers further up in the estuary were not contaminated, and yet, when the information went to the public, there was a total depression of all seafood consumption all the way from North Carolina to Boston, mmkay? I mean, just total! Total deprivation of economic interest in seafood right across. Same thing happened in PBB; we contaminated the dairy cattle, you couldn't sell *any* Michigan produce—meat produce: dairy, poultry, beef, chicken, swine, you name it, okay? That is, the public was *not*—[you] know, we find enough to be able to realize that it was one hotspot that was dangerous, all the area around it was clean. The only contamination, initially, into the Chesapeake was a bluefish that came in and migrated, all right? It was two populations of bluefish: one came up in the James and came back out again and the other one went straight up. If you actually plot Kepone in the populations, it was bimodal; these were the ones that migrated in, these are the ones that didn't. Trouble is, you couldn't tell by looking at the bluefish which ones were contaminated, okay? Only an organic chemist could tell you, and you wouldn't have the money to find out.

The other interesting thing is: here's Maryland. Blue crabs in Maryland didn't have any Kepone. Distribution of Kepone in public record stops right there, and by political declaration, blue crabs in Maryland were clean, okay? [*laughter*] We had the same thing true with PBB in Michigan—Ohio [and] Indiana didn't have any PBB. The distributional boundary was a nice, straight line. Just amazing how well-behaved that chemical was. So you also get several of these kinds of patterns.

Well, it's… probably the best example I can give you to illustrate the complexity of that problem. I can't sit here and give you neat solutions like I can with some of the other ones; we don't know what to do with this one. If you've noticed that Allied Chemical got fined thirteen and a half million dollars, which is the largest pollution fine I know of in this country. It's kinda interesting how that happened 'cause Allied Chem went, "Not us! We had nothin' to do with it!" Life Sciences declared bankruptcy, we couldn't sue them. All right, what happened was Bob Huggett, who's a biochemist, a marine geochemist, down here at the Virginia center for marine sciences right on the lower Chesapeake, had been studying DDT and oysters, blue crabs, and fish back in 1955… 1958, in that period, and had put fish in his freezer and kept 'em. And this was back in the time before Life Sciences was operating and Allied was still operating the plant, so he went back and he got those fish out of the freezer and he analyzed ‘em. And they had as much Kepone back in ‘58 as they had in ‘75, and that was the information that the judge used to fine Allied Chemical thirteen and a half million dollars. If those fish had not been in the freezer, that industry would have not been fined one dime, they’re absolutely legally free, mmkay?

Now, this kind of a situation, there isn’t any way that people are gonna ignore that. You see one of those things and, you know, the impact on the people in Virginia was devastating, and it still is, and if we don't find a solution to that, that thing is going to be his head again, and again, again for a long period of time. That's the kind of case study, all right, that was a major motivating force behind the Toxic Materials Act. The state of Virginia attempted to essentially handle it bureaucratically and it blew up in their face, with a lot of alienation between the people and the government. It was a situation that—I can't prove it—EPA tried to get criminal action against the officials of Life Sciences and to get criminal action, you gotta prove intent to hurt, and they couldn't prove that so they dropped their case. There's no question in my mind that these people didn't know what they were doing. They knew—they designed—they built Kepone, they had the patent on it, they developed it. They knew damn well what its toxicology was, okay? And now anybody—nobody dumps 10% of their productivity… A lot of it was dumped at night; we have a sanitation landfill down there now. They dumped a lot of the stuff at night, didn’t tell anybody. There’s contaminated groundwater. The more you look, the more you find. It’s probably an extreme case in terms of industrial irresponsibility, but I can show you cases in Michigan of not quite this scale where the same kind of thing goes on, particularly with small, independent industrial waste haulers, particularly with small, small corporations that are just getting started that are operating in a very margin so they gotta cut corners just to stay alive. That's where, essentially, you run into this kind of a risk.

Now, the other situation was PBB in Michigan, and it has some similar things so I won't repeat those, but it also has some different properties. PBB is polybrominated biphenyl. This is a fire retardant. It’s a compound—in this case, it didn't intentionally be dumped in the environment. It’s a compound that accidentally got mixed up in the dairy feed. There was a small Michigan Chemical operating here in the state [*pointing to map*] right about there, all right? It was making this as a fire retardant… It’s kind of interesting, you can go back in the records and both—I believe it was DuPont and Dow Chemical looked at this product about 10 years ago and decided not to make it. There’s many other ways to make fire retardants, and it was in their own judgment that this thing was too environmentally risky and didn't need to run the risk of further environmental contamination to make a product to sell; they had other alternatives. Michigan Chemical was, again, a very small little operation—they own the bromine deposits there in Michigan—and so in the same little constellation of buildings, they were making this

PBB, this FireMaster, as it was called, all right? In the same—right next door in the same little shed—right next to that shed—they were making an animal feed that was a nitrogen oxide that went into magnesium oxide, it was an additive in dairy products called [Nutri]Master. So these two little sheds side by side, one of 'em making FireMaster, one of 'em making [Nutri]Master, both brown sacks with different labels, okay? You know, just the same label but different names. And here's some guy making a buck sixty-five an hour runnin' a front-end loader, okay? The invoice comes along that says, "I want the 18 sacks of animal feed." The guy makes a mistake and loads up FireMaster instead, okay? Now, again, in this particular case it was documented—it was a human accident—but here you got a case where you got a routinized job, okay? We all know from past experience that where you expect human error is where you've got some mundane job you do it, you know, 20 times a day and after a while you get—you don't even read anymore—you go, you just pick it up and do it. It's just a matter of time before that happens.

So the message there is you shouldn't allow *any* storage, transportation, and production of a toxic material and something that goes in animal feed in the same facility, okay? For the same reason hospitals, they don't put, you know, salt and sugar in maternity wards or in the, you know, baby wards, because it's just too damn easy to mix 'em up. So you just absolutely separate the whole support system; so physically, you start with the assumption a human error's gonna happen, and you make the system idiot-proof. There's no way you could protect yourself from a human error in a situation like that; that's the message we learned from this one, but we learned it the hard way.

What happened is this stuff got mixed in, it went off to Michigan Farm Bureau, okay? Michigan Farm Bureau is a quasi public/private institution set up for farmers—it's their own institution! It wasn't out to, you know, it wasn't out to damage its own society. The guy there—two human errors back-to-back. The invoice says "animal feed," the bag says the mix… you know, FireMaster. It was probably mixed mechanically, the guy didn't even read it. It went in. It wasn't caught. The stuff diffuses out to the state and it's animal feed, and that's the reason that I know damn well that it went cross to Indiana and Ohio 'cause I've talked to the guys that transported it, but those states formally didn't have PBB. But it essentially goes out to all the little, you know, farm communities with their local graneries, and the guy comes in, he grinds his corn, he dries it, he adds it to animal feed, he sells some of that to his neighbors, there's an instant diffusion system that goes like that. There's an infrastructure, in this case, that maximized the rate with which that stuff spread.

Now, again, we have the Department of Agriculture, it's a regulatory agency. We have a lot of meat inspectors and dairy inspectors whose job it is to go out and systematically monitor, you know, milk and cheese and butter, ice cream, from all the dairy, you know, farms in Michigan to guarantee food quality [so] that this kind of stuff would not get into the human food chain. But the problem is, what do you monitor for? Remember I mentioned, you monitor for what? The standard crises of 10 years ago, ‘cause you've got standard off-the-shelf technology—you got standard equipment, you’re handling 200 samples a day, all right? It takes two days to handle one milk sample to do an analysis of PBB. There’s no way you’re gonna systematically monitor for that, besides, nobody expected it anyway! How would you know which organic compound you should monitor, from—of the *two million that are out there*! So there’s no way! All right?

So what happened, this thing goes out, several weeks go by, nobody catches it. The farmers come in, they’re probably right across from them, they say, “Hey, my cow is sick.” Say, “Well, what do you mean they’re sick?” “Well, they don’t look good! Their eyes are droopy, you know?” They go out and they milk the cow twice a day. It’s like your dog; you can tell when he’s not feeling well, he just kinda droops around. The point is that they couldn’t quantify it, they couldn’t put a number on it, they couldn’t be very specific about it. Department of Agriculture, I’m from Michigan State University, a land grant institution. We have a whole extension service—experiment service—that goes out and helps farmers, and they sent out a group of, you know, experts, nutrition, *bacteria*, that kind of stuff, they looked around, didn’t find anything. Came back and filed a report, said, “Must’ve been mismanagement.” Okay? Exactly the same response as what? The doctor giving that guy a tranquilizer, right? The standard kind of diagnostic pathologies weren’t there. So you say, “Well, this must just be in their head. There must be something that’s kind of soft.” The point is the existing agencies are so… push so hard with existing regulatory… they haven't got *time* for a crisis. They don't want one. It’s not [that] they don’t care, it’s that they—before they *stop* doing what they’re normally gonna do—just keeping permits flowing, and keeping the system operating—you gotta *convince* them that’s got something’s that’s a crisis. You can't expect them to just be sittin’ there waiting for you to come in, and say, “Hey doc, I got a problem.” All right?

And so it goes on, several weeks go by. The guys come in—farmers come in—they’re keepin’, you know, records of the milk production. It's going down in time. Now you got somethin’ quantitative. Aha! Somethin’ real. It’s goin’ on. You go out, you do your… again, normal kinds of investigation, nothing shows up—everything’s negative. Now, stop and think about it. What does a negative sign mean? What if you go out and see a big fat zero? I go out and monitor, I don’t find somethin’. Does that mean it’s safe? Or does that mean, for all you know, you haven't measured the right thing? That's the reason for no hypotheses being like they are. If I measure somethin’ and I find it, I know where I am. I don't find it, I don't know where I am. Zero could either be nothing’s there, or zero could be: I’m using the long observational technique and I'm not gonna see it, and you can never tell the difference, okay? That's the reason the law was written the way it was, and it's the reason scientists operate that way… but the law today says it's the opposite, all right?

Now, eventually what happened is… this's about 6-8 months now. Actually, the pathology in the cattle by now is really gross; their hooves grow up—have you ever see that? If you saw the *60 Minutes*—grow up in great, big arcs like this. They get knock-kneed, okay? Bow-legged. And they're actually droppin' dead on the ground, so that everybody knew we'd get something wrong now. So they quarantine the cattle. What they're doin' is… you go to the biochemist, you go to the toxicologists, and say, "What's the safe level?" Well, there's no studies been done! You know, you go in to your University and say, "Tell me about the toxicology of PBB." You go to […] and nothing's gonna be there. That's a typical kind of situation. Things are there for the past crises, not the new ones. So for a while, again, the decision-maker, what the hell do you do?

Now, when they first got into this thing, it took 'em about nine months to find out, and the first indication was a little bit of bromine. As it turns out, as I mentioned this morning, Michigan has three big industries and they're all energy intensive. That was the summer of the oil embargo. So here's automobiles and recreation in a big economic slump, and you've got a little bit of data that says bromine in animal feed, and you don't have any idea where the hell it came from, okay? And you shut down the third remaining industry. Boy, you talk about someone being in the hot seat. Okay? It's really easy to be at Monday morning quarterback three years later saying he shoulda had better insight, okay? But if you're the guy sittin' there with that kind of information, I tell ya it's one heck of a different situation as to how… what you're gonna do and how you're gonna justify it.

As it turns out, what they were doing was that they were setting their standards, in terms of action levels, by what they could measure, and it was 5 parts per million. Then they could get better technology and it was 4 parts per million, and each time they dropped a level, of course, the state had to quarantine another three to four to five thousand cattle. They finally got it down to 3 parts per million, okay, and everybody's sayin', "Hey guys, this is *safe*. Relax, PBB is not that toxic. It's only mildly toxic, nowhere near as toxic as Kepone, okay? And we're beginning to get toxicological data and it doesn't look like it's that dangerous." Of course, the public exposed to this thing is not very sympathetic by now. In Michigan, the data went right from the biochemist's shelf immediately into the newspapers. It was the opposite of Virginia. Direct, one-way flow. It was sensationalized, the whole works. You could read articles in the Grand Rapids newspapers by editors editorializing on this thing where they're debating whether the kids of these farmer families that consumed dairy products before it was diluted with uncontaminated milk, whether they'll live past the age of 21. They did some surveys in terms of surveying these kids as to whether or not there were, you know, health statistic problems you could identify, and of course the parents of these farm kids claimed that they were, you know, all kinds of things they were seeing: they didn't sleep well, their grades were dropping, they were very, you know, they were very psychologically disturbed, but what's it due to? It is due to, essentially, the toxicological effects of this compound? Or is it due to all the stress of the economic dislocation of the farms? Or the fact that now they're sensitive to it, they're seeing things they just weren't observing before? How the hell do you tell? You know, that kind of data is almost uninterpretable, there's no way that you could tell what the heck that looks like.

About this stage of the game, we had buried over 25,000 dairy cattle. Okay? You talk about the economic impact where the state quarantined these things, shot 'em, and buried 'em. *Tremendous* economic impact on the farm families, and if you don't know anything about dairy herds: you don't go and buy a dairy herd, you breed 'em. You know, these are handed down from father to son. One calf a year, genetically inbred, you know, very highly controlled. It's part of the farm community, you don't just go out and commercialize somethin' like that. There's no way you could put a dollar value on it, okay? At this stage of the game, the governor was *really* takin' a beatin'—the whole state legislature was takin' a beatin', okay? Saying that, "Well, we'll go out, we'll bring in some external experts. We'll bring in some independent… a panel of independent blue ribbon people to give us our credibility." And Professor Selikoff, who was a very fine toxicologist from New York Sinai Hospital, came in with a team of people and he looked at this and he saw just about the same literature that existed, of course, "Well, there's nothing there!" And after three or four months study, they released to the newspapers their results and essentially they said, "We don't know about PBB, so there's no data. But PBB—" listen to this now, "—it's a close chemical cousin to PCB, and PCBs are thought to be carcinogenic, and so if you have to err, you should err on the conservative side and if you should… if you can measure it, you better kill the cattle," and [they] recommended one part per billion… okay? Which is *one* hell of a gap. A 300-fold difference. Now, what little credibility was left in state government at that stage of the game went right down the tubes. I mean, the impact of that onto the… you know, the average person walkin' the street only can believe what he reads. And what this meant was that for the individual, every blue ribbon committee absolutely said, "Hey, state government has been conning you right down the line." Okay?

Now, this was about a year-and-a-half ago. Our state… the federal government kept the level there. Our state government, with tremendous trauma of public hearings and so forth in the last nine months, went through all kinds of investigations and public hearings and people claiming their kids were killed and other people claiming it's all in their mind and the whole works, and decided to set the state level at 20 parts per billion, which is the lowest level that's quantitatively detectable. We now have something like four to five hundred cattle. So we had buried most of ‘em up to here. We didn’t have anywhere to incinerate ‘em, we had to bury ‘em. We have about four to five hundred cattle now between 20 parts per billion and 3 parts per million, and since… well, by state law, now, we have to… the state has to officially take these cattle off, pay the farmers $800 apiece and do somethin’ with ‘em. The same legislature that passed the law sayin’, “Hey, you gotta quarantine these things,” turned right around and says, “But you can’t bury ‘em in my Congressional district.” Every damn one of ‘em… okay? And *every* site that the state went to find… to get a permit for burial, the state legislature and the people rose up, got a court injunction and said, “Not here.” Right across the state, mmkay? So of course they had to do something with the cattle sitting there. So what do you do with ‘em? They’re not gonna go away, okay? And so then what happened, they tried to get permission to hold ‘em on a researched wildlife area so they could decide what to do with ‘em. The court there—the local citizens got so concerned and so uptight, they got a court injunction prohibiting from holding them on the surface. So here we got a state that says, “You gotta take ‘em, you can’t bury ‘em, you can’t keep ‘em on the surface.” Mmkay?

[*audience member shouts something that causes a bit of laughter in the audience*]

Well, one of the guys commented we can put it and shoot it into orbit, and we have the herd shot around the world. [*laughter and some groans*] But, no, you… Stop and think about it! And again, this… Michigan’s not a backwards state! These are a bunch of people in the state who have learned through the public media and have been scared absolutely senseless. And the state legislature is reflecting that same paranoid… it’s no longer a scientific debate at all. The sum total—if you take those four to five hundred cattle—you know the sum total amount of PBB in those cattle is less than an ounce—a teaspoon full? Do you know how much 20 parts per billion is? Okay? There’s probably one molecule in this whole room. There you got one ounce, and here we—if you had one good house fire—what they don’t realize is what was PBB made for? Well, it’s a fire retardant; it’s in baby’s clothes, it’s in your plastic handle of your telephone, it’s in your… a lot of it’s in insulation in the house. What they’re talkin’ about is that one little accident that got here. What about the several million pounds of the stuff they’ve been making for the last 10-15 years, okay? You get more of that released into the atmosphere with one good house fire than you would from all 400 of those cattle. But it’s, you know… that’s no longer the point, the point is it’s caught up in this *tremendous* social trauma of what do you do with toxic materials, all right? And it's gotten to point where we finally got an order of court injunction to go up here in Kalkaska and take a burial pit, and the judge ruled that they had to line it with 20 feet of clay. The total cost is to two and a quarter million dollars to haul in by truck and load 20 feet of clay all the way around six sides, and they did that. They got that done three weeks ago. There were 600 people were out there demonstrating, hanging the government in effigy, okay? They got a court injunction once they developed the pit, not to let them use it, and it was going to the Supreme Court in Michigan. They went up last week to the Supreme Court, they asked the local court to give ‘em advice; that came in two days ago, and they said, “Well, since you built the pit, go ahead and bury ‘em for the next six months, then go to incineration, okay? Of course there’s no incinerators built, and that’s gone… that went back to the Supreme Court today, supposedly.

Now, here's a case where, you know, if you argue in terms of science, there isn’t any rational way whatsoever that this kind of thing should be happening. If you look at it from the point of view of the *gap* between the knowledge of the average public has walkin’ the street dealing with organic toxic materials, and what the bureaucrat says he has to do to solve a problem, that information gap is, to me, *the* single biggest source of problems. I’ve seen it with Kepone, I’ve seen it with PBB, I’ve seen it with storage of nuclear waste, where the solutions to these problems to protect the environment require technology to acquire kinds of mitigating techniques that the average public has no knowledge about whatsoever. And it’s very, very vulnerable, then, to this kind of mass hysteria game where, you know, I can show you cases we’re now monitoring, I can show you compounds that are orders of magnitude more toxic being dumped by industrial waste haulers down open sanitation drains, being dumped directly in rivers at night in the state of Michigan right now. These are orders of magnitude worse than PBB. This is somewhere between Kepone and aspirin in terms of the toxicology, okay?

I’ll show you the problems one has and… Michigan Chemical, of course, when this happened, did the same thing that Life Sciences did: they immediately declared bankruptcy. Now, the problem was, they were also discharging in the Pine River. The Pine River runs right through that plant and goes in the Saginaw Bay of Lake Huron, and we wanted to, essentially, get them to stop discharging as fast as possible, all right? The problem is, our Attorney General says, “Yeah, but if you just take them to court, the average court, you know, the time for resolution in court’s about 18 months, and they can legally keep dumping during the 18 months.” So the state, then, in order to get them to stop right now [*snaps fingers*] had to give them a general release, had to give the industry something that they wanted, to stop automatically, all right? And they gave ‘em a general release so that the state would not pursue any legal liability claims of all compounds, of all amounts in all waters both known and unknown ‘til 1978, okay? And they shut down the plant.

Six weeks later, we found a sanitation landfill 20 miles away with 356,000 pounds of PBB buried in it. That's still sitting there right now, and of course we can't—the state, I mean—we criticize the hell out of ‘em for doin’ it, but they felt at the time they had to do it. They cannot pursue… legally, okay, economic penalties now. Both Michigan Chemical and Michigan Farm Bureau paid off insurance, the largest environmental insurance fees about 30 million bucks, of course that was the extent of their coverage. Michigan Chemical has declared bankruptcy. The federal court, just two weeks ago, gave them each a $1,000 fine in each of four accounts under a no contest charge, which means it stopped all testimony in federal court, so there's no way to pursue that, okay?

The question is: what do you do with this kind of thing? I mean it's very easy to say, "Well, we just find the guy responsible for this thing and hang him." [*writing on the board*] The guy that actually made the mistake with the forklift, what's the point of hanging him? Okay? The basic mistake was allowing two operations to exist in the same facility where this kinda thing goes on. Now, as a result of this, in Michigan, we have analyzed a number of alternatives. We made nine recommendations to the governor, he's implemented all nine of 'em. Very briefly, the kind of things that we recommended, none of 'em will *stop* the event—there's no way you can go out and anticipate where this is gonna happen and stop it. The best you can do is get ways of responding rapidly and get the authority to go in and mandate.

We now have… legislation has passed that sets up a toxic commission in the state that has police powers, so that as soon as one of these things break, it can subpoena all records, it can put a halt on all production, all shipment, all sales of any compound in the state, unilaterally. And this is a citizens' commission with seven members appointed by the governor—no state officials, okay? We have got appropriations in the state to build a dedicated incinerator that's a stable design, and probably get the private enterprise sector to run. I'm on the group to design the damn thing… where we want a dedicated facility to do everything from burning cattle to handle industrial waste of all kinds; everything from incineration to lead oxidation to deep well disposal. It's a dedicated site and it requires any industry in the state that's dealing with a toxic material either to prove that they have their own waste facilities themselves, or be forced by regulation to operate within the state facility—one or the other. They've also got legislation to set up a manifest system that if you have certain kinds of compounds that are toxic enough to warrant this, that… the paperwork is tremendous. To actually have an manifest invoice system where you track the total load of this stuff. Where if General Motors produces 400 tons of compound X that's toxic, they actually have a manifest system recording where it goes and who's got it until you can actually show it's disposed of. Okay? The same way we do with radioactive waste.

But that is a very, very costly and difficult thing to implement, and you won't do that unless you have a really bad—you know, a bad kind of toxicological problem, or potential problem. We've also implemented a specimen bank program. Remember I mentioned the fact that the only way Allied Chemical was held accountable was the fish that he had in the freezer? We've got the money to the legislature and we're working with EPA to set up a specimen bank in the Great Lakes where we are storing organic samples at -80 degrees, where the organic integrity of the sample is maintained. So what you do is you go in and you take a sample fish […] of the Great Lakes, and you do that chemical fingerprint I showed ya, okay? And you store that in a computer and you put the rest of the organic sample in liquid nitrogen or something that will essentially maintain the organic nature, so it won't decompose in time. So it won't stop the problem from happening, but if we had that kind of databank and all of a sudden 10 years from now we got a new crisis… the unknown, it hits, okay? What you can do is you can go back and you can sample through your databank on the computer, and find out where that spike was and where it showed up. And you know what samples are there, and you go out and take a small amount of that sample, analyze for it, and very rapidly tell where the problem started, how far it's gone, what the levels were, and who's been affected. It's like we're doing that now with blood in humans. It turns out that public health kept blood samples for human health disease diagnostic reasons in a blood bank. And you can go back now—and we have—and systematically monitored for PBB, and in the fall of '73, winter '74 PBB shows in the human blood, just like that. Beautiful. And you can just track it from that point of discharge how it diffuses through the state and how fast it's going.

Now, the one other alternative that often times comes up is people say, "Well, why don't you just ban these things?" Often times we'll say, "Look it, so much for these kinds of organic compounds, I don't wanna live with 'em. No matter what you say as a technocrat or bureaucrat, I don't want the risk, okay, of having to deal with that kind of uncertainty. Take the damn things off the market." Those of you that heard John Billingham yesterday talking about the human settlement. That he's talking about that human settlement in the L5 orbit. I was involved last summer with designing the interior ecological support system for that thing. For the first time—what this is, it's an L5 orbit off the moon, they want to put a human settlement up there. The sociologists tell 'em that 10,000 people is the smallest social unit you could isolate and keep happy so that work efficiency is up, so they've designed that thing for the minimum of 10,000 people, okay? And they want to put that thing up in space and keep it there and have 'em work like hell and be very, you know, it's kinda like an old pioneering town or the old gold mining town, where they want to have a very rustic existence but a very high work efficiency.

And the sociologists and humanists have gone through and analyzed case studies like, you know, sailors in nuclear subs that are isolated for nine months at a time, or crews of people down in the Antarctic where you put 'em down there for a year at a time. They've also done studies on the astronauts in the Apollo program, and what they've found, at least in their interpretation, is in order to keep that kind of high work ethic, you gotta keep 'em happy. And the way you keep 'em happy is to have a rich array of consumer goods: good food, bright colors, all kinds of novelty, all kinds of trinkets, okay? And of course they're assuming, then, the head architect for this thing came from General Motors, and they're assuming all kinds of elaborate fibers and the neat kinds of things you'd take up. And so we walked them through this whole Kepone, PBB, toxic materials… 'course you get up there in the closed ecosystem and you haven't got room for a mistake, do ya?

'Cause see, down here on Earth the oceans, the atmosphere, the soils are our big sink—they're a buffer—so you make a mistake and, to a great degree, the environment can assimilate it. It doesn't go away, it just kinda stores it, absorbs it, binds it up. Where it takes a really major mistake before it hurts you. Kepone and PBB are not unique events that go on everyday. The only thing unique about it is it happened with enough of it that the spike was so high, you couldn't afford to ignore it. Well, in something like a spaceship with no sinks, no buffers, the system's online and any little mistake comes along with the same amplitude of error, okay? So the control system there is infinitely more complicated. If we walk them through these things, and of course they say, "Well, there's no way we can control those. So what we'll do is we'll just outlaw 'em; we'll have a *list* that says any of these toxic compounds we will not allow on our little closed ecosystem." Which is an interesting kind of intellectual exercise to go through.

So what we did is we went down to Palo Alto last summer, we called the EPA office at San Francisco and said, "Hey, give me your list of toxic materials," and they have 129 of them on their list. Well, that's not only because there's 129, there's 129 that we know how to monitor, and I'll tell you the first one. They keep adding them as they get better technology, but there's 129 on there. So we took just the top 30, and went back to the architects, said, "Okay, now let's go down through all your plastic toothbrushes and your, you know, television sets, and your bright acrylic paints on your wall, and any one of these things that either has one of these 30 compounds or breaks down into one of these as some by-product, we'll take off the list." And you can you imagine what happened. What you end up with is a titanium shield with silicon windows, both made out of moon rock… [*laughter*] okay? And that's why, again, one of the reasons that I made the statement that I think that the Toxic Materials and Substances Act is one of the most pervasive pieces of environmental legislation; that if you really tried to enforce that, the letter of that law, and you stop and think to the degree to which our society here has become dependent upon synthetic chemistry for a very, very diversified, enjoyable lifestyle, okay, and our primitive knowledge is to what… which of these are the bad actors and which are not. It's gonna have a *tremendous* impact in the near future. We'll begin to see it in Michigan right away. Just last week… the gypsy moth is a forest insect on the East Coast that's raised an awful lot of problems. Now it's in Pennsylvania and deforesting large areas. We have small resident populations in Michigan. Department of Agriculture wanted to spray with Dimilin, it's an insecticide, to try to eradicate the gypsy moth this year. They had claimed the thing was absolutely safe, but they're gonna spray about 140,000 acres of farmland—all the trees including those around the farms. Some of 'em are organic farms; organic farmers didn't like it. We got a report just last week that his thing breaks down into something that looks like it's potentially carcinogenic. The data's lousy. The study is very marginal—the National Cancer Institute agrees that it's very preliminary data, but the *law* doesn't allow that. The new law says the data has to be absolutely ironclad it's safe. If there's any doubt at all, that thing can't be sprayed. That is, that law has reversed the scientific process. Before you had to keep workin', okay? Until you could actually show it was dangerous. Now, all the data has to be is not conclusively zero effect, which makes it a brand-new ball game, and that legislation lays out not only mutagenicity, carcinogenicity, teratogenicity which is, you know, embryological development—abnormal development—but also ecosystem, community, and population effects ecologically. This spells out the total array of toxicological pathological things, both in the human ecosystem, and the natural ecosystem.

Now, where they're gonna go from that is, again, look at one of these examples where there's a major crisis: Kepone and PBB. The public reacts, the legislature says, "Well, we'll solve that problem. We'll pass a law saying it won't happen, okay? Appropriate 100 new positions for EPA to carry out the law." You could take all the biochemists, all the toxicologists in this country—both private and public—and you couldn't carry out that law. So obviously what they're gonna have to do is to pick and choose. And someone's gonna have to decide, "Well, these six compounds we'll start on first and we'll get conclusive data, and then we'll take the next six." There isn't any way, or if they do get sucked into trying to take on all 30,000 at once, it's gonna be just total chaos. But it's one that you ought to look at. It's one, that if you wanted to lay out a interesting case study in terms of a generic set of problems, it won't take you very much to pick up the phone and look at your industries here in Oregon. I could tell you the ones in Michigan 'cause I've dealt with 'em. I'll guarantee you got the same types of problems here. A different set of companies, a different set of compounds, but the same technology. It'd be very easy, I'm sure, to get ahold of your local public health and DNR and so forth, and get good example you can use as case studies—not that anybody has the right answer, here's a case where with environmental decision-making that nobody can just tell ya, "I know how to do it," except do nothing, which you're not gonna do. And it's an interesting one in the sense that there're no, you know, concrete right and wrong answers—it's easy to tell the ones that are bad, but pick one that's new and try to decide whether or not it's one you should outlaw or not, that's where it's really tricky. Okay? I think my time's up. We'll continue our discussion later.

[*comment in the background*]

COOPER: Which one?

[*inaudible response; voices in backgroupd*]

COOPER: This gentleman has a question here.

[*inaudible question*]

COOPER [at a slight distance from microphone; some phrases are unintelligible]: Well, yeah, we… I met with a group here 11 o'clock this morning for questions and this came up. Interestingly put, it has not been released yet, it's [been] done by the Bureau of Commercial Fisheries, where the result of this is monitoring toxic materials in fish on both Pacific and Atlantic Coast within a forty-mile limit. And… tuna fish, swordfish, cape, flounder, red snapper, and lobster, those fish are all above the FDA action level of 5/10ths a part per million of mercury. If you heard about the tuna fish, that was the one with the smallest industry to make a case out of it. It now has got data that… the interesting thing is, as far as they could tell, these are natural levels, they're not pollution. These are natural food chain accumulations of a toxic material, at least by law, and that is the base level. Now, the way they're trying to establish that is, of course, going back into museum collections—but you have to be careful, of course, those preservers didn't have mercury in 'em, so you do this for different preservers, different lengths of time, different styles of potential contamination. And of course, with mercury it's inorganic and won't decompose, so you can tell that. Or […] glass, you have to be careful about that.

The other thing is [if] you look at it regionally, the same levels over hundreds of miles. That is, the areas that have high industrial affluent and those who don't have the same levels of mercury. So you put those two pieces of information together, and it looks as if these are natural, endemic levels of mercury, okay? And then the policy question, the new one, is like, "Okay, well, what do you think of that?" And the average person I've dealt with [says], "Well, obviously the level is just at the wrong level,"... because somehow if that it was a man-made pollutant, it's fair to regulate it. If it's a natural level, then the people oughta have the risk to expose themselves as they want. You wanna eat poisonous mushrooms, it's your choice, but you shouldn't regulate it. It's an interesting debate. If you really enforce the FDA levels like it is right now, you would not let any of those fish […]. Now, if we were to dodge it right now, and not make it a public issue out of it, then one of the big lobbyists against that is Weight Watchers. They lobby like heck, and you know why, they eat fish, […] diet, low-fat and […]. And of course, you can immediately say, "Well, wait, well, what makes you so sure that your 5 parts per million is that accurate? […] 100,000 as a fudge factor?" It's in there. But now you ask yourself the question, "Well, if you can rationalize moving it up to 1 part per million, is it safe?" Part moves down to 1/10th of a part per million, what makes you sure your erring […] way? It gets pretty wild! But by law, FDA has to set those; some bureaucrat has to put a number on that. The law… then the law will say, “We don’t know enough, we’ll wait.” So that’s an interesting one to watch. I’m not sure what they’re gonna do with it. They have not made that information very public yet.

[*inaudible comment*]

COOPER: You won’t live long enough.

[*laughter; voices in background; program ends*]