(The Court recessed from 3:10 p.m. to 3:25 p.m.)

DEFENDANT'S WITNESS, ROBERT GEORGE KALEY, SWORN

DIRECT EXAMINATION

QUESTIONS BY MR. FRUEHWALD:

Q Would you state your name, sir.

A My name is Robert George Kaley, II.

Q Would you spell your last for the reporter?

A K-a-l-e-y.

Q Mr. Kaley, are you currently employed?

A Yes, I am.

Q By whom are you employed?

A Employed by Monsanto Company.

Q Where did you grow up, Mr. Kaley?

A I grew up in South Bend, Indiana.

Q Where did you go to college?

A I went to undergraduate school at Purdue University.

Q What degree did you get there?

A B.S. in chemistry.

Q What postgraduate education have you had?

A I attended the University of Illinois and received a Masters degree in analytical chemistry and also a doctorate in analytical chemistry.

Q Are you a member of any professional associations?

A Yes, I am.

Q What?

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A I am member of the American Chemical Society, the American Society for Testing of Materials. I am also a member of the American Society for Mass Spectrometry, and a member of several local groups in St. Louis.

Q Is that where you currently work is in St. Louis?

A Yes, it is.

Q What is your current residence address in St. Louis?

A 1965 Schoettler, that's S-c-h-o-e-t-t-l-e-r, Schoettler Valley Drive in Chesterfield.

Q Mr. Kaley, have you written any articles in your field of analytical chemistry?

A Yes, I have.

Q Have you written any articles with regard to PCBs?

A Yes, I have.

Q Can you describe to the jury what articles you have written in that area?

A There are approximately four or five articles which have been written over the years. I wrote in about 1975 co-authored with some of my co-employees an article describing the general characteristics of PCBs and how they behave in the laboratory and in the environment.

I also wrote a study summarizing some animal feeding studies that we had done and how the PCBs behave when they are being fed to animals and that exposure to the animals is ceased. I wrote, co-authored a paper with a group of other

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industrial chemists describing the analysis of PCBs in a variety of materials of industrial concern, materials that make the analysis of PCBs very difficult.

Q You have mentioned two papers, the first paper on the characterization of PCB, what was the eventual audience for that paper?

A That paper was presented at an EPA-sponsored symposium at Chicago, Illinois in 1975. The EPA had gathered together a group of world reknowned scientists actually to describe what was known about PCBs at the time, what various researches were being done on those PCBs, and to discuss options for the management of PCBs.

The paper was also presented by me at another EPA conference at a laboratory near Detroit, Michigan about a year later.

Q And that last paper you talked about in terms of the -- with the other industrial chemists in terms of detecting PCBs and the difficulties?

A Yes.

Q What was the use of that paper?

A That paper was also presented at an EPA-sponsored conference in 1982, I believe. Anyway, sometime during the 1980s. That paper was much the same. It was more describing the analytical chemistry of PCB. But the conference was organized for the same reasons that the original conference

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was, it was to relook at the PCB issue for various worldwide researchers, describe the kind of results they were seeing in their laboratories, and to discuss what the implications were for PCBs in the environment at that time.

Q When were you employed by Monsanto Company?

A I joined Monsanto in December of 1973.

Q And what positions did you hold at that time and thereafter?

A Okay. I joined the company as an entry level chemist in 1973 as an analytical chemist right out of graduate school; began doing analyses on PCBs immediately on my employ. I joined a group whose primary focus was the analysis of PCBs and investigations of the environmental characteristics of those materials.

About two years later I transferred to another associated group where I developed skills in mass spectrometry. In about 1979 I was made a group leader of an environmental chemistry group which also had some responsibility for the analysis of PCBs.

In 1981 I transferred to our corporate laboratories as a specialist in mass spectrometry.

And about 1985 I transferred to our corporate environmental policy staff to work in a more administrative role on environmental problems.

Q Has your work with Monsanto and your research given you a

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familiarity with the physical characteristics of PCBs?
A Yes, it has.
Q Can you describe for the jury first of all what is a chlorinated biphenyl?
A A chlorinated biphenyl is a molecule, a common organic -- is based on a common organic molecule which is called biphenyl. It is essentially a double ring structure. Two rings are connected together. After those rings have been connected together, there are ten positions, five on each ring, where a chlorine can be attached to that molecule. And APCB is one of 209 possible chemicals that can be formed by attaching one or up to ten chlorines to these two rings that are hooked together.
Q Can you give us the terminology of the various subdivisions of PCBs, congeners, isomers, what those things mean?
A Some of the language I'll be using gets a little confusing at times. As I mentioned, there are 209 possible PCBs. I will speak of these each as -- each one of these as a congener which is kind of a chemical cousin. They are all related but -- there are, in fact, 209 separate compounds that can each of which could be called a PCB.

There are several ways of grouping these compounds. And one of the common ways of grouping the compounds is to count the number of chlorines that are on both rings together. So, that if -- we could have one chlorine on the two rings, on

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either of the rings, we would call that a mono, meaning one, much like mononucleosis means you have one cell in your white blood cells.

A monochlorobiphenyl contains one chlorine. We could then go all the way up to ten chlorine and we would have a decachlorobiphenyl. Each of these groupings by the group of chlorines on the molecule is called a congener class or class of similar molecules, the similarity being the number of chlorines on the ring. And these are also often spoken of as homologs which is a term you may have heard.

Q Are you aware of the commercial mixtures of PCBs that were produced by Monsanto?

A Yes, I am.

Q Let me show you what's been marked as Exhibit 5231. Does this chart display some information about the distribution of molecules in various mixtures?

A Yes. This chart is kind of an overview chart describing the composition of the various products that Monsanto manufactured and sold as materials. And it is -- we used the term homolog just a minute ago. It talks about the make-up of these Aroclor mixtures by their homologs.

MR. FRUEHWALD: Let me stop you there. Let me offer at this time, Your Honor, Exhibit 5231.

MR. KARAGANIS: No objection, Your Honor.

THE COURT: It will be received.

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(Defendant's Exhibit No. 5231 received in evidence.)

Q Can you see it there, Bob?

A Yes.

MR. FRUEHWALD: Your Honor, should I move it for you?

THE COURT: No. Just be sure all the members of the jury see it. I think you've got it turned around so some of them on the back row can't see it too well.

Q Mr. Kaley, can you explain this portion of the chart which refers to the as-produced Aroclors?

A Okay. Monsanto produced a series of products which were marketed as Aroclor mixtures or Aroclor fluids. If we would ignore for a minute the 1016 in the initial column heading, if we look at 1242, 1248, 1254 and 1260, the 12 was an internal code within Monsanto which designated these products as polychlorinated biphenyls or PCBs.

The second two digits, the 42, 48, etc., spoke to the percentage of chlorine in the mixture as produced. So that chemists have a way of measuring the percentage of a given element in a mixture. If we looked at 1242, that would tell us that that material on average was 42 percent chlorine by weight; we weighed all the atoms that were in that molecule, 42 percent of that weight would be accounted for by chlorine. Same for 1254 would be the 54 percent chlorine by weight.

I might speak to 1016 for a moment. 1016 was a material developed by Monsanto during the 1970s to be a more

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environmentally compatible PCB. It's very closely related to Aroclor 1242; and, in fact, contains about 41 percent chlorine by weight. So that, in fact, under normal circumstances we might have called it 1241. The reason it was called 1016 was because as it was developed as an experimental material, a test material for our customers, we had what we called our MCS numbers which stands for Monsanto Chemical Substance. It's just a sequential number of new compounds that Monsanto tests for a variety of reasons. They have nothing to do with the fact whether it's a PCB or not.

Our customers began to call this material by its MCS number, MCS 1016, so that when we commercialized it, rather than changing the numerical designation, we left it as 1016.

Q What do the numbers that are in the columns underneath the various Aroclor designations mean?

A Okay. If we look at the far left-hand column, it speaks to chlorine molecules. This goes back to the homologs or congener classes I just spoke about. So that the first row of that column, row one means that there's one chlorine on the two rings in the molecule, so that would be a monochlorobiphenyl and so on down the chart. If we get to four, that means that there were four chlorines on those rings.

The numbers in the table itself speak to the percentage of each product composing -- or composed of these various congener classes. If we look at 1242, for example, the chart tells us

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that the material contained one percent monochlorobiphenyl or one chlorine biphenyl. It contained 16 percent two chlorine biphenyl, it contained 49 percent or almost half three chlorine biphenyl, 25 percent four chlorine, eight percent five chlorine, and one percent six chlorine.

If we look at the chart, as you can see, as you might expect, as the numbers in the Aroclor series increase, the number of more highly chlorinated materials increases also. So if we look at Aroclor 1260, we note that 38 percent or just a little under half of that material is six chlorines. That then accounts for the fact that it has more chlorine by weight because on average there are more chlorines on each molecule.

Q Okay. Am I correct that given this chart that, for example, the contents of 1016 and the contents of 1260 have only an overlap in these two and otherwise contain completely different molecules?

A That's correct, Mr. Fruehwald. If you look at the chart, whereas Aroclor 1016 does contain 21 percent, tetrachlorobiphenyl, the first -- the lowest chlorinated material in 1260 is, in fact, a four chlorine biphenyl and there's only one percent of that. So there is very little overlap among the molecules making up those two mixtures.

Q Mr. Kaley, have you done experiments and research as to whether the different Aroclor mixtures behave differently in various physical characteristics?

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A Yes. We've done work like that at Monsanto as have a variety of people in other laboratories throughout the world.

Q In what characteristics do the different Aroclor mixtures respond differently?

A Okay. If we think, first of all, as just what does this material look like, there are differences in the products on that basis. The Aroclor 1016 and 1242 are clear liquids, almost like a very lightly colored vegetable oil, a Wesson oil type material. As we go up to 1254, the material begins to look like a thick amber, yellow molasses. Aroclor 1260 at room temperature is, in fact, a waxsy solid. So we have a range in the appearance of the materials.

Another characteristic of interest is the solubility in water of these various Aroclor mixtures. As you know if you put sugar in your tea or sugar in your coffee, you can put in sugar and it will all dissolve, and if you put a little more sugar, that will all dissolve. Pretty soon you get to the point where you can put in enough sugar that no matter how much you stir your coffee and no matter how hot it is, some of that material is not going to go into that solution any more. You have saturated the solution. You can't put any more sugar in that coffee.

The same kind of characteristics can be described for PCBs or any chemical. We put the material in water and try to see how much of that material will dissolve in the water. So

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that's one characteristic we look at.

Another characteristic we looked -- or we have looked at is how quickly does the material evaporate, what is its tendency to evaporate. If you leave a bowl of water sitting in your kitchen over a period of a day or two, that water will disappear. Same thing will happen with chemicals. Some of them will disappear more quickly than others.

So for instance Aroclor 1242 has what we call a higher vapor pressure or greater tendency to evaporate than 1260. Aroclor 1260 has essentially no tendency to evaporate. It will sit for a long, very long time and you will notice a change in volume.

Q What other characteristics have you detected differences among the Aroclors?

A We have looked at their behavior in the environment, how they are degraded by micro-organisms. We've looked at the way that they behave in soil, how tightly they adhere to soil, whether they can be washed out of soil by water or other chemicals. So a variety of things have been investigated for these materials.

Q Let's go through the various items that you mentioned. First the question of solubility. How do the Aroclor mixtures or the molecules differ in their solubility?

A Okay. The solubility, as I said, is the tendency to dissolve in water, so a high solubility means that more

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material will dissolve in water. The lower chlorinated materials will dissolve to a greater extent in water than the lower chlorinated material.

In other words, Aroclor 1242 or 1016 has a higher water solubility than Aroclor 1260. Although we need to mention that in normal terms, the solubilities are very, very low in any case, they certainly will not dissolve in water to the extent that sugar or salt will.

Q Has it been determined by experiment what the maximum solubility of any of these compounds is?

A Yes. The Aroclor 1242, and since Aroclor 1016 is very close, dissolve in water at about 200 parts per billion. So less than a part per million of these materials will dissolve in water.

Q When you talk about the maximum solubility of a substance as you just have, what's the procedure to determine that?

A To determine maximum solubility and determine what we consider solubility, we go through a very -- in fact, what you would call a tedious procedure to make sure we get the maximum amount, the most material to dissolve we can.

We put the material in water. We may, in fact, heat the water to make the material dissolve more easily. Sugar for instance will dissolve in hot coffee much easier than cold ice tea. And we shake the water and the PCB mixture together for periods of 48 to -- 48 hours to a week to be sure that we have

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got as much PCBs in the solution as possible to try to maximize the value.

Q When you say the maximum solubility of PCBs or Aroclor 1242 is in the neighborhood of 200 parts per billion, that's not what you would find in any sample that had not gone through the treatment that you have described?

A That's correct. In general, if you just put PCBs and water together, you would measure a much lower number for the solubility.

Q Over at the other side of the chart there's a reference to different percentages dissolved in water. Can you explain what that's about?

A Okay. As we talked about solubility among the mixtures, we noted that the more -- the lower chlorinated materials dissolved to a greater extent than the higher chlorinated materials. This is really a result of the fact that the lower chlorinated materials considered as congener classes, as the number of chlorines on the molecule dissolve much more readily so that the monochloral and two chlorine materials will dissolve in water at a much higher level relatively speaking than the four or five molecule.

If you do the experiment I described and try to measure the solubility and then look at the material that's been dissolved in the water, it turns out that it doesn't look like the original material anymore. The reason is that the more low --

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the more lower chlorinated materials, for instance, the monochlorobiphenyls go into water very nicely. And, in fact, if you look at the chart where -- let's look at the 1016 numbers, the first numbers in each one.

1016 as a product manufactured by Monsanto only contained one percent of the one chlorine molecule. After we have done our experiment to try to dissolve it in water, 12 percent of the material that dissolved in water is now monochloral or one chlorine biphenyl. The same thing can be noticed for the dichloral. It goes up.

If we look at the four chlorine -- well, that's probably not quite so good. Well, the four chlorine for 1016 doesn't change very much. But you can see that as you go to more chlorines on the ring, the relative amount dissolved in water goes down.

Q You have mentioned another characteristic of evaporization. How do the different Aroclor mixtures vary in terms of their evaporization?

A Okay. The same characteristics that we've described to solubility also apply to evaporization. The materials with less chlorine on the rings evaporate more rapidly. So that as I mentioned in my general discussion, Aroclor 1242, the mono and dichlorobiphenyls will evaporate fairly readily from a material sitting in air.

If we looked at 1260, it would be very hard to even measure

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any evaporization at all. That material will tend not to evaporate at all.

Q Okay. You mentioned also biodegradation. First off, explain what that means and how you test for it.

A All right. Biodegradation is a term which is used to describe how the material behaves in an environmental system where there are micro-organisms or what we call bugs available.

The bugs are around us everywhere, as we all know. We have bugs in our body. We have bugs in our gardens, micro-organisms, bacteria and small things that have to live. And these things live by eating materials that are available to them. And if there are chemicals available, they will eat chemicals. In fact, everything is chemical so they are always eating chemicals in one form or another.

We measure what we call then the biodegradation by putting a chemical of interest, in this case PCBs is what we're talking about, we put the chemical of interest in a system containing micro-organisms and measure how rapidly those bugs eat the PCBs. We do it under controlled circumstances and over a long period of time to get what we consider a valid measure of biodegradation.

Q Have you done these type of experiments yourself?

A I have participated in these experiments and have done analyses of samples which have been taken from experimental systems. I've not actually fed the PCBs to the bugs, but it

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was being done in the group I was working in.

Q Have you reviewed the literature on biodegradation of PCBs?

A Yes, I have.

Q Do PCBs biodegradate -- or biodegrade?

A Yes, they do. The common wisdom is that PCBs are not degradeable. If you put PCBs in the environment, they will be there. In fact, that is in general not true, especially if we look at the lower chlorinated materials, the Aroclor 1016s and 1242s, put in an environmental system, put in a soil system containing bugs, put in a sewage sludge system containing bugs, put in a river containing bugs or a sediment containing bugs or micro-organisms, they, in fact, are degraded over time.

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Q Mr. Kaley, has Monsanto done research as to the rate of biodegradation of any of the Aroclor products?
A Yes. That was a very extensive part of the work our group was doing in the early 1970's.
Q I show you what has been marked as Exhibit 5606. Can you identify what that is, please.
A This is a report generated from the group that I worked in at Monsanto when I first joined the company, an actual published paper describing the work that Monsanto has done on biodegradation of PCBs.
Q Was this paper distributed to anybody else besides Monsanto employees?
A Yes, this paper was published in a scientific journal available to anyone who was interested.
Q This document doesn't contain a date on its cover. At any rate, do you recall the approximate time this was published?
A The work would have been done in the early 1970's. I would guess the publication date would have been--I don't know for sure--I would guess '73, '74, or something like that. '73 or '74. It may have been a little earlier or a little later but in the early to mid 1970s.

MR. FRUEHWALD: Your Honor, let me offer at this time Exhibit 5206.

MR. KARAGANIS: Your Honor, if this witness wants to speak to his own research or wants to use the learned treatise

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exception to the hearsay rule, I have no objection. But this is a research article. The normal way it's supposed to come in is either through reliance or quoting the appropriate passages, not the entire document.

THE COURT: I understood it was something he did or participated in doing; is that right?

THE WITNESS: Yes. This specific paper I didn't contribute to. I have done that type of work that is described in this paper.

MR. KARAGANIS: He is not the author or one of the participating researchers. He can quote from it under the learned treatise doctrine. I have no problem with that, Judge.

THE COURT: I think that's right.

Q Mr. Kaley, can you tell us please what, as a result of this research and the research you have seen, can you give us any kind of quantification of the rate of degradation that you would expect or could be expected from this research of any of the Aroclor products?

A There is a table in this publication which summarizes the results Monsanto obtained for a variety of these products. For instance, Aroclor 1016 over a period of 48 hours in a biodegradation system degrades at a rate looks to be about 32 percent. So over a period of 48 hours in the system, 48 percent of Aroclor 1016 will degrade.

Q How does that compare to 1242?

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A 1242 is slightly lower. It looks to be about 25 percent from the chart presented here.

Q Are you aware of any research on any kind of longer term perspective of degradation in terms of the ultimate rates?

A Yes, I am. There is work reported in the literature and there was also work done at Monsanto and in fact also in the European labs at Monsanto which have described some of these types of studies.

Some of the or one of the numbers I recall for Aroclor 1016 was over a period of 100 days or a little over three months, about 90 to 95 percent of the Aroclor 1016 disappeared as a result of biodegradation.

Q When you talk about these rates in these experiments, these are optimum degradation conditions, are they not?

A Yes, that's right. Before the experiment is actually begun, we do what we call acclimating the micro-organisms. We feed the micro-organisms increasing amounts of the material to get them used to eating this particular material.

It's like going to a different kind of restaurant. You don't know whether you like the food or not. You eat a little bit at a time. And then pretty soon you might develop a taste for it.

Micro-organisms do the same thing. They don't necessarily jump right in and gobble everything in sight. But they over time can develop a taste for a chemical. And that's what

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happens. So we use bugs that have developed this taste.
Q What would you expect of the rates you have been talking about in terms of a system in the environment or a sewage treatment plant that had not gone through these conditions?
A They would be somewhat lower depending. They could go from significantly lower to just slightly lower depending on whether the materials had been supposed to these or similar compounds. But you would expect them to be lower.
Q How do the other Aroclors compare in terms of degradation rates you talked about for 1016 and 1242?
A As the weight of chlorine goes you up, the bugs don't like it as well. So that 1248 degrades at a lower rate than 1242, 1254 even slower, and 1260 degrades even slower.
Q You also talked about characteristics in soil. Can you explain what you are looking for and what methodology is used to examine that quality.
A One of the things that we are concerned about with the material that's for one reason or another that gets into the environment is what happens to it if it is in the environment, if there is a spill of the material.

One of the things that can happen is that the material binds very tightly to soil or other materials that are in the environment. And it turns out that PCBs do this. PCBs, we talked about solubility. And their water solubility is very, very low. They don't like to be in water.

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What they do like to do is be bound to something like soil or like another organic compound so that they can avoid being dissolved in water. PCBs then adhere to soil. This adherence also increases with increasing Aroclor numbers.

So that the Aroclor 1254s and 1260s more tightly bind to soil, hold onto the soil than do Aroclor 1016 and 1242.

Q Did Monsanto do experiments to determine the rates of migration through soils and their adherence to soils?

A Yes, there were some experiments done to look at what happens. Basically we were investigating what happens if PCBs are spilled on soil and then the rains come and other environmental effects happen. What happens to the PCBs?

So we would take a column of different kinds of soil, put some PCBs on top of the soil, run water through that soil, and determine whether the PCBs would do what we call leach or migrate through that soil column.

Q What was found by doing those experiments?

A Basically the experiments that have been done and have been published by Monsanto show that only for Aroclor 1016 and only for very sandy soils, soils which do not contain much clay or organic matter, do the PCBs leach through or reach the bottom of that soil column at all.

Q What does that mean for an environmental situation? What is a comparable environmental situation that that experiment is designed to recreate?

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A There are a couple things. One would be a spill, a transformer for instance that contained PCBs should happen to develop a leak, that material material was spilled on the soil. Those results tell us that the PCBs are going to stay where they are spilled. They are not going to move through a soil column.

The same approach could be used to describe the expected behavior of PCBs in a landfill. They would be expected to stay on the top of the soil basically where they were put rather than migrate through the soil as it rained or other things happened.

Q Does the migration of PCBs through the soil change with the presence of other chemicals?

A Yes, it does.

Q How is that affected?

A Again we are going back to the question of water solubility and the fact that PCBs don't like to be dissolved in water. So if it rains and you are talking about water moving PCBs through the soil, they tend to stay on the soil.

There are other materials which would move PCBs that PCBs like to be dissolved in. For instance, a common solvent we would talk about would be something like hexane or even something we talked earlier a little bit about, Wesson oil, or a vegetable oil. PCBs would dissolve very nicely in a vegetable oil.

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So if you had a column of soil and poured a great deal of vegetable oil on it, then the PCBs would move through that soil because they would dissolve in the vegetable oil and be carried through with that vegetable oil.

Q Mr. Kaley, you joined Monsanto in what, 1973?

A Yes.

Q Had the technology for detecting and measuring PCBs been completely developed?

A No. It's not been completely developed to this day. It's a continuing area of scientific research.

Q Recognizing that we are all laymen, can you describe for the jury in as simple terms as you can, what you have to do to measure PCBs or to find them at the parts per million level in, for example, water or any kind of sample.

A Okay. Bear with me. If PCBs are present in water at a, say a part per million--that's a nice round number; let's talk about a part per million--it is not possible to take that water and throw it into some sort of black box and get a number that comes up on a screen that goes one.

There is a very complicated procedure that must be gone through. The first procedure that we have to do is to get the PCBs away from the water. We do that by taking an organic solvent--I mentioned hexane earlier. Hexane is much like gasoline. We could think of it as a gasoline type material. You have heard of the octane number in gasoline. Hexane is

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much like octane. It's a gasoline type material.

We add that to the water and shake it very hard. The PCBs don't want to be in the water. They want to be in the hexane. So they move to the hexane layer. We can then throw away the water because it doesn't contain PCBs anymore.

We take the hexane and evaporate it. Hexane is a very volatile material. If you leave a little in a dish sitting on the table, it will evaporate in a matter of minutes.

So we evaporate the hexane which concentrates the PCBs to a much higher concentration. If we started with, for instance, a gallon of water, and let's say then we--let's talk about a quarter. It's easier. We start with a quarter of water and say we put in a quart of this hexane.

We would end up after our first step with a quart of hexane containing still one part per million PCBs because we have the same volume. If we concentrate that hexane down to a thousandth of a quart, then we have--the PCBs do not evaporate because they have much higher boiling points than the hexane. So they stay there.

Since we have a thousand times less volume but the same level of PCBs, we now have a small volume of hexane containing instead of a part per million, a thousand parts per million of PCBs. We have concentrated it by a factor of a thousand.

Q What is done with this concentration in 24 of what equipment is used thereafter to make the measure?

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A After we measure, after we concentrate it, we use an instrument called a gas chromatograph which is basically an instrument for separating chemical compounds.

Chromatography is a very widely used technique in analytical chemistry. Basically it separates compounds based on their tendency to adhere to a solid material, a powder, a sandy type material, in a glass column.

In fact, each of you have probably done some chromatography without thinking about it. If you have ever written a note on a piece of paper napkin and then that napkin has got wet, you will notice sometimes that the material, the ink spreads out. You might see a red band and blue band and purple band from where the ink has moved along that napkin.

That, in fact, is doing chromatography. Gas chromatography is a fancy way of doing the same thing. Each of the bands represents a chemical that is present in the ink. And you can visualize it with ink. With PCBs you can't visualize it. But the instrument visualizes it for you. So you are essentially separating the components of the mixture.

Q When did the technology to be able to measure PCBs in that type of a quantity, when did that develop?

A The problem with PCBs is that when they are present in the environment, they are present with a lot of other materials.

Chromatography really developed--the basic chromatography developed about the early 1950's. But about the middle of

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1960's, around 1964 to 1966, a new technique for detecting the PCBs, measuring the PCBs, after they came out of the chromatograph was developed, something we call an electron capture detector.

We need to know nothing about it other than the fact it is very, very sensitive to PCBs. It will see much lower levels of PCBs than the detector used previously. And also it will pick PCBs and other materials containing chlorine out from chemicals which do not contain PCBs.

Q Prior to the middle 1960's, was there technology around that could detect PCBs at those levels?

A No, there wasn't. It really took the development of this technique in the 1960's to measure the part per million.

MR. KARAGANIS: Are we talking about part per million?

MR. FRUEHWALD: Yes.

THE WITNESS: We are talking about parts per million, give or take some, yes.

Q Since that time, has the technology for detecting and measuring PCBs increased?

A Yes. As I said, when we initiated this questioning, it has continued to develop even to the present day. The detector, the electron capture detector, was improved significantly from the mid sixties when it was developed through the mid seventies. By the mid seventies it was probably as good as it's going to get.

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But there were other techniques developed. There were new ways of doing chromatography developed that allowed us to do much better separations. So there have been a whole series of improvements.

Q What was the level of detection given the best technology in 1970, if you can give us--

A In 1970, if we are going to talk about water, I would say probably 10 to 100 parts per billion would have been a good technique about that time.

Q What is it today?

A Today a good analytical chemist in a good laboratory can probably do tens to hundreds of parts per trillion fairly routinely.

Q Mr. Kaley, when you were doing work at Monsanto in your initial employment in the group you described, did you have any contact with the Westinghouse Corporation?

A Yes, I did.

Q What was that contact?

A Well, as I described earlier, I was hired as an analytical chemist. And came into Monsanto at the time we were developing new products and really beginning to, not beginning--it had been a long time--but we were concerned about the behavior of our materials in the environment.

One of the things we were doing was working with our customers, from my point of view, on an analytical basis to be

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sure that our customers, Westinghouse included, were able to do low level PCB analyses as well as we thought we could.

So we worked with some people from Westinghouse comparing our analytical techniques, comparing the results we got on what we call split samples that would take a quart of water. And we would get a pint, and Westinghouse would get a pint. We both do the analyses and see if our numbers were the same.

Q Who did you work with at the Westinghouse Corporation in connection with that work?

A My contact there was a name names Mr. Kurz.

Q Let me show you what has been previously marked as Exhibit 4646 in evidence. It's a letter from Mr. Kurz to Scott Tucker. Who was Mr. Tucker in relation to your work?

A Scott Tucker was my group leader at the time I joined Monsanto. He was my immediate supervisor.

Q Are you familiar with the work samples that are described in that letter?

A Yes.

Q Was that the type of analytical improvement you were discussing earlier?

A Yes, that's correct. I am sure many of these results were generated by me.

Q Were the results of your work of your analytical lab ever communicated to the marketing department or the other management in Monsanto?

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A I don't have any recollection of that. My results would have been--we talked on the phone to the Westinghouse people. Basically we were lab people working together to compare results. I know I talked to Mr. Kurz.

The results were obviously communicated to my supervision, but I don't know where else they may have been communicated.

MR. FRUEHWALD: I believe that's all I have, Your Honor.

CROSS-EXAMINATION

QUESTIONS BY MR. KARAGANIS

Q Mr. Kaley, would you be kind enough to explain to the jury the difference between a lab experiment and a field experiment.

A Well, the basic difference is a matter of scale. A laboratory experiment is designed to look at a small system to give us an idea of what might happen in a larger system.

So we use pints or quarts of material rather than gallons of material. Basically that's the difference. It's a matter of scale.

I guess the other difference would be we tend to use purer materials that might be encountered in an environmental system. We are looking for specific chemicals rather than a large mixture of chemicals.

Q Would it be fair to say that doing a table top experiment in the lab, that you are able to control the variables that you are applying to the exercise much more carefully than in the

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field?
A Certainly that's true, yes.
Q Would it be also be correct that basically you are--the stirrer in the experiment you described, the number on that was 5206? The device in which materials were placed for purposes of measuring degradation was a device of 1500 milliliters?
A If you are reading it, I will take your word for it. That sounds appropriate. That's a quart and a half. That's probably about right.
Q I want to be careful. You take a look at it and tell me.
A Yes, that's correct. It's about a quart and a half.
Q So the experiment on degradation was done in a jar. And what was done with the jar, the quart jar?
A The quart jar contained water which also contained sewage sludge. It was put in a laboratory. It was stirred. Mechanically stirred. We had a little stirring bar in the middle that kept the sludge dissolved in the water so we would have good contact.

Periodically, it was also aerated. It had oxygen added or air added to the system because the micro-organisms need air to survive.
Q You indicated that in 1016, what were the percentages in the lab experiment?
A As I recall, it was in the mid to high 30 percent degradability.

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Q 30 percent in 48 hours?
A That's correct.
Q Does that mean there would be another 30 percent in the next 48 hours and another 30 percent.?
A That's correct. But we continually fed the system from day-to-day. So that as the material degraded, more material as added day-to-day. We were feeding the material, the bugs the materials, every 48 hours.
Q If you were looking at this thing and stopping and kept mixing up and things like that, how many days would you take to get down to zero? I am not having word problems.
A In the particular system that we were using in the laboratory, we might never get down to zero. We talked earlier the fact that the lower chlorinated materials tend to degrade more readily than the higher chlorinated materials.

So in fact if we are measuring 30 percent degradation, that 30 percent degradation is primarily made up of the tri and di, the two and three and one chlorinated materials. So that the fours and fives, what little fives were in there would continue to accumulate.
Q So the 1016 that was left would start looking more with a higher percentage of the heavier chlorinated compounds; is that correct?
A That's correct.
Q As a matter of fact, so-called degraded environmental

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samples of 1016 often look like other kinds of PCBs to the lab analyzer, do they not?

A They resemble. I don't know that they really look like them, but there are some similarities.

Q What typical compounds do they look like?

A Well, over a period of time, they will begin to have more and more of the characteristics of an Aroclor 1248 or an Aroclor 1254.

Q And that's true of 1242, is it not?

A It's more true of 1242 than 1016. 1016 was designed not to contain very much of these five and six chlorinated materials. So it would not--it would not have the tendency to resemble the others as much as 1242.

Q But it would have that tendency but just not as much?

A To a certain extent, that's correct.

Q Let's stay with 1242. What was the rate on that?

A As I recall, it was mid twenties, 25 percent.

Q So if my arithmetic is right, that's 25 percent in 48 hours?

A That's correct.

Q And then another 25 percent in the next 48 hours?

A 25 percent of what was added additionally.

Q In a couple of weeks, I am basically down to nothing; is that right?

A In the system we were using in the laboratory, we have

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continued to add Aroclor 1242 to the system. So that the 25 percent from the first day, then we added more PCBs; and 25 percent of that total was then degraded. We added more PCBs than 25. So we didn't actually do the experiment trying to get down to zero.

Q If you stopped adding PCBs to the system and kept mixing around and adding air and doing whatever you were doing, 25 percent the first two days, 25 percent the next two days, by a couple of weeks, we would be down to pretty close to nothing?

A That's not true. As I just described, the materials that we are measuring the biodegradation of tend to be the lower chlorinated materials.

Q What would we have left?

A You would have the higher chlorinated materials will begin to accumulate. Those will not degrade at a rate such that in two days, we would notice that degradation or even possibly weeks. So that we would never get to zero in that system.

Q The higher chlorinated compounds that are present, the ones that would remain after degradation, are present in 1016 and 1242?

A They are more present in 1242. It depends on which particular congeners we are talking about. But there are certainly traces of those materials even in 1016.

Q And basically again, if you add enough 1016 and the light stuff degrades, you have still got a lot of heavier chlorinated

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compounds?
A That's true. The material, the heavily chlorinated material, will not degrade nearly as rapidly and will continue to accumulate.
Q The input that you have got to add is how much you are putting into your experiment; is that right, how much 1016 or 1242 you are putting in?
THE WITNESS: I am not sure I understand the point of your question.
Q If I put a little 1016 into the experiment, I will have a little of the heavier chlorinated compounds left.
A That's correct.
Q If I put a lot of 1016 into the experiment, I will have a lot of the heavier chlorinated compounds left?
A On a relative basis, that's certainly correct.
Q That's my level of arithmetic.
Have you tested your hypothesis at the Bloomington lagoon?
A I don't have a hypothesis, but I have not tested the Bloomington lagoon, no.
Q Let me ask is there anything about the sewage lagoon at Bloomington which would, or any sewage lagoon, which would tend to retard or degrade your ability to biodegrade, to limit your ability?
A Well, as I mentioned in describing the experimental system, it was made to optimize biodegradation. So it was stirred.

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Oxygen was added. So if some of these things did not happen, certainly the biodegradation rates would be lower.

Q It would be significantly lower, would it not?

A Depending on the extent of the differences, correct.

Q As a matter of fact, in an oxygen-poor system where pH isn't being controlled, there are things that could very well stop biodegradation almost altogether; isn't that right?

A If the bugs died, the biodegradation would stop.

Q In a lagoon that is oxygen poor--are you familiar with sewage lagoons that are oxygen rich?

A Most of the ones that I am familiar with have some means of oxygenation or aeration, yes.

Q Mr. Kaley I am not talking about the aeration lagoons of a sewage treatment plant. I am talking about the sewage lagoon where the sewage that is in the final clarifying--excuse me.

MR. FRUEHWALD: I object to this line of questioning. Mr. Kaley was not giving opinions on the Bloomington situation. He was giving general opinions on expectations about the product and the chemicals rather than any application to Bloomington.

MR. KARAGANIS: He has raised aeration, and I am entitled to ask about whether or not the lagoon is aerated.

THE COURT: Go ahead.

MR. KARAGANIS: I will be brief.

Q Mr. Kaley, I show you what has been marked as Plaintiffs'

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WATER_PCB-SD0000028897

Exhibit 4520.

When you are talking about an aeration in a sewage treatment plant, what chamber are you talking about?

A I am no expert in sewage treatment plants, but I guess I am talking about an aeration chamber. I am not an engineer, and I am not familiar with the operation of the plant.

Q If there is not an aeration chamber in a sewage lagoon, is it possible that degradation might be much slower than you told in your testimony?

A Well, it would certainly--if there were no means for oxygen exchange--obviously, there is some oxygen exchange on an open system--but the rate will depend on how much oxygen is getting into the system, no question about that.

Q And if there are low oxygen--are you familiar with the term anaerobic condition?

A Yes, I am.

Q If there is no oxygen or little oxygen, could the process take tens of years?

A I think it could. There is work coming out of General Electric Laboratories which say--which they have found their anaerobic processes, oxygen poor or oxygen absent processes, which will degrade PCBs so that there are those processes which can then take over. But the aerobic will certainly decline. Could they last ten years? It's conceivable.

Q Could it be hundreds of years?

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A I don't know the answer to that. PCBs have only been distributed 60 years. Whether they can last hundreds, I don't think anybody knows the answer to that.
Q It's not your testimony here today that the PCBs in Bloomington, if we simply wait a few weeks, will go away?
A I would be very surprised if that happened.
Q Let's take movement of PCBs. When you talk about how PCBs move, again, some of your testimony was based on laboratory experiments, was it not?
A Yes, some of it was.
Q That's taking a soil column in a large glass tube and pouring PCBs on the top and see if any come out the bottom?
A That was a rough description of one of the experiments we did, yes.
Q Isn't a landfill, doesn't that give us essentially a field experiment? That gives us a soil column, does it not?
A Yes, it.
Q So if we were to pour PCBs on top of the soil column, if they came down out of the bottom, what could we conclude from that?
A Well, we conclude there was some process going on which was causing them to come out the bottom.
Q And it's possible, is it not, for field conditions to exist if you pour PCBs in the top, PCBs will come out the bottom?
A It's certainly conceivable.

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Q As a matter of fact, one of the things that when one looks at the ability of soil to adsorb--isn't that the term that's used?
A Yes, it it.
Q To adsorb a chemical, an organic chemical, there is a limited capacity of the soil column to adsorb a chemical?
A That's true.
Q And if you pour enough of the chemical on the top, you can exceed the capacity of that soil column to hold all that chemical; is that right?
A Yes, that's true.
Q So that if you poured enough at the top and you exceeded the capacity of the column, you would get stuff at the bottom; is that correct?
A That's correct.
Q How did Monsanto test the chemical composition of 1242 in the fifties? In other words, how did they know they had 1242 when they made it?
A My understanding is it's based on the reaction conditions in the plants they were making it. They basically could measure the weight percent of chlorine in the mixture and knew the conditions to run the plant to get to that weight percent.
Q In the fifties, what is the--what was the detection level? If Monsanto wanted to go out in the fifties and detect PCBs in the environment, at what level could that detect it?

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A I would say tens of percent. I am just guessing. I don't know what technique they would have used in the 1950's.
Q 20 percent, 30 percent?
A Your guess is as good as mine frankly. I don't know what technique that would have been used at that time. So I don't know what the detection level would have been. But it would have been very high.
Q Just so we have our nomenclature right--I have done this before--you have mentioned--and I think I took this down right; I may be in error--290 separate congeners?
A Yes.
Q 209 congeners or 209 isomers?
A 209 congeners.
Q What are isomers then?
A If we go to our congener classes, so we have 209 congeners, 209 individual separate chemicals. We can group those into ten congener classes or homologs depending on how many chlorines they have on the ring.

Within each of those congener classes, there are a variety of ways to put that number of chlorines on the biphenyl molecule. If we look at--let's do the easiest first.

There is only one way to put ten chlorines on a biphenyl molecule. There are only ten places on the two rings that contain--that may contain chlorine. So there is only one way to put ten on. So there is one isomer of deca, meaning ten,

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decachlorobiphenyl. There is only one arrangement of those ten chlorines.

If we look at pentachlorobiphenyls which means there are five chlorines somewhere on those two rings, there are 46 different ways to put five chlorines on those two rings. So there are 46 isomers of pentachlorobiphenyls.

There are 46 isomers within that five-chlorine class. We could think of all five on one ring and no chlorines on the other ring. That would be one of the isomers, one of the 46 ways to put five chlorines on the ring.

So you can, strictly speaking, only talk about isomers of materials in the PCBs case which have the same number of chlorines on the molecule.

Q So you only use the isomer within the congener class?

A That's the correct usage, yes.

Q Now, you mentioned the movement of PCBs through a system. Apart from the water phase--and you acknowledge, do you not, that some PCBs can move in water, a soluble fraction of the water?

A Yes, low levels.

Q Apart from the soluble water phase, PCBs can also move as a liquid, what they call a nonmiscible liquid; is that right?

A If the capacity--we talked earlier about soil capacity. If in fact the soil capacity had been exceeded, then I guess the PCBs could move excluding dissolving in water and moving with

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the water.
Q If you would take a cup of water and pour PCBs on top of water, the PCBs that don't go in the water aren't solid. They are in a liquid nonaqueous phase, are they not?
A That's correct.
Q PCBs could also move attached to one of these particles that you talk about; is that right?
A That's correct.
Q If you have a glass of water in your tap at home and you turn it on and the water has a lot of cloudy particles in it, is that particulate matter typically?
A Pardon?
Q Is that particulate matter?
A Yes, it is particulate matter.
Q So particulate matter can move through water systems in little fine particles, can it not?
A Presumably most water systems are filtered. But there would be some limits of that filtering, I suppose.
Q All well water systems are filtered?
A I don't know.
MR. KARAGANIS: No further questions. Thank you.
MR. FRUEHWALD: I have nothing further.
THE COURT: That's all. Thank you.
THE COURT: Do you have a 20 minute witness.
MR. FRUEHWALD: No, sir. This was all I could bring

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