BEFORE HILLSBOROUGH COUNTY
BOARD OF COUNTY COMMISSIONERS
PUBLIC HEARING

IN RE:	
GARDINIER APPLICATION FOR DEVELOPMENT APPROVAL AND REZONING	DRI PET. #76 REZONING APPLICATION #83-6

TRANSCRIPT OF TESTIMONY AND PROCEEDINGS

BEFORE: Rodney Colson, Chairman
Jan Platt
John Paulk
Matt Jetton
E. L. Bing

TAKEN AT: Brandon High School
Brandon, Florida

DATE & TIME: 29 February 1984
5:30 o'clock p.m.

REPORTED BY: Linda S. Hughes
CSR, RPR, CP
Notary Public
Deputy Court Reporter

MR. RHODES: I think it would be appropriate at this time for both Dr. Rogers and Dr. Cole to be sworn.

MISS LOCKWOOD: Would you raise your right hands, please. Do you swear to tell the truth, the whole truth and nothing but the truth, so help you God?

DR. ROGERS: I do.

DR. COLE: I do.

THE CLERK: Thank you.

MR. RHODES: Members of the Commission, the first witness is Dr. Lou Rogers. Dr. Rogers has over fifty years of teaching, working and consulting experience in the areas of chemistry and air pollution control.

He is currently the senior staff consultant to the Air Division of the Environmental Science and Engineering, which is a Gainesville-based environmental consulting firm. He's held this position for five years.

Dr. Rogers began his long career with sixteen years of teaching at the University of Florida, where he became a full professor of Chemistry. He then worked on analytic chemistry issues for Union Carbide in the National Dairy

Research Laboratory.

He then served as Senior Chemist for the Air Pollution Foundation, and finally worked for several years in analytical research and chemistry and research and development for the private firm of Automation, Inc.

In 1971, Dr. Rogers became the Executive Vice President and publisher of the prestigious journal of the Air Pollution Control Association, a position that he held for seven years.

Dr. Rogers holds a B.S. in Chemical Engineering and a Masters of Science and a Ph.D. and a Masters of Science and Chemistry from the University of Florida.

He also received his Ph.D. in Chemistry from Cornell University.

Dr. Rogers has published over fifty articles in the national and international journals on air pollution control and chemistry issues.

DIRECT EXAMINATION

BY MR. RHODES:

Q Dr. Rogers, is the information that's contained in your resume, that is part of Gardinier Exhibit 3, true and accurate?

A Yes.

Q Is the summary of your professional qualifications that I just provided to the Board also true and accurate?

A Yes, it is.

Q Are you familiar with the proposal by Gardinier to construct a new gypsum disposal field?

A Yes.

Q Have you been retained by Gardinier to provide expert consulting services in connection with this proposal?

A Yes.

Q When did you undertake this work for Gardinier?

A November of 1983.

Q What did Gardinier ask you to do?

A They asked me to review any reports or scientific publications for any data on the ambient fluoride, ambient air fluoride concentrations in the vicinity of their plant, to compare this with the standards that might be announced for a fluoride -- ambient air fluoride concentrations, and to compare this with any health effects on people.

Q Now, what are the sources of fluoride emissions that may arise at the Gardinier fertilizer plant?

A There are basically three sources. One is the plant itself and all the operations that go on inside the plant. The second is from the cooling water ponds, and the third is from the pond on top of the fluoride stack -- the gypsum stack.

Q What impact, if any, do you expect to arise out of the construction of the new gypsum stack with regard to the total fluoride emissions from the facility?

A I would not expect there to be any increase in the fluoride concentrations because there's no proposal to increase the total production at the plant.

Q Will the existing gypsum stack and pond on top of that stack continue in operation when the new stack is constructed?

A No. The existing stack is to be shut down and the new stack would be put into operation.

Q Have you attempted to evaluate the concentrations of fluoride in the ambient area -- in the ambient air in the area near the Gardinier facility?

A Yes, I have.

Q Would you tell us what you did to carry out that analysis?

A I studied whatever reports I could find on this matter, on the ambient air fluoride concentrations. There's very little data. The main data that I have found was compiled by the Hillsborough County EPC, and I have here a chart which is also in my report, a chart which shows the fluoride concentration as measured by what is called "a plate method" over a period of thirteen months with two months of missing data. These are the data as compiled by the EPC.

Q Let me interrupt you for a second. The members of the Commission have been provided with a reduced version.

A Bar chart.

Q That's on --

A That is Table 1, Page 3. These are the same numbers that you have on the table in front of you.

This is the data from December the 15th, 1983, through January 15th, 1984. This plate method is a petri dish into which you put a cellulose pad which has been soaked in a solution of calcium oxide. The calcium oxide -- then this plate is turned upside-down so as to protect it from any dust that might fall on it. So that as the wind blows the fluoride, the ambient air fluoride, past this plate, it is absorbed in this cellulose pad, and this is left in the field for a month and then it's taken to the laboratory and is analyzed for fluoride.

I'm going to use a concentration here which is the same numbers that the EPC used. It's called nanograms of fluoride per square centimeter per day. Even though this pad is left out for a month it's calculated, it's reduced to so many nanograms per day.

A nanogram is one-billionth of a gram, and a gram is a thirtieth of an ounce. So this is a very small number.

These numbers range from 355 nanograms up to 341 nanograms, with an average of 344 nanograms. The EPC also provided a calibration curve so that you could convert these numbers into the numbers that we ordinarily talk about in air pollution measurements. This converts to 300 -- the 344 converts to 3.2 parts per billion. Parts per billion.

Q Where was the sampling station located from which you obtained these data?

A Okay. This is what the EPC calls their Station 10. It's located at Gardinier Park which is just across Route 41 from the plant itself.

Q Could you point it out on Gardinier Exhibit #1, please?

A Yes. Here's the Alafia River. Here's the gypsum at the Gardinier plant. And this Gardinier Park is right at this point (indicating). It's just across 41 from the plant itself.

Q How would you characterize the location of this sampling point with regard to the relative concentrations of fluoride in the ambient air in the general area?

A Well, from Gardinier's standpoint it's the worst possible location because it's quite close to the plant and the fluoride has not had a chance to dissipate very much by the time it reaches its sampling apparatus.

Q Dr. Rogers, are there any published standards that would be used to regulate fluoride concentrations from a public health standpoint?

A There's no EPA standard for fluoride. The only standard that I have been able to find is a standard from OSHA. That's the Occupational Safety and Health Administration. And while it's not strictly applicable to this situation because OSHA is designed to regulate the concentrations for people who are working inside an enclosed area, nevertheless, it gives us some guidelines as to the reference for this concentration here.

Let me express the OSHA standard and then convert it into something that relates to this.

OSHA standard is three parts per million -- million, that is -- for an eight-hour day.

Now, people who work an eight-hour day, forty hours a week, would only be exposed to that many hours of three parts per million of fluoride.

So, we have taken that and just as a basis for some kind of -- some kind of comparison, we've related this to what would be -- what would happen if you were exposed to it twenty-four hours a day, seven days a week.

The conversion factor for that is -- well, you divide the three parts per million by five, and you come out with .6 parts per million. Understand, this is not an EPA standard. This is the OSHA standard, but it's just to give you some reference for the kinds of numbers we're talking about here.

This was -- let me just use three parts per billion. It's an approximation. Three point two is the way this comes out. But three parts per billion compared to .6 parts per million. So this number, the three parts per billion -- let me see if my arithmetic is correct -- is approximately one two-hundredths. Three into point three parts per billion, that would be six hundred parts per billion for the OSHA standard. So that would be one two-hundredths, or two hundred times less for the amount of fluoride that was measured by the EPC at this point.

Q Have you had an opportunity to try to look at any published studies with regard to fluoride impacts on human health?

A Yes.

Q Could you summarize for us what you found in your literature review?

A I'm referring to Table 2, Page 7. Do you have a copy of this?

Q No, just please just review what you found in connection with your studies there.

A This is a series of experiments on five people who were exposed at different times in a chamber to concentrations of hydrogen fluoride. The exposure concentrations varied from 2.7 to 4.7 parts per million and they inhaled the hydrogen fluoride six hours a day, five days a week, for fifteen days. And the effects were very slight irritation of the eyes and nose and slight reddening of the skin. And it is from data such as this that this standard for OSHA was derived.

Q Now, how did the exposure levels that those individuals were subject to relate to the ambient concentrations that you're calculating for Gardinier Park?

A Well, if we go back to this 3.2 and compare it -- let's call the average of this other as three parts per million. That is a thousand times -- this number is a thousand times less than the number I quoted here for these experiments in a chamber.

Q Do you know if the United States Environmental Protection Agency has made any findings or determination in regard to the potential health impacts of fluorides from phosphate fertilizer plants?

A Yes, they have. I have here a document on Final Guideline Document: Control of Fluoride Emissions from Existing Phosphate Fertilizer Plants. And on Page 2-10, it says, "Therefore the administrator has concluded that fluoride emissions from phosphate fertilizer facilities do not contribute to the endangerment of public health."

Q Okay. That document appears as part of Gardinier Exhibit 4, which has previously been admitted into evidence.

Dr. Rogers, have you prepared a report in connection with this work that you've done?

A Yes, I have.

Q And you have available to you a document that's previously been marked as Gardinier's Exhibit 26. Would you identify that for me, please?

A Yes, sir. It's this document (indicating).

Q Would you just tell me what that is, please?

A Summary of testimony to be presented on Gardinier's proposed new gypsum disposal site and its effect on fluoride emissions.

Q The chart that you have been referring to during the course of your testimony, does that appear in the document you just identified?

A Yes, it does. It is Table 1.

Q And is the report that you refer to one that's been prepared by you or under your supervision?

A Yes.

MR. RHODES: We move Gardinier's Exhibit 26 into evidence, and that's all the questions we have of Dr. Rogers at this time, and we would like to call Dr. Cole to proceed on to, basically, finish up our case in terms of the health impacts, if any, that may be associated with the proposed stack.

Dr. Cole, Dr. Philip Cole, is currently professor and head of the Department of Epidemiology of the School of Public Health of the

University of Alabama in Birmingham. He also serves as the Associate Director of Epidemiology of the Comprehensive Cancer Center, associated with that university.

For the ten years prior to his move to the University of Alabama, Dr. Cole taught in the Department of Epidemiology at the Harvard School of Public Health, where he obtained the rank of full professor. Dr. Cole is a physician, having earned his M.D. Degree from the University of Vermont in 1965.

He holds a Masters and a Doctorate in Public Health from Harvard University.

Dr. Cole has served on several major scientific advisory committees. For example, from 1978 to 1980 he was a member of the Scientific Advisory Committee of the Division of Cancer Cause and Prevention of the National Cancer Institute. He is currently a member of the General Motors United Auto Workers Occupational Health Advisory Board.

In addition, he is the Associate Editor of the American Journal of Epidemiology.

Dr. Cole has authored or co-authored approximately one hundred articles related to the field of Epidemiology, nearly all which deal with the various types and causes of cancer.

(Dr. Cole having been previously duly sworn to tell the truth, the whole truth and nothing but the truth, was examined and testified as follows:)

DIRECT EXAMINATION

BY MR. RHODES:

Q Dr. Cole, is the information contained in your resume, which has been submitted as part of Gardinier's Exhibit 3, true and correct?

A Yes, it is.

Q And is the brief summary which I just provided to the Board concerning your professional qualifications also true and correct?

A Yes, it is.

Q Dr. Cole, have you prepared a report in conjunction with your work for Gardinier?

A I have.

Q I call your attention to a document which we've marked as Gardinier's Exhibit 27 which should be adjacent to you somewhere, and ask if you can identify it, please.

A Yes

Q Could you tell me what it is, please?

A This is the document that I prepared which was a summary of the reviews that I had made.

Q Did you prepare that report yourself?

A Yes.

MR. RHODES: We'll move Gardinier Exhibit 27 into evidence at this time and ask Dr. Cole to make his presentation.

THE WITNESS: Ladies and gentlemen, I am very happy to be here this evening and to give you the overview that I have extracted from the various materials that I've reviewed.

My presentation will be brief and try to save as much time as possible for questions.

I would like to begin by giving you just a brief explanation of what an epidemiologist is, because the meaning of the word has changed somewhat in the last few years. An epidemiologist is usually a physician who has gone on after medical school to specialize not in the treatment and diagnosis of diseases most physicians do, but rather in the study of the causes of disease and in the methods for bringing about the control of disease.

It's our forefathers in epidemiology that brought about the control of the great plagues: the cholera plague, typhus and the like. But the modern focus of epidemiology is on the chronic diseases: the vascular diseases, hypertension, neurologic diseases, and in my own case, the malignant diseases.

An epidemiologist, in addition to being a physician, goes on to study the basic science of preventive medicine, statistics, pathology, and two or three areas which will be most particularly relevant to his specialty area. In my own case, that's chemical carcinogenesis and other mechanisms of carcinogenesis.

I was asked by Gardinier to review documents that were prepared by Dr. Rogers, by Dr. Roessler, and by Dr. Walsh.

The first of these deals with the question of fluorides; the second with the question of cancer risks; especially lung cancer risks subsequent to the development of the proposed pile.

I found all of these reports competent, thorough, and very professional. I do not mean in any sense to imply that I endorse them categorically and that I wouldn't disagree with a point here or there; I do. But by and large, those disagreements are minor and the fundamental conclusions of the reports that I've just alluded to, as well as mine, are essentially in harmony.

Let me deal, first, with the question of fluorides. As Dr. Rogers just described to you, when fluorides are administered to volunteers at levels that are approximately one thousand times -- that's one thousand times higher than those in the ambient air in the Gardinier Park -- mild symptoms are elicited. Ordinarily, though, at levels that are on the order of one one-thousandth of that, on the order of one part per million, when given in water, fluoride constitues the greatest public health triumph in the twentieth century today. That is, it is our approach to the elimination of caries and is, of course, voluntarily elected to be given. In some places, of course, not so, but in many it is elected to be given in water supplies at the level of one part per million for the prevention of caries. In many instances where water is not available in the public water supply, for whatever reason, responsible parents have fluorides applied to their children's teeth topically.

Fluoride is, then, for all practical purposes, an extremely valuable adjunct to public health procedures in this country.

At the extremely low levels that Dr. Rogers found in the Gardinier Park -- that is, on the order of three parts per billion of ambient air, fluoride has no known effect on human beings, neither beneficial nor adverse, at least none that I've been able to find out about.

The one effect that is of some concern to me, that is, which I was interested in, not of which I'm particularly concerned about, is the relationship of variations in cancer rate with fluoride levels. This has been studied in some detail because of the question of adding fluoride to water supplies. I think we can say that this has been quite persuasively and convincingly shown to be no relationship. That is, cancer in no way varies as a function of fluoride supplies in water.

Let me go on now, very briefly, to the report of Dr. Roessler. You will recall that he found that the proposed stack would raise levels of radiation flux in the area by anywhere from thirty to fifty percent. As far as I can tell, that's an entirely meaningful and not particularly surprising finding.

Go on now to the report by Walsh, which attempted to interpret Roessler's findings into cancer risks and especially lung cancer risks, and Walsh came to the judgment that the findings by Roessler would be converted to a lung cancer incremental risk that could lie somewhere between one in three thousand and one in thirty thousand. That is, among three thousand people exposed to the incremental background radiation, perhaps one would develop lung cancer who otherwise wouldn't. On the other hand, it might be as little as one not in three thousand but in thirty thousand, depending upon the range of exposures that one would accept as real.

Now, one in three thousand or one in thirty thousand, I want to point out that these are worst case estimates because they're based on observations made on the west side of the stack, which is in the lee of the prevailing winds.

On the east side of the prevailing winds the exposures would be -- this is something of an estimate, but perhaps only one-tenth of those that they would be on the west side.

Now, let's consider this risk just a little bit further. This is, if you will, a model that Dr. Walsh has constructed which takes the observations by Dr. Roessler and tries to interpret them in terms of lung cancer risk. The interpolation is based on information that is available to us from studies of primarily underground radiation minings. So a lot of assumptions are involved in making this extrapolation.

So I asked myself the question, then, what are the data that could be used to substantiate, refute, in any case evaluate, this use of the model in this situation. There have been a large number of studies that have been done to evaluate the extent to which cancer risks and rates vary in this country as a function of background levels in radiation. These studies, with virtually no exception, are negative. That is, cancer appears not to vary as a function of background radiation levels, even when those levels are as much as ten-fold different.

However, it's true that the American studies have been criticized on the basis of the mobility of the American population. People are born in one region, brought up in another, work and eventually die in yet another. So they are difficult to interpret.

But in that context, I would like to describe for you one study which I believe is particularly important and valuable and speaks directly to the issue, not in any theoretical sense, but in a strictly empirical one. I would like to take just a moment and put just a couple of numbers up on the easel here for you.

MR. RHODES: Take the chart down on the left there, and I think you'll find a Magic Marker underneath the podium.

THE WITNESS: Let's see. I think I need three hands to do this. I'll get along with just two.

This is a study that was done in Mainland China in the late 1970's. The important distinguishing characteristic of it is that unlike Americans, Chinese are very stable. Most of these people can trace their ancestries in the locality back to ten generations or more, a surprising, stunning figure.

There were two regions studied in cancer in that China. One was a low area where the background radiation levels are essentially identical to those here in the Tampa area, and a high radiation area where the levels were approximately two to two and a half times greater. These two regions being about a hundred miles apart.

The cancer mortality rate in the low area was forty-six per hundred thousand people per year And in the high, it was forty-five. That is essentially identical. So, in this stable population with a two-and-a-half-fold variation of background levels of radiation, there was no variation in cancer risks. And the alteration of the background levels from the proposed pile would be well within the range encompassed from this Chinese experience.

Now, I'm going to make a side issue here. It has nothing to do with my major presentation on cancer. Although I think it's important and I want to present it to you. If you can just tuck it away for later reference.

This study also evaluated other health outcomes. One of which was the frequency of miscarriage in these populations. That was 73 miscarriages for a thousand pregnancies in the low-risk area; 74 in the high. And, finally, congenital malformations: the numbers of malformations per thousand live-born children, 15 in the low exposure area; 14 in the high. Let me just correct myself. This is congenital malformations and other inborn conditions of immune deficiency.

In short, the message is pretty clear that, at least in that range of background radiation variation, there is no meaningful effect on health.

It is proposed by these Chinese workers -- there's some reason to believe it from other kinds of studies -- that at very low levels; that is, background levels of radiation, the human organism is refractory to genetic damage. This is almost certainly true for one form of radiation. I think it's true for the other form, as well, but that's less well-established. So there is a credible biological mechanism, I believe, to explain -- to explain this.

Let me deal, finally -- final point -- now, with this concern about one lung cancer death in excess in 3,500 people over the course of their lifetime. It is very difficult to get an intuitive grasp of what a risk of that magnitude means. I deal with numbers of that sort all the time, and I'm happy to tell you, I really can't relate to it in any direct way. I have to compare it to other things. You're talking about 3,500 people who are going to live on an average for 75 years. That's approximately 2,500 years of human life.

In that experience, there could be -- very worst case now -- upper limit of exposure -- one extra lung cancer death.

Now, on the one hand, one doesn't want to seem callous and indifferent. After all, one death is one death. Why should we have it?

On the other hand, what does that actually mean in terms of an increase morbidity and mortality experience for a population? That is, when you look at it from the public health point of view. Well, it means this. It's one one-hundredth of the risk of dying in a motor vehicle accident over the course of a lifetime.

Now, I personally feel that the estimate is, even so, too high by a factor of at least ten in probably one hundred. If you accept my point of view or my interpretation of the available information, it would be that conceivably the stack increases the risk of death from lung cancer by one in approximately 30,000. That would be one one-thousandth probability of dying from a motor vehicle accident.

There are rules and guidelines that are established. Obviously, you don't have to accept them, but they are general guidelines for what are meaningful risks. These risks, whether it's one in 3,500 lifetimes or one in 30,000 lifetimes are considered risks that are immeasurable, generally acceptable, and for all practical purposes, nonexistent. And that's my point of view here. Thank you.

MR. RHODES: That's all the questions we have on direct presentation. We would offer Dr. Rogers and Dr. Cole for cross-examination.

DR. COLE: We stay here now?

MR. RHODES: At the pleasure of Mr. Dee up there. He'll direct you.

DR. COLE: Is Dr. Rogers going to join me?

MR. RHODES: No.

CROSS-EXAMINATION

BY MR. DEE:

Q Dr. Cole, I do have a few questions for you. Now, prior to this case you've never tried to estimate the risk associated with a phosphate mine or gypsum stack, have you?

A That is correct.

Q And in this particular case you did not collect any of the data that was used to evaluate the emissions from the proposed stack?

A That's correct. I tried to help Gardinier and now I'm trying to help you understand what the measures that Dr. Roessler has made and Dr. Walsh, and my own interpretations of them mean.

Q Yes, sir. Your analysis is based on the assumption that Dr. Roessler's data is correct?

A That's correct. That's true.

Q And your analysis is also based -- your analysis is also based on the assumption that the modeling study by Dames and Moore is correct?

A Yes.

Q Now, Doctor, isn't it true that when EPA calculates risk, that they assume that there is no safe threshold for radiation exposure?

A I think that --

Q Excuse me. Is that a correct statement?

A Yes, it is, but I really don't think to just answer with a yes conveys the whole truth of the matter, so I would like to expand upon it, if I may.

Q Yes, sir.

A Okay. The EPA and other regulatory agencies use the concept of no threshold, to use a shorthand for the idea that any degree of exposure may connote some degree of risk. Not as a basis for policy-making but for a basis of inferring the worst possible situation that might exist. It does not imply that the EPA can regulate the nature of human biology or science, nor that they believe they can. Nobody knows, nobody, how the human body responds with carcinogenesis at extremely low levels of radiation.

The one thing that we do know is that for one form of radiation the response is nonlinear; that is, there is low-dose breakaway. At low doses, you get a disproportionately low level of cancer. Now, that's not established, I acknowledge, for all forms of radiation, but it is established for one form.

So that we have to understand that the EPA guideline is a guideline for policy-making. It's not an attempt to say how human beings work. It's to provide them with the basis for erring on what they would call the conservative side.

Q And isn't that exactly what the Board of County Commissioners is trying to do in this case, sir? Aren't they trying to evaluate the potential for risk in this case?

A I don't --

Q For that reason, wouldn't it be appropriate in this case to just use that same assumption, the assumption that EPA uses?

A Well, I really think that the Commission should determine which guiding philosophy they want to use. I really don't think I should try to say.

Q Well, in this case it is undisputed, isn't it, that there will be some increase in the exposure to the residents of Progress Village?

A Yes. I think the whole essence of the question is whether or not that exposure can be seen to translate into some sort of meaningful augmentation of cancer risks or not, and even if it were, whether or not that would come to balance the possible benefits of having the stack there. At least that's what I had thought was the purpose of this.

Q Yes, sir, but again, that's a decision for the Commissioners to decide, isn't it?

A Right.

Q Thank you.

I have no further questions.

MR. DEE: I have no questions. Well, excuse me. I would like to ask just a few questions of Dr. Rogers.

Whereupon,

LEWIS H. ROGERS, PhD,

was recalled to the podium and testified as follows:

CROSS EXAMINATION

BY MR. DEE:

Q Dr. Rogers, you testified about fluorides and I would like to clarify just a few things about your testimony. You were not expressing an opinion as a medical doctor, were you?

A No, sir.

Q And you're not a biologist?

A No, sir.

Q Or a botanist?

A No, sir.

Q And you've never studied fluorides at any other phosphate plant prior to this case, have you?

A That's correct.

Q And you've done no work concerning fluorides whatsoever, have you, sir, not since 1952, at the earliest?

A That is correct.

Q So, you, in this case, have reviewed the available literature concerning fluorides and you're simply informing the Commissioners about what you found in the literature?

A Correct.

Q Thank you, sir.

COMMISSIONER COLSON: Mr. Reese.

CROSS EXAMINATION

BY MR. REESE:

Q Dr. Rogers, you're at the microphone so we'll start with you, first.

A Okay.

Q In your review of the EPC gaseous flouride emissions, the data collected was on a monthly average, was it not?

A Yes.

Q And the monthly average was three parts per billion?

A Yes.

Q And you had a high of one month of, approximately, four parts per billion?

A Correct.

Q And flowering plants and berries and other types of fruit are sensitive to one part per billion and up?

A But you've gone now to the welfare effects. I was talking about fluorides to human effects. You want to switch to vegetation?

Q Yes.

A Would you repeat your question?
Q There are plants and types of vegetation that are sensitive to fluoride levels of one part per billion?
A That's correct, over a ten day period of exposure.
Q And you have an average of three parts per billion with a high of four parts per billion?
A Correct.
Q And those are monthly averages?
A Correct.
Q And some of the adverse effects on vegetation could be damage to flowers?
A The most sensitive plant -- yes, in answer to your question. The most sensitive plant is probably glads, gladiolas, and they are sensitive to one part per billion if exposed for a ten day period.
Q And sweet corn is also sensitive, is it not?
A Yes. People at the Boise Thompson Institute have classified plants into three categories: Sensitive, mildly sensitive, and tolerant. Gladiolas come in the first category.
Q The actual flower on a flowering plant would be sensitive to fluoride?
A It is usually the leaves. The first effect

that you see of fluoride on plants is on the leaves, and it causes a necrosis, a dying, a browning of the edges of the leaves.

Q Do you know of any studies that could advise the Commission on what levels of gaseous fluorides on various plants that residents would have in their yards would be sensitive?

A Yes. Boise Thompson Institute has published a number of such studies.

Q At what level would a begonia be sensitive?

A I don't remember. I would have to look in the Boise Thompson Reports.

Q So, if I went down a list of flowers that people that lived in the area that would have in their yards, you couldn't tell me right now whether they would be damaged by four parts per billion of flouride?

A Not without referring to the report, no, sir. There are several hundred plants in these reports and I don't remember all of them.

Q Now, Florida doesn't have a fluoride standard for grass, does it?

A No, sir.

Q But six to eight states do have a standard of forty parts per million?

A That's correct, for pasture grasses.

Q And the samples that the EPC has of pasture grass near Gardinier has an average of forty-two parts per million with a high of ninety-two parts per million?

A That was a series -- yes, you're right. That was a series of analyses reported in an EPC Report and there was a small number of analyses, but you're basically correct.

Q Now, you testified that there would be no total increase in the fluoride emissions by this proposed new pile.

A That is correct.

Q But there will be a relocation of where the emissions are going to occur, will there not?

A That is correct.

Q They're going to be closer to residential areas?

A It will be closer to some of the residential areas, yes.

Q In fact, some of the people that are right adjacent to the proposed pile have vegetable fields and other types of flowering plants that could be affected by this proposed pile, could they not?

A I assume so.

MR. REESE: I have no further questions.

Dr. Cole.

Whereupon,

PHILIP COLE, M.D.,

was recalled to the podium and testified as follows:

CROSS EXAMINATION

BY MR. REESE:

Q It's correct that Gardinier is paying you for your testimony here tonight?

A Yes.

Q And you're not testifying free of charge, as a public service?

A Is that somehow different from the question that you just asked? Do I miss something here?

Q The answer to both is that you are being paid?

A Yes.

Q And that your principle field of expertise is in chemical carcinogenesis, correct, not radiation carcinogenesis?

A No. My area of expertise is cancer epidemiology.

Q Stressing chemically caused cancer?

A If you consider that there are various causes, various categories of cause of cancer, then I would say depending on the level of specification that you want to get down to, that my area of expertise is endocrine carcinogenesis, which I guess you can say is a subset of chemical carcinogenesis. But my other area is occupational carcinogensis, which relates both to chemical and to radiation carcinogenesis.

Q You haven't done any independent research on radiation carcinogenesis, have you?

A You mean, by independent research, research that involved de nova data gathering?

Q Correct.

A That's right. I have not.

Q And you've never testified as an expert in radiocarcinogenesis, have you?

A No.

Q On February 2nd, when we took your deposition, you made no mention of the Chinese study that you went into detail about here tonight. When did you first discover that study?

A Mr. Reese, as you will recall, I told you, at the time of my deposition, that I was in the process of making a survey of the literature for the purpose of finding the information that I could find about that question. As you can understand, being from China, although it was published in science, I did not retrieve this paper on my first pass through of the literature search, which I had done at the time of the deposition. Well, I found it -- well, I don't recall now -- perhaps a week or so later.

Q And you had already reached your conclusion in this case prior to finding that study, did you not?

A Well, you say conclusion. You know, a conclusion is antithetical to a scientist. My mind is always open. If you're asking has my impression of the magnitude of the risk changed in that intervening period, the answer is no.

Q Well, this two-page report that is marked as Gardinier Exhibit 27 is the identical report that you had at your deposition, is it not?

A Yes.

Q And that was done prior to finding the Chinese study?

A In fact, it was done prior to having surveyed the literature for information on background radiation as a cause of cancer.

Q And this Chinese study, who did that?

A The authorship is attributed to a group. It's called the "High Background Radiation Research Group of China." One man's named -- well, I'm sorry; I'm not sure if it is a man. One name is given here as the person to correspond with, so I assume he's the chairman or writer for the group. His name is Luxin, L-u-x-i-n.

Q And what type of radiation was involved?

A Background radiation. They were both types; that is, gamma and radium, radon and decayed products.

Q Was the radon inhalation a large factor?

A Well, why don't I tell you what it was and then you can see if you think it's large. It was approximately twenty-four millirems per year in the control area out of a total of ninety-six millirems per year. That's in the control, the low level exposure group.

Q What was the source of this radon?

A Naturally occurring. I don't believe the source is otherwise specified here.

Q How was the population controlled? Over what time period was the study done?

A The study was done -- there are actually two studies recorded here. I mentioned only one because the two studies give identical results with respect to cancer. The first study doesn't deal with the malformations and the like.

Let's see here. The retrospective study -- excuse me for a minute here. Here we are. Okay. The retrospective was 1970 through 1974 and the concurrent study, the one I reported was, I believe, '75 through '77. Well, I don't see it right here, right now, but that's approximately when it was.

Q Go ahead.

A I was just going to say the paper was published in '80, 1980.

Q Was this a comparison of Cancer Registry's data for this four year time period?

A No, there was an archive search made for death certificates in both regions.

Q So, this study is based on some sort of a search for death certificates in China, the rural area of China?

A Is there some adverse implication of the use of the words "some sort of"?

Q Do you know how thorough the search of death certificates was and can you tell us what accuracy death certificates in China are made out?

A I can tell you this, not from personal experience, but the world's epidemiologists have the highest regard for death reports in China. In fact, they set the standards. They have systems of mortality registrations that countries in the West, most especially this country, might try to emulate.

As to how carefully these were sought in this particular study, I don't know. But I can tell you that it's a rather impressive paper, in my opinion.

Q How did you happen to find this report?

A We have done several medlar and medline searches and I think the explanation as to why I didn't find it -- I'm not sure of this, now. If you've ever done these kinds of computer researches, you might sympathize with this. I think the reason is because there's no mention of cancer in the title of the paper. And when I relaxed that constraint on the citation, then this paper came up and I decided to look at it.

Q Now, prior to your work on this particular project, did you ever, or in your work on this project did you ever contact HRS here in Florida or the U.S. EPA Office or radiation programs to ask for input?

A No. I don't even know what HRS is.

Q And you're not familiar with the Thomas and McNeil Study in analyzing the various epidemiological studies that was done for the Canadian Atomic Energy Commission?

A No.

Q At your deposition, you stated you weren't familiar with the Swedish and Czechoslovakia minor studies.

A That's correct, I'm not.

Q And you also stated you weren't familiar with the EPA 1979 Report on indoor radon levels in structures built on reclaimed phosphate land?

A That is correct.

Q And you're not familiar with the T.R. Horton Report measuring -- measuring various radon flex levels off of gypsum piles that was done for --

A That is correct.

Q And you're not aware of what the relative risk model that the U.S. EPA uses in doing radiation risk assessment?

A Perhaps I am. Maybe you can explain to me and I can say whether it is one I am familiar with or not.

Q Well, do you know what the relative risk number is that the EPA uses in their radiation risk models?

A I don't think I can interpret that question. Maybe you can clarify it. I don't understand what you mean by "a number in a relative risk model." The two things could be independent.

Q What percentage do they use as a relative risk factor?

A I can't -- I don't know.

Q At your deposition, you also stated you didn't know whether the U.S. EPA had ever identified radionuclides as a hazardous air pollutant?

A I hope I didn't say that. Perhaps I did. If I did, I misspoke.

Q Are you aware of it now?

A Yes.

Q How did you become aware of it?

A I was aware of it then, too. I just either misunderstood your question at the time or, as I say, I misspoke.

Q On Page 35 of your deposition, the question was: "Do you know whether EPA has identified radionuclides as a hazardous air pollutant under the Clean Air Act?

"ANSWER: I'm not sure whether they did or not.

Do you remember that?

A I don't specifically remember it, but I suppose it's what I said at the time. It sounds like I might have said that at that time.

Q You also stated at your deposition that the field of risk assessment is an extremely subjective area and it's an area where reasonable men differ in their opinions and their assessments?

A Yes, I think that's true. Both that I said it and that it's true.

Q And you also stated that radon is a real

Pandora's Box, and it can cause cancer probably in every organ. Is that correct?

A I don't recall saying that.

Q On Page 102 of your deposition, on Line 14, "QUESTION: In relation to skin cancers or --" And the answer is: "Radon is a Pandora's Box."

A Could I hear the question again?

Q The question was: "In relation to skin cancers or --" and the sentence was never -- the question was never completed. The answer is: "Radon is a Pandora's Box. It can cause cancer probably in every organ. I really don't know how to answer your question except to say that for those for which the risk assessment is well documented or the three that we have spoke of: lung, bone and marrow. I don't know what other effects."

A Mr. Reese, I like to make it a policy, although I guess it's going unfeasible in these logistical situations, not to respond to a printed document that I can't hold in my hand and read.

It strikes me that I was continuing to answer the previous question.

MR. DEE: I'm giving you that as a matter of fairness because I think Mr. Reese ought to let you see the document.

THE WITNESS: It sounds like --

BY MR. REESE:

Q You would probably want to start on Line 5. The question was: "Would radon exposure cause non-fatal cancers other than lung cancer and leukemia, which you mentioned?"

A Why don't please continue reading and I think it will become clear what I was talking about.

Q The answer was: "I didn't mention radon exposure would cause these things. Are you speaking of radon exposure here or in general?

"QUESTION: In general.

"ANSWER: Could cause osteoporosis, carcinoma of the bone.

"QUESTION: In relation to skin cancers?"

And that's when you stated -- your answer was: "Radon's a Pandora's Box."

A That's what it says here. I'm a little embarrassed to see that I used such an expression, but I guess I did.

Q So, it could probably cause cancer of any organ?

A I wouldn't deny the possibility. That is, I have no evidence that it doesn't, but I think we generally think of three organs when we think of its adverse effects.

Q Are you aware of any of the epidemiological studies that have been done in the Southwest Area of the United States; particularly, the Four Corners' Area for genetic defects?

A No.

Q Specifically, I'm referring to a 1981 March of Dimes study of birth defects among Navaho Indians that live near uranium mill tailing piles?

A I'm not familiar with it.

Q It's possible that airborne radon and radon progeny will trap and build up inside structures, is it not?

A I think we can go a little bit further on that and say it's not only possible but there's evidence that it occurs.

Q Dr. Roessler assumed that it would not in his model, did he not?

A I think that's right. Could you excuse me for just a moment while I get a little bit of water?

Q Please. At your deposition, you stated the national average lung cancer death rate is approximately five out of, I believe it was a hundred. Is that approximately correct?

A I hope I didn't say that. That's not a rate. That's a lifetime risk, but that is correct as a risk. The chances of dying from lung cancer in this country are five per hundred per lifetime.

Q And that includes smokers and nonsmokers?

A That's right.

Q Are you aware of any risks that break down in between smokers and nonsmokers?

A Oh, yes, many estimates.

Q Could you give us some that you think are representative?

A You could take -- let me see. I have to convert these now to lifetime risk because that's not usually they're measured. They're usually measured as rates. So let me just think here for a moment.

Let's say -- now, I hope you won't hold me to this to the decimal, to the second decimal place, but for nonsmokers, the risk would be about zero point seven deaths per hundred nonsmokers per lifetime. And for smokers, it would be about ten times that or about seven deaths per hundred smokers per lifetime, averaging out in a weighted average to about five per hundred people per lifetime.

Q So, the lifetime risk of a fatal lung cancer for a nonsmoker would be approximately one and a half per thousand? Point seven per hundred would be approximately --

A About seven per thousand. Point seven per hundred, seven per thousand.

Q Seven per thousand, you're right. Thank you. I didn't major in mathematics.

A Neither did I.

Q Have you had the opportunity to review the recent study done on the cancer rates of Brewster Phosphate employees?

A I think there was a cough at a crucial element and I missed a few words. Could you just repeat it?

Q Have you had the opportunity to review the recent study on cancer rates of Brewster Phosphate employees that was released last week?

A No, sir.

Q At your deposition, you stated that the relationship between exposure to radon and adverse impact or effect is a linear relationship; is that correct?

A Again, it depends on the context. Let's -- let me say, unless we're going to go into this in great depth, yes, I would say that. And over the range of exposures that I think are of interest to us and to the Commission, that would be true, with the possibility that at very low levels, there is low dose breakout and no effect at all. But, you know, that gives me pause, if I could, to just return to this issue about the linearity of the exposure, the linearity of the effect, conditional unexposure in the question that I was asked earlier, because I think I gave a misimpression

Both Dr. Walsh and I, although I think we both share a view, share the opinion that there is low dose breakout, that have low exposure levels, risks, are disproportionately low. Although I think we both believe that -- certainly I do -- we both have used a linear model because we both have to use -- your language -- in acord with EPA recommendation for the most conservative estimate. It is in that sense that I feel the risk of one lung cancer death of thirty-five hundred people in a lifetime is what I refer to as a worst case. It's worst case in that sense that it already accommodates the linear model. And furthermore, it relates to these people on the west side of the stack.

So it's worst case both in taking a maximal estimate of dose and making the maximum interpretation of dose. So that's why I feel justified in my own perception that the truth of the matter -- not the truth of the matter -- the better estimate is one-tenth of that. That is more like one in thirty thousand lifetimes.

Q Well, at your deposition, you stated that there has never been a threshhold established in a living creature, a safe threshhold; is that correct?

A Again, I don't know whether my hearing is bad up here or not. I missed the last two words, I think. In a living creature or, did you say?

Q The quote out of your deposition is "No threshhold has ever been demonstrated to exist in living creatures."

A That's correct. It should be made clear, though, the practical realities of attempting to do that, particularly for cancer, even in animals, much less in human beings are enormous. In human beings, it probably is an unatainable goal.

Certainly, I have to recognize and concede that if there is a threshhold, it's at levels that are very low; that is, levels of exposure that are very low. But on the other hand, by very low, I still mean perhaps well above background levels.

In the China Study, for example, the levels are low to moderate, apparently no effect.

Q Well, isn't true that most lung cancers are caused by the inhalation of radiation?

A Absolutely not. Not even among nonsmokers, in my opinion, and certainly not among smokers.

Among smokers, ninety percent or more of lung cancer is due to the smoking. We should make no mistake about that.

Now, the question is what about among nonsmokers. Some people have contended and there is some evidence, that among nonsmokers, some lung cancers may be due to background radiation. I personally find that evidence completely unconvincing. And as far as I'm concerned, the causes of nonoccupationally exposed -- these are usually to gases, fumes and the like -- people who are nonsmokers, the causes of lung cancer are entirely unknown and it is nothing but speculation to attribute them to background radiation.

I find it a position that is particularly difficult to accept because it has been used, I think, quite unjustifiably, to indict all sorts of air pollution everywhere in this country and around the world.

Q Well, this ninety percent lung cancer rate that you attribute to smoking, do no smokers inhale a large volume of radiation in the process of smoking?

A Firstly, let me try to be very careful here in what we're saying. I didn't say anything about a rate. I said that among smokers, ninety percent of their lung cancer experience it attributable to smoking. Fine. I hope we can agree on that.

Now, the question becomes what is it due to in the smoking. Yes, it's true that some people would attribute it to radioactive polonium in the smoke. I'm not one of those, nor is that the fashionable, nor widely held point of view.

Most people believe, and I do, that the active pulmonary carcinogen in cigarette smoke is benzopyrene, formed during the process of the combustion of the tobacco and most especially of the additives to the tobacco.

Q Well, do not smokers have a higher cancer rate of all organs, not just the lung?

A Well, they very well may, but certainly that hasn't been established but for two or three organs with a high level of certainty and maybe an additional one or two with some degree of certainty. But I wouldn't want to make the statement that you just made: That smokers have increase cancer risk of all organs.

Q If they did have a higher cancer rate for other organs, would it not be logical to think that radiation could be a cause of that?

A I'd have to -- I'm just not prepared to answer that. I would have to consider that at some length and perhaps review some literature on that. I couldn't really say.

Let me point out that the organs of the body for which cancer is most closely linked to cigarette smoking are in the airway. That is, they're a part of the airway. Once you get away from the airway, our level of confidence in the association and the causal nature of the association diminishes very much.

Q Dr. Walsh's report relied on the assumption that the basal cells of the bronchial epithelium are the critical exposure route. Do you agree with that?

A Let me say this. I think that that's a reasonable possiblity. I personally, from the way I read it, perhaps I don't hold that point of view quite as firmly as he does it, but it's a reasonable possibility.

Q Are not the secretory cells five to six times more susceptible to radiation and aren't they the critical exposure?

A They may. They would be the ones I would favor.

MR. REESE: I have no further questions.

COMMISSIONER COLSON: Does the representative of Progress Village have questions?

All right. At this time, Mr. Varn, would it be appropriate for you to make a statement as you did the other night about redirect or recross?

MR. VARN: I think everybody remembers from the other night, but it would be appropriate, at this time, if the Commissioners have any questions.

COMMISSIONER COLSON: Commissioners?

COMMISSIONER PAULK: I'll ask one question.

COMMISSIONER COLSON: Okay.

COMMISSIONER PAULK: Probably Dr. Cole, but either one of you can answer it. The sampling station for the fluoride was the Gardinier Park. Did you expect the majority or what percentage of the fluorides that were in that sampling that came from the pile or came from the actual manufacturing plant there, can you give us a feel for that?

DR. ROGERS: I don't have any data, so all I can do is speculate and I would rather not speculate, unless you want me to.

COMMISSIONER PAULK: I thought it might be obvious. You know, you got a fluoride -- you got the gypsum pile there with the gypsum and the water there and around the plant, you have steam and the various things and dust coming from the plant site.

If you can't, I guess you can't.

DR. ROGERS: I would judge there might be more from the plant than from the pond.

COMMISSIONER PAULK: Thank you.

COMMISSIONER COLSON: Along that same line, that is located east of the plant, isn't it?

DR. ROGERS: Yes.

COMMISSIONER COLSON: I believe the report was that there would be heavier concentrations to the west of the plant.

DR. ROGERS: I don't have any measurements west of the plant. The sampling stations that the EPC ran were all east of the plant and on out further in the eastern side of the county.

COMISSIONER COLSON: How would the concentr-tion be immediately adjacent to the stack as opposed to a hundred yards, two hundred yards, or the distance away from the stack?

DR. ROGERS: Again, I'll have to reason from chemical principles. Fluoride dissipates very, very quickly in the atmosphere and you would find a rapid fall-off as you moved away from the stack. I have no measurements.

COMMISSIONER COLSON: Thank you.

Question by a Board Member?

COMMISSIONER JETTON: This wind, what's the effect of wind?

DR. ROGERS: Wind, of course, affects these numbers substantially. A prevailing wind taken from the Tampa Airport, an average over a five year period, and that is also in my report, is prevailing from the east. About fifteen percent of the time, it is from the east. I have a wind rose in the report.

What would be a good experiment, of course, would be to correlate these fluoride concentrations with the wind. When you're measuring over an average of a month, you probably have the complete three hundred and sixty degrees of wind. So it wouldn't be possible to do it with this technique. You would have to use an instantaneous measurement of the fluoride to correlate it with the wind direction. As far as I know, that has not been done.

COMMISSIONER COLSON: Would you know why the EPA has not established standards for fluorides?

DR. ROGERS: They considered it not a serious health effect.

COMMISSIONER COLSON: Miss Platt.

COMMISSIONER PLATT: In your response to Commissioner Paulk in regard to that study that was done at Gardinier Park, you don't know for a fact whether it was from the plant or the stack?

DR. ROGERS: No. I qualified my remarks, I think.

COMMISSIONER PLATT: I wanted to make sure of that. And then, secondly, is there the possibility of fluorides getting into the soil in any way?

DR. ROGERS: Well, there is fluoride in the pasture grasses, as was mentioned by Mr. Reese, and that has to come from somewhere.

COMMISSIONER PLATT: Have there been any studies about -- about fluoride in the top soil or the possibility of that occurring?

DR. ROGERS: Well, when I was at the University in the College of Agriculture, I ran a great many soil samples using spectrochemical analysis and the spectrograph is not a particularly sensitive method for doing this, but we never found any, never found any fluoride, but I suspect there is some there. I'm sure there is some there, if you use a sufficiently sensitive method of analysis.

COMMISSIONER PLATT: But there have been no extensive studies to make determinations in that regard?

DR. ROGERS: Not to my knowledge.

COMMISSIONER PLATT: Or to determine the impact of those traces in the soil upon humans that come in contact with that?

DR. ROGERS: Not to my knowledge. But there is fluoride taken up in plants and so when -- in our daily food, we get substantial amounts of fluoride. I say substantial, several hundred micrograms a day from food.

COMMISSIONER PLATT: The reason I raise the question is I think one of the concerns is that Progress Village School is nearby and that the children are playing in the dirt and sliding and coming into bodily contact with the ground, the sands, as children will do, and I was just wondering if there were any kinds of studies about -- about fluoride in the soil and any kind of human contacts?

DR. ROGERS: Not to my knowledge. Perhaps Dr. Cole has some information.

COMMISSIONER PAULK: Mr. Chairman. Knowing the byproduct or the product that they turn out at Gardinier is fertilizer, what kind of fluorides would be in the fertilizers?

DR. ROGERS: There would be traces of fluoride in the fertilizer.

COMMISSIONER PAULK: Would there be more in the fertilizer or more from the air?

DR. ROGERS: There would be more in the fertilizer.

COMMISSIONER PLATT: But children don't play in fertilizer, do they?

DR. ROGERS: I suspect Gardinier wouldn't encourage.

COMMISSIONER COLSON: Commissioner Bing.

COMMISSIONER BING: Just one question I would like to know What's your estimation of the distance from the pile, the present pile, to the Gardinier Park?

DR. ROGERS: That sampling station?

COMMISSIONER BING: Right.

DR. ROGERS: I would judge twenty-five hundred feet.

COMMISSIONER BING: So that's about seven hundred feet?

DR. ROGERS: Say a half a mile.

COMMISSIONER BING: That's a further distance than the eighteen hundred feet that the proposed stack would be from Progress Village School.

DR. ROGERS: Yes, I believe that's been quoted: eighteen hundred feet, or something like that.

COMMISSIONER COLSON: Any other questions by the Commissioners?

No further questions by the Commissioners.

DR. ROGERS: Am I excused?

MR. RHODES: Dr. Cole, do you want to try to respond to the fluoride in the dirt question?

DR. COLE: I would just add one thing. You have to understand that the normal movement of fluorides through the human body is one point two milligrams per day. Relative to that, which comes mainly from water and food, the amount of fluroide that the body takes in, that nets in, considering that there's the airborne fluoride that's expired as well as inspired at the level of 3ppb is utterly inconsequential.

What there may be in the terms of dirt exposure of children or children getting their hands dirty and I don't know what, rubbing it on themselves, and they're sweaty and skin absorption that would be speculation.

But at the ambient levels that Dr. Roessler spoke about, that's just a nonmeaningful exposure. It would comprise just an immeasureable proportion of the total movement of fluoride in the body.

MR. RHODES: We have no redirect examination of either witness.

MR. WARD: Do you have further questions of Dr. Cole? The Commission?

COMMISSIONER COLSON: No, we do not have any questions.

MR. WARD: Do you want us to put on an additional witness now or do you wish to take a break?

COMMISSIONER COLSON: I'll ask Mr. Varn. You go to redirect?

MR. VARN: We're through with these two witnesses. It would appropriate to call the next witness unless you want to take a break.

COMMISSIONER COLSON: Let's go with the next witness, because we'll have the two hour span either way it goes.

MR. WARD: The next witness we would like to call is Mr. Rudy Cabina of Gardinier.

Mr. Cabina, were you previously sworn?

MR. CABINA: No.

MR. WARD: You've not been sworn, have you?

MR. CABINA: Correct.

MR. WARD: Would you swear the witness, please?

MS. LOCKWOOD: Would you raise your right hand please. Do you swear to tell the truth, the whole truth and nothing but truth so help you God?

MR. CABINA: I do.

MS. LOCKWOOD: Thank you.

MR. WARD: Mr. Rudy Cabina is Vice-President of Technical Services for Gardinier, Inc. He holds a Bachelor's Degree in Chemical Engineering from the University of Florida and has some thirty odd years of experience in research and development process engineering and administration of production operation.

He's worked at the Gardinier Facility, which is the subject matter of this hearing, generally, continuously since 1959.

DIRECT EXAMINATION

BY MR. WARD:

Q Mr. Cabina, is the brief summary of your academic and professional experience which I have just read accurate?

A Yes, sir.

Q What has been yourrresponsibility in connection with the Gardinier proposal to construct the proposed new gypsum disposal area?

A I have the overall responsibility for project planning, obtaining all the necessary environmental permits, including land use approval.

Q Are you familiar with the various alternatives that Gardinier has considered to the site currently under proposal for the -- under consideration for the proposed gypsum field?

A Yes, I am.

Q Would you please review for the Board the various alternatives which Gardinier has considered?

A Mr. Chairman, Commissioners, I would like to summarize the various investigations and studies conducted by Gardinier regarding alternate sites.

Gardinier initiated an investigation into the selection of a site for storage of gypsum back in the mid seventies. In addition to the proposed site five other sites were considered. I might add that we also considered the transport of gypsum back to our Fort Meade mining operation, approximately fifty miles from our East Tampa fertilizer plant, as well as looking for a remote site, say, sixteen, twenty miles from the East Tampa plant.

The first site under consideration was the area north of the present gypsum field. Let me point this out on the location map for you. The first site I mentioned was investigated back in 1974. We utilized the consulting firm of Woodward Clyde to look at the geology and the site location. We have Archie Creek, which basically flows east to west through the Gardinier property. We have Highway 41 running north and south. The site under review was the area north of Archie Creek, west of Highway 41, with the western boundary being Hillsborough Bay.

We have approximately two hundred and fourteen acres in this area. Essentially, the site was reviewed by both DER and Hillsborough County EPC; and since the area consisted of marsh land, tidal area, mangroves, the use of this site was denied by DER and EPC.

I might add, we did submit a permit application and received denial. I believe the date was October 7, 1976. I had a copy of the permit application appraisal. It's signed by Al G. Burdett, Department of Environmental Regulation, October 7, 1976.

In addition, Hillsborough County EPC reviewed the property and also felt that use of this area, the tidal area, Hillsborough Bay was not appropriate for industrial use. We received a letter from EPC, dated July 23rd, 1979. This is written by Richard G. Wilkins, Senior Environmentalist Scientist, EPC, dated July 23rd, 1979.

Moving southward, we have looked at the present gypsum field to see if it is possible to add any additional volume of gypsum to the present site. Our complex here is located south of Archie Creek. Looking -- we don't have the actual gypsum site on the location map. From a distance standpoint, we have approximately two hundred and fifty feet of open area on the north side of our gypsum field going toward Archie Creek.

Then we have an area on the east side which would run parallel to Highway 41, in which we have a thirty-five acre cooling pond presently on site. It is feasible to consider expanding the base of the present field to the east. The thirty-five acre area where the present cooling pond is located could be possibly utilized for gypsum disposal. The number of years or the extent of, say, adding additional life to the stack is difficult to determine, at this time.

We would have to proceed with the environmental permiting. We would need the appraisal by both DER and EPC.

The study that I'm referring to for this site was essentially a geotechnical investigation conducted by our consultants. We were encouraged, as we discussed some of the findings with EPC and DER, to look elsewhere for a new site.

I might add that our present gypsum field was started in the '30's, around 1930, and has been in operation for over fifty years. Since the field is over fifty years old, it was not designed to today's stringent engineering or environmental considerations.

Our efforts were then directed to sites east of Highway 41. Looking east of Highway 41 and south of Archie Creek were north of Riverview Drive and west of 78th Street. The area in black outlined is our current, what we refer to as our water cooling ponds. The water cooling ponds occupy approximately two hundred and fifty acres. We looked at this site for the possibility of utilizing for gypsum storage.

However, in 1977, we had need for the installation, for the construction of the water retention ponds to meet the 1977 Federal and State Water Quality Standards. So we went ahead and built the ponds that are currently in operation.

Two years' time elapsed, and in the summer of 1979, we embarked upon a program we refer to as our modernization program and also it is referred to as the Phase I of the DRI we are currently considering. Phase I essentially was a modernization of the fertilizer plant, which we had expenditures of around seventy million dollars. We reduced air emissions, improved air quality by converting from dry rock grinding to the state of the art: wet rock. There was a tremendous energy savings incorporated in this project and they did expand the capacity of the plant by approximately twenty percent.

Phase I was approved by the Board of County Commissioners in, I believe, August of 1980 and the development order was issued September 1980.

I might also add, in the Phase I document, as we presented the DRI, and starting with, say, the Summer of 1979, when we submitted our plans to the various agencies, starting with the EPA, DER, and EPC, we did note the fact that a future gypsum site would be required for the Gardinier operations. We had indicated the need for a four hundred acre site for the storage of gypsum. We do have property -- I would say the next area that was considered -- we have approximately a hundred and sixteen acres of land which would be just south of our retention ponds. This total area (indicating). We're east of Highway 41. We're south of Archie Creek, north of Riverview Drive. I would say our property line would be approximately about a eleven hundred feet below the southern base of our retention pond.

We have in this area a total of three hundred and sixty-six acres. As I mentioned, the retention pond occupies two hundred and fifty acres and then the open land that we currently have is approximately a hundred and sixteen acres, for a total of three hundred and sixty-six acres.

It is feasible to consider the placement of gypsum in this area. We have a wetland area, which is adjacent on the western boundary of the retention pond. And I believe if we consider various setbacks and certainly we would have to work with the various agencies, EPC, DER, I would estimate that possibly we could utilize a hundred and seventy to two hundred acres of the total three hundred and sixty-six acres as, say, gypsum storage. Of course, we would have to find another location for the water retention ponds, which are certainly required with the present operation.

Our review continued to two other large tracts of land which we own. We have what we refer to as the Goldstein Property, a tract which would be located east of 78th Street. We would be north of Riverview Drive and south of Progress Village.

We have approximately a thousand acres in this tract, and we looked at the possibility of placing a four hundred and fifty acre gypsum storage area on the site. A geotechnical investigation was conducted by our consultants, Woodward Clyde, and they found the existence of sink holes, wetlands, and bald eagle nesting area. The sink holes were further pursued. They cored some of the sink holes and found out that there was a fracture of the Hawthorne formation. This is the formation that overlies your Tampa drinking water formation. We had a fracture that had gone all the way through the Hawthorne formation down into the Tampa drinking water formation.

It was concluded that the presence of the sink holes certainly pose a grave risk to considering the building of a gypsum field on the site.

We had the sites reviewed. Of course, I might mention that we are presently working with the proposed site, which is north of Archie Creek, west of 78th Street, as outlined in green on the location map.

We had DER, EPA and the Corps of Engineer personnel visit the site, review all the geotechnical information, and they concluded that the site selected was the most suitable site.

I might add that this finding was issued in a joint notice by both EPA and DER in October of 1980, the document that we refer to as the Finding of No Significant Impact. The concluded, after reviewing all the data, that the site selected for the proposed gysum field was the most suitable site.

Q. Mr. Cabina, during your presentation, you mentioned a DER permit assessment. Do you have such a document with?

A Yes, I do.

Q Could you identify it for me, please, sir?

A I refer to the permit application appraisal, a document which I have in my hand, signed by Allen G. Burdett of DER, signed October 7, 1976.

Q Is that document marked Gardinier Exhibit 28?

A That is correct.

MR. WARD: Okay. We would like to admit this into evidence, at this time, if we could, Mr. Chairman, as Gardinier's Exhibit Number 28.

(Whereupon, the above-referenced document was received in evidence as Gardinier's Exhibit Number 28.)

BY MR. WARD:

Q Mr. Cabina, you also mentioned a letter from Mr. Wilkins of the Hillsborough County Environmental Protection Commission. Do you have such a document with you, at this time?

A Yes, I do.

Q Is that marked Gardinier Exhibit Number 29?

A That is correct.

Q Would you further identify that document for us, please, sir?

A The document I have in my hand is the document dated July 23rd, 1979, from Hillsborough County Environmental Protection Commission to Gardinier, signed by Richard G. Wilkins.

MR. WARD: Mr. Chairman, we would like to have admitted into evidence Gardinier Exhibit Number 25, which Mr. Cabina just referred to -- 29, excuse me.

(Whereupon, the above-referenced document was received in evidence as Gardinier's Exhibit Number 29.)

BY MR. WARD:

Q Mr. Cabina, would you describe, a little bit, what that document is about, please, sir? That is Exhibit 29 from the EPC?

A Yes. The subject is suitability of certain areas, Gardinier's property, for industrial use. It mentions that the areas outlined on the attached aerial photograph, and they're referring to an area north of Archie Creek,"The areas outlined on the attached aerial photograph are tidal waters of Hillsborough Bay and Archie Creek. As such, these areas are "Waters of Hillsborough County", and are under the jurisdiction of the Hillsborough County Environmental Protection Commission. These areas are ecologically important and would not be suitable for industrial use."

MR. WARD: I believe you previously admitted into evidence this document as Gardinier Exhibit 29.

COMMISSIONER COLSON: Yes.

BY MR. WARD:

Q Mr. Cabina, did Gardinier have any technical analyses or reports made concerning the various alternative sites which you have alluded to this evening?

A Yes, they did.

Q Do you have with you a series of documents which compromise these analyses and reports?

A Yes, I do.

Q Would you please identify those?

A I have five documents reference to the five sites that I just mentioned. The first document, Exhibit G-30 is the Alternate Site Report North of the Gypsum Field, compiled by Woodward Thorstenson* dated December 1974.

The second document, titled "Alternate Gypsum Storage Field Adjacent to the Existing Field" -- this

*phonetic

was the second site I described -- dated May 1980, compiled by Woodward Clyde.

Q Is that exhibit you just previously referred to Gardinier Exhibit Number 31?

A That is correct.

Q And the one you are now referring to, that's in your left hand as Gardinier Exhibit Number 32?

A That is correct. Exhibit 32 is the Alternate Site Report, Retention Ponds. We have two volumes, Volumes I and II. This Volume I. This Volume II, dated June 1977, Woodward Clyde Consultants.

The next exhibit is Gardinier Exhibit Number 33 entitled "Proposed 116-Acre Gypsum Field." The report is dated June 19, 1979, compiled by Woodward Clyde Consultants.

Q Do you have one final document?

A The last document is Gardinier Exhibit Number 34, 450-Acre Gypsum Field, Goldstein Tract, dated July 1979, compiled by Woodward Clyde, Consultants.

Q You said that's Exhibit Number 34?

A That is correct.

MR. WARD: Mr. Chairman, we would like to have admitted into evidence, at this time, Gardinier Exhibits 30 through 34, which Mr. Cabina's just referred to.

COMMISSION COLSON: Okay.

(Whereupon, the above-referenced documents were received in evidence as Gardinier's Exhibit Numbers 30 through 34.)

MR. WARD: At this time, we have no further questions of Mr. Cabina. Well, let me interrupt.

BY MR. WARD:

Q Mr. Cabina, you have just testified regarding the alternate sites associated or adjacent to the present chemical plant. I believe there are other alternates that Gardinier has considered in the process of selecting the site under consideration tonight. Would you please tell the Commission about those.

A Okay. As I mentioned, we have made studies regarding alterante site locations. First mentioned, that we did consider the pumping or the return of the gypsum from our East Tampa facility back to our Fort Meade mine. We initially looked at the pumping of the gypsum slurry back to the Fort Meade mine through pipelines. This would encompass approximately fifty miles of pipes, the expenditure, the cost of piping system, the total system and we would need a total of four pipelines because we would be pumping the slurry. I think we mentioned in the previous testimony that the gypsum is slurried. We add water to the solid material, the gypsum, and it is pumped through the pipeline onto the present gypsum field. This is the method of transport we use, the current operation. The gypsum is deposited on the field. We refer to this as the wet hydraulic method and so we consider the transport of the gypsum as slurry through pipelines back to the Fort Meade mine location, a total of fifty miles. The total cost we would need to install pumping or booster stations every three miles -- gypsum by itself is a very heavy material -- and we would need to install booster stations every three miles in order to move the material along. We're working with a very large volume, six thousand gallons per minute. We would need at least a five hundred horse power motor to move the gypsum, say, three miles. It would take a total of fifteen, sixteen of these stations, pump stations, drive motors, the electrical power and so forth. When you take the total cost together, the piping, the installation of the piping, the pump stations, the motors, the electrical system, we would be looking at an initial capital expenditure of a hundred and twenty-eight million dollars.

Also, I might add, we would have to, at the mine location, construct a gypsum field similar to what we're proposing for East Tampa. In other words, we would have the clay liner, the drainage system to ensure we collect all the seepage, to ensure we do not contaminate the ground water. We would have to return the water, liquid, back to Tampa. As I mentioned, we're working a very large volume, six thousand gallons per minute. We would have to return the water back to Tampa so it could be reused.

We visualize the gypsum slurry return lines to be installed above ground. This type of piping system will require right-of-way, which we feel would be certainly doubtful that we could acquire since we do not have condemnation rights or eminent domain powers. There would be very costly energy and operating costs associated with this type of system, as I mentioned, the large horse power motors, the operation and maintenance cost of the fifty mile pipeline. We would be looking at an annual operating cost of a little under eight million dollars per year.

When you combine the capital costs, the hundred and twenty-eight million dollars, with the annual operating costs, we would be looking at a total cost of around eleven million dollars per year for this system. With this type of total cost, Gardinier would not be able to compete in the market place with the other phosphate producers and Gardinier would have to cease operations. This is not a viable option.

We then conducted studies regarding the transport of the gypsum back to the Fort Meade Mine location, utilizing railroad cars. And this concept, we would take the gypsum -- it's basically produced in what we call the filtration section -- the gypsum would come off and we would need to dewater the gypsum, place the gypsum on a conveyor belt, convey it to a storage area where we could store the material. Again, we're working in very large volumes. We would be working with twelve thousand tons of gypsum per day. We feel we would need a storage area, out at East Tampa, at least, say, twenty thousand tons, whereby we could take the solid gypsum material and place it into railroad cars. Quite costly system.

In turn, the gypsum would be transported back to the Fort Meade Mine and we would have to then unload. First, the operation would visualize having a system where we could dump the cars. Again, we would have to stockpile the gypsum and then, of course, we would work towards the storage.

I feel that we would need a similar system with the clay liner. Possibly we could reduce the number of drains encompassed in the design since we would be working with the gypsum. Even though you might refer to it as dry gypsum, it's still in a wet state. To give you a little background, the gypsum's mass produced in our operation. It's calcium sulfate but the compound naturally has water associated with the material. In other words, you would have two molecules of water with the gypsum. To that, you always have a certain amount of moisture of water that's associated with the material. I think the lowest we can possibly get the gypsum, from a total water standpoint, would be, say, twenty, twenty-five percent. So even though it's moved into railroad cars, you're looking at, still, the total water contents, this would be what we refer to as free moisture in the combined water, around twenty to twenty-five percent.

The total cost of what I just described, the dewatering system of Tampa, the conveyor belt, the storage, the loading of more railroad cars, then the transport, reversing the process, the total capital cost would be a hundred million dollars to build the total facility.

We would also have to bring in additional railroad cars. In the process of manufacturing fertilizer, for every one ton of gypsum that -- I'm sorry --

for every one ton of phosphate rock that comes to the fertilizer plant, we produce one and a half tons of gypsum. The reason being, you have the rock coming in the -- the phosphate rock. We extract the phosphate portion. You have left, say, the calcium portion, some sand, silica, but then you add the sulfate.

In our process, we produce sulfuric acid. It's another primary ingredient to produce the fertilizer. It takes a phosphate rock, add it to the sulfuric acid to produce the phosphoric acid and then you have left over, as I mentioned, the calcium portion from the rock and the sand that came in with the rock, plus the sulfate. And then the waters I mentioned, you always have assoicated at least twenty-five percent water, twenty-five percent total water with the calcium sulfate. So we have one and a half tons of gypsum for every one ton of rock coming in.

We would have to increase -- if we're able to utilize the same cars for backhauling the gypsum, we would require an additional fifty percent increase in the number of railroad cars. We've talked with the Seaboard Coast Line on several occasions and Seaboard's fairly independent. The railroads are deregulated. They feel that they would want us to use a different series of cars, strictly have cars in gypsum service while the rock cars would remain in the phosphate rock service. In other words, we transport our rock from Fort Meade into railroad cars to the Tampa Plant. They would want to utilize another set of railroad cars. Nevertheless the additional cars, any way you look at it, you would be increasing them by, at least, fifty percent with the additional, say, if you're working with a hundred and fifty railroad cars, would certainly add to the congestion of the cars we're currently handling.

The real problem comes when you look at the rail freight, the cost to transport the gypsum back, of the volumes I mentioned, we would be looking at sixteen million dollars per year cost.

You would be lookingaat three dollars per ton for the hauling of the gypsum back to Fort Meade.

Then when we add the operating cost, the cost to operate all this equipment, the labor, the maintenance, the power, you would add another six and a half million dollars to this cost.

So when you combine the capital cost, as I mentioned, the first hundred million dollars, then the freight cost of sixteen million dollars per year, the annual cost of, say, six and a half million dollars per year, you would come up with a total cost of twenty-five million dollars per year.

Very excessive.

Again, this is not a viable option because we cannot definitely compete in the marketplace with this type of cost and we would have to cease operations.

We then considered the possibility of trying to locate another site. Say, we were looking sixteen, twenty miles east of the plant, southeast of the Tampa facility, to see if we could locate a tract. We would need about a thousand acres because besides the storage of gypsum, you would need the water retention ponds which are part of the operation. Any rainfall that would fall on top of the gypsum stack, it is part of our program to contain all that water. The rainfall comes in contact with the phosphate and so all this water is contained in the water retention pond as part of our water program. So in addition to the gypsum storage area, you would need a site adjacent to the gypsum stack for water retention. And this is the reason we work with about a thousand acres.

We cannot find a viable site. We had our land manager look the various tracts over. We cannot find a contiguous site to consider. Also looking at the pipeline, if we considered, say, piping the gypsum, say, twenty miles from the plant site, again, the question of could you acquire the right-of-way. We see this as being very difficult since we can't condemn the property. And so when we look at this option, we feel that this alternate is not a viable alternate.

In summary, I believe that Gardinier has made a dedicated, intensive effort to find a reliable site for the storage of gypsum and we feel that the proposed site is one that certainly meets the geotechnical environmental and land use considerations. Thank you.

MR. WARD: Thank you, Mr. Cabina. We have no further questions on the direct examination of Mr. Cabina.

COMMISSIONER COLSON: Would it be appropriate -- at this time, we've gone past the midpoint. I would like to recess for a ten minute break, at this point, and then we'll take up the cross-examination.

(Whereupon, there was a short recess taken.)

COMMISSIONER COLSON: If we can get back under-way, at this time, we would appreciate it.

At this time, Hillsborough County will have the cross-examination of Mr. Cabina.

CROSS-EXAMINATION

BY MR. DEE:

Q Mr. Cabina, I would like to ask you a few questions, if I may?

A Yes, sir.

Q First, I would like to make sure that I understand the substance of your testimony. Am I correct in my understanding that it's your testimony that Gardinier will have to close its east Tampa facility if it does not get approval for the proposed site?

A That is correct.

Q And you're also testifying that there are no viable sites in the area near the east Tampa facility other than the one that's been proposed in this case?

A Other than proposed and what I described, for example, with the retention ponds.

Q Mr. Cabina, how many years of phosphate reserves does Gardinier have at its Ft. Meade mine?

A We have over a hundred years phosphate reserves.

Q And how long is the proposed gypsum stack suppose to serve the east Tampa facility?

A Based on the capacities utilized in our program, we're looking at forty years.

Q So, you've got a hundred years of reserves and a stack that will last for forty years?

A That is correct.

Q Isn't it inevitable that Gardinier is going to have to move from the east Tampa facility?

A We're hopeful that since we do have phosphate reserves for a hundred years, that we can be in business for another hundred years. We've been in operation for six years and certainly changes are made in technology. We are undergoing or looking at various research projects in which, hopefully, there would be a utilization of gypsum in some area. We're looking at the use of gypsum in roadways and so we're hopeful that maybe in the next ten, fifteen years, some use of gypsum would be developed.

Q So, you expect that there might be an alternative for gypsum and therefore there will no longer be a need for the stack at some point in the future?

A If finally certain utilization of the gypsum could be developed and, of course, we realize that we're looking at very large volumes, very large tonages, certainly if the gypsum material could be utilized in some other way safely and certainly with all the necessary environmental approvals, why, we have no problem in, say, not using the storage as a means of disposing gypsum.

Q Well, in that case, you don't really know, do you, exactly how long you're going to need this stack?

A We feel that, based on our program -- and I'm going back to 1979, we have made a capital expenditure and modernization of around one hundred million dollars -- so, we feel it is only good business judgment to look at storage of gypsum for a long term. It's very difficult to predict what research might bring about in ten, fifteen years. I think strictly from a business standpoint, the consideration of storing gypsum for forty years is reasonable, based on the fact that we had made an expenditure of a hundred million dollars, which certainly did improve the environment. Plus, I might add, we did increase our capacity by twenty percent.

Q But, at this time, you can only speculate about what your need will be in the future insofar as this stack is concerned?

A Again, I have to go back to our original basis of we feel, in any type of long range planning, certainly is -- I think Tampa and St. Pete considered a ball park stadium. They're looking at a use of fifty to sixty years. So as they look at the traffic pattern, the other factors, the monies required to make this type of a commitment, they're looking at long term. I think that's the only way we can look at the storage of gypsum.

Q Wouldn't it be appropriate for Gardinier to come back before the County Commissioners in ten or fifteen years and show that there is still a continuing need for the proposed stack?

A Again, I must just restate that we're looking at the long term commitment. We're certainly undertaking research, but I think in all honesty, that we should be looking at a commitment in which we can certainly insure that the plant will be able to operate. We're looking at a lot of jobs, a lot of people involved. We've made major improvements in the operation, not only in the environment, but in working conditions. And so I feel certain that in asking for the storage of the gypsum for this term is reasonable.

Q Mr. Cabina, you've mentioned on several occasions that the plant was modernized a few years ago. At the time of the modernization, did anyone promise Gardinier that the approval of the phase one DRI would result in an approval of the second phase of the DRI?

A No, they didn't.

Q So, there's been no promise that Gardinier would be able to get the gypsum stack even if it made these improvements in the east Tampa plant?

A That is correct.

Q So, the decision to modernize the plant was one that Gardinier took at its own risk.

A Correct. We looked at the modernization. As I mentioned, there were improvements in the are emissions. We were being asked by EPC to consider going to wet rock and I think when you take all the factors into consideration, there was a federal study made in 1978 and '79, referred to as a DIS Study, Environmental Impact Statement, and they recommended that existing fertilizer plants be modernized, meeting all the new technology, which we did, and certainly I feel that we were following all the requirements in our permitting process. We worked with the EPA. We have approval from EPA. We worked with DER. They intend to issue a permit. We worked with County EPC. They intend to issue a permit. We have worked with the Region. They have approved conditionally the new site. So I feel we were never told there were any facets of what we were trying to do. The proposed gypsum stack was always a part of our program. It's documented, starting 1979, and we realize that we will certainly have to come back before the Board of County Commissioners to certainly present all the facts, which we are currently doing, and I'm hopeful the Board of County Commissioners, after hearing all the facts, would grant us approval for the proposed site.

Q Mr. Cabina, were you here on the first night of this hearing?

A Yes.

Q Excuse me?

A Yes, I was.

Q Did you hear Mr. Gibson testify?

A That is correct.

Q Did you hear him say that the sink holes on the

Goldstein property could be grouted?

A I think he did make the statement that he felt that the sink holes could be grouted.

Q Wouldn't that eliminate the major obstacle to the use of the Goldstein tract?

A I might add that there were no further questions and Mr. Gibson did not elaborate. I think when you look at the potential of the sink holes on a piece of property, and several were noted, they were cored. We did find them fractured through the hawthron. I think we share Commissioner Platt's concern in building a gypsum field of the size we're proposing, that certainly no one, including Woodward Clyde or any other engineering firm, would guarantee or assure Gardinier or the Board of County Commissioners that the placement of the gypsum stack on that property would not pose a threat. The potential of a sink hole occurring would be real. And I feel that they or any other engineering firm would not assure Gardinier or the Board of County Commissioners that this potential could not occur.

Q Well, what about the property that you referred to as the current cooling ponds. I believe you said there are about two hundred and fifty acres there; is that correct?

A That is correct.

Q And then there's another one hundred and seventy or two hundred acres of land that could be used just to the south of the cooling ponds?

A I believe the area south of the cooling ponds is approximately a hundred and sixteen acres.

Q Now, maybe I misunderstood you, but I thought you said the area where the cooling ponds are located would be viable as an alternative site; is that correct?

A We looked at the site from a time standpoint. This was 1977, and it is feasible to consider that area for gypsum storage. We made the commitment to replace the water cooling ponds in that area. As I mentioned, we had the requirement to meet the 1977 federal and state water quality standards. So that's certainly looking at the situation today, it is feasible to consider that area.

However, again, the size of the area, the amount of storage that would be possible, I estimated approximately a hundred and seventy to two hundred acres.

Q And how long would that allow you to operate the east Tampa plant if you use that site?

A Probably -- I would have to go back and you're working with another basin. We would have to make some calculations. They're fairly straight forward and I can't really give you a specific answer tonight.

Q More than ten years?

A Yes. I believe it would be more than ten years.

Q Do you know whether it would be more than twenty years?

A I can't tell you exactly.

Q What about the area just south of the cooling ponds, the one hundred and sixteen acre site, is that also a viable site?

A The geotechnical investigation indicated that the site was viable. As I mentioned, the land area by itself would be too small to consider by itself.

Q What if it were used in conjunction with the area where the cooling ponds are currently located?

A This is where I mentioned when we combined, say, that area with the cooling ponds, it is feasible to consider. Finally, you would have to look at, as I mentioned, the set back requirements. We would have to look at the area to the west of the cooling ponds, the wetland area, and definitely, we would have to conduct some additional geotechnical studies, but I would estimate that we could possibly visualize a gypsum field in the size range of a hundred and seventy to two hundred acres.

Q And how long would that gypsum field last?

A This goes back to your question, a couple questions before that, and that's where I can't tell you the exact years of life.

Q Okay. Now, you mentioned the fact that there are wetlands on that site. There are wetlands on the proposed site as well, aren't there?

A The wetlands, I believe, on the proposed site would be very small. If I recollect correctly, possibly, maybe, an acre, an acre and a half.

Q So, the fact that there are wetlands there is not an insurmountable problem?

A No, sir. Hopefully, we would be able to mitigate them, say, replace those wetlands in the immediate area.

Q Now, you mentioned that you had looked at the possibility of going sixteen, eighteen miles to the east of the east Tampa facility. Why didn't you look at any sites closer in to the east Tampa facility?

A Well, actually, we did, but as you go east from the plant site, you're going into the Brandon area and there are no large tracts north of the Alafia River. So that in our investigation, we basically would be looking, going, say, southeast of the Tampa facility.

Q Mr. Cabina, could you give us an estimate of the cost that would be involved in using the one hundred and sixteen acre site and the two hundred and fifty acre site?

A In what respect?

Q How much would it cost to build a gypsum stack on either one or both of those two sites?

A If you work with a smaller area, say, a smaller base, certainly, the cost of the field itself would be less. The projected cost for the gypsum field, the three hundred and eighty-nine acre field, is thirty-five million dollars. So the cost would be less. However, we would have to then look at the cost of relocating the cooling ponds. This would be a considerable cost and any other factor that we would have to consider.

Q Well, if you used the current cooling ponds as a site, wouldn't you be able to sell the site that you currently have for the proposed gypsum field and use that as an offset to the cost of building a gypsum stack?

A We would have to -- as I mentioned, the retention ponds and water cooling ponds are necessary to the operation, and we would have to have an area in similar size, say, around two hundred and fifty acres for water storage.

Q How much would it cost to relocate the ponds?

A I can't give you a figure this evening.

Q Do you have even a rough estimate?

A No.

Q Now, you've told us it cost thirty-five million dollars to build the proposed three hundred and eighty-nine acre gypsum stack. And you've told us what the operating cost would be for these other alternatives that you've evaluated.

What are the annual operating costs involved with the proposed stack?

A The proposed stack, we would be looking at an annual operating cost, operation maintenance of around two million dollars per year.

Q That was two million dollars, sir?

A That is correct.

Q You've given us the capital investment cost and the annual operating cost for these alternatives of sending the gypsum back to Polk County. Do you have any chart or a diagram that would break out those numbers? So far you've just given us the total amounts.

A I can give you a description of the various costs that were utilized to arrive at those numbers.

Q Could you do that, please?

A Sure. Working with the pipeline study, we're working with a fifty mile pipeline. We had the total cost of the piping system. As I mentioned, we would be working with four pipelines. We would be working with polyethelene line, steel pipelines, for the gypsum; in fact, also for the water. You would be looking at at least a twenty-two inch diameter pipeline and when you look at the total cost of the piping and installation, you would be looking at a total capital expenditure of seventy million dollars.

Then I mentioned, you would need booster stations. This is a station which you would lift the gypsum and move it every three miles, utilizing five hundred horsepower motors. So when you take the cost of the booster stations, the pumps, the motors, electrical service, you would be looking at an additional twelve, thirteen million dollars. This would take you up to, say, around eighty-two, eighty-three million. And then you would need the acquiring of right-of-way. We calculated right-of-way cost approaching five million dollars. And then with engineering, we would be looking at, say, a total cost of around ninety million dollars.

Then, in turn, we would need to add the cost of the gypsum storage area, which is thirty-five million. And then I believe we had three million dollars we would have to go through the permitting process, DRI Study. So that, I believe, takes ninety million and add thirty-five, additional three, and I believe it would be at a hundred and twenty-eight, if my math is correct.

Q Mr. Cabina, could you also break out the costs that were involved in your estimate regarding the use of a railroad?

A Okay. In the railroad case, we work with the gypsum which was coming from our operation, coming from -- what we refer to as our filter table and we would take the gypsum and we would need to dewater. Then we would be conveying the material into a storage area. I believe we mentioned we were working with a storage area around twenty thousand tons. As I mentioned, we, of course, are dealing with a very large high volume material. We're producing twelve thousand tons per day.

Then you would need the railroad track, the loading system to load the gypsum aboard the railroad cars. In turn, the railroad cars, when they arrived at the Ft. Meade mine site, would have to unload the gypsum from the railroad cars. Again, we would have to handle the material, convey it, get it into an area whereby we could utilize the gypsum and stockpile it. Similar principle of placing the gypsum above ground, utilizing a clay liner. Even though it might be in a dryer form, it possibly does not have as much water as compared with the wet hydraulic method in stockpiling. Certainly when it would rain, the rainfall that would fall on top of the field, certainly rainfall would pick up some of the phosphate. Before, you would either have to collect all the -- what we call leachate. All the water that's generated, it would have to be contained to insure no ground water pollution.

So that the actual station, say of both Tampa and Ft. Meade, the dewatering, the conveyors, the motors, the storage area, the loading equipment, facility for loading and, again, we're loading a very large volume, we calculate the cost for both loading stations, the engineering, at seventy million dollars. And we feel then the actual construction of the new gypsum storage area, possibly, we can be able to reduce the number of drainage, the pipes involved in the drainage since we would not have the volume of liquid to handle. We estimate that cost at, say, thirty million dollars for a total of one hundred million dollars.

Q Mr. Cabina, you had mentioned the operating costs for the new stack as being two million dollars a year. Now, is that the operating cost or the annual cost, the total?

A I think -- say that we're comparing apples with apples, I think the two million is what we call the annual operating cost, operating and maintenance. But we would need to add, say, the million dollars in capital for the stack. So to compare with the eleven million and the twenty-five, you would need to compare with three million to have it all on the same basis. So a total cost, let's say, a total cost for the new gypsum disposal field, which would be the capital amount, thirty-five million dollars, and the outgoing costs would be three million dollars, compared to the eleven, compared to the twenty-five.

Q How did you arrive at the figure of thirty-five million dollars for the new stack? What are the components of that?

A The proposed stack -- of course, we've done considerable engineering. We know we're working with a compacted clay liner. We've made numerous investigations, calculations on how we would obtain the clay material, how it would be compacted. We know the total piping system involved in the design. And so when you take all the components in building the new stack, you're looking at a total cost of thirty-five million. I hoped it would be less, but unfortunately, our industry is highly capital intensive and normally the projects run five, ten percent more than we estimate.

Q How much would it cost to build the leachate collection system beneath the stack, just the under drain system beneath the base of the stack?

A I can't give you the exact breakdown of the base of the stack and the other components.

Q Can you tell me how much it would cost to add to the peripheral drain system on the sides of the stack as the stack goes up? Can you break that down into a yearly amount?

A The peripheral drains are added at twenty foot intervals and I can't give you a breakdown. The numbers are recorded and certainly we can provide them to you, but I can't give you the specific dollars for various pieces that you're looking at.

Q Can you tell me how tall the proposed stack will be in ten year increments? That is, how tall it will be after ten years, after twenty years, after thirty, and, obviously, at forty years, it's predicated to be two hundred feet. What about the intervening time period?

A Okay. Based on the average production rate of twenty-seven thousand tons of production, the gypsum field would be, say, at the end of ten years -- at the end of ten years, it would be forty feet in height. This is vertical height. At the end of twenty years, it would be seventy-five feet. At the end of thirty years, it would be a hundred and forty feet, and at the end of forty years, it would be two hundred feet.

Q Mr. Cabina, are you involved in Gardinier's research program for developing alternative uses of gypsum?

A Yes, I do get involved with that program.

Q In Mr. Ward's opening statement, he mentioned that Gardinier would continue to do research on potential uses of gypsum. Can you tell us specifically what it is that Gardinier is doing, what it intends to do?

A Okay. We have conducted extensive research into utilization of gypsum over the last thirty, forty, fifty years. I would say starting with the 60's, back in 1966, we had a major project in which we tried to recover the sulphur from the gypsum. It was a two year project. We actually had a pilot plan and we were able to recover the sulphur from the gypsum after two years of hard work, of many technical problems that had to be overcome and I believe we easily spent a million and a half dollars, which was certainly a lot of money in 1966, '67. And further research was conducted by us in the 80's, utilizing outside engineering firms. We even had a research chemist on our premises for nine months working some new ideas and again trying to recover the sulphur from gypsum.

Also, a number of papers have been printed of various engineering firms that have looked at this process. And what it has boiled down to, the cost of recovering the sulphur, it takes a lot of energy. You have to heat the gypsum to very high temperatures. I believe we were working with, like, two thousand degrees of Fahrenheit. You're trying to break the sulphur away from the compound.

As I mentioned, you have the water inherent in the gypsum material. Of course, you're also driving the water off which comes in contact with, say, some of the fluoride phosphate. Tremendous involvement in, say, scrubbing gases to insure that the discharge of any air emissions would certainly meet all standards, county, state and federal.

The cost to finally recover a ton of sulphur was always at least fifty percent higher than what you could say to purchase a ton of sulphur on the open market. It was never economically viable to recover the sulphur from the gypsum. In other words, you could possibly buy sulphur today at a hundred and fifteen dollars a ton and to recover the sulphur from the gypsum, you would be working with maybe two hundred dollars per ton. Of course, we always recognize the high cost of energy.

And we've made numerous other studies with gypsum. I mentioned, we're working currently for road use. We're working with the University of Miami. They have extensive programs underway. We're hopeful that we will be able to build a test road, using the gypsum material in combination with fly ash. There is extensive work going on in Texas. There have been some roads built with gypsum in the State of Texas. They look very good and they're moving ahead to build a state primary road out of gypsum, I believe, and fly ash. Gypsum would be the same type of gypsum we produce. It's from a fertilizing operation.

Then there are other utilizations, other uses of, say, insulation work being conducted. We know the Japanese, I believe the French and several other countries, utilize gypsum in insulation materials. So it is being used extensively.

Also, in agriculture, I think approximately a million tons of gypsum per year is used throughout the United States, Georgia, North Carolina, Virginia, for, say, the sulphur additive. It's also applied in Arkansas, out west of California, extensively, say, for reducing the PH of akaline soil. So gypsum is used as a soil additive in many states and probably a few other areas that it's being considered. So there is extensive work going on and we are participating.

As I mentioned, again, you can't predict what research will bring about, but certainly, we're making an effort to determine if it can be utilized in some other way.

Q Mr. Cabina, you mentioned that the sites that were looked at in the eastern portion of Hillsborough County would be prohibitively expensive and that they were not viable from an economic viewpoint. Now, what criteria did you utilize to determine whether a site was economically viable or not?

A I mentioned we really could not locate a site large enough for both the gypsum field and the retention pond. And I mentioned that when you look at the piping of material, trying to transport the gypsum by pipeline, the number of problems, the acquiring of property, how you would finally get the right-of-ways, we feel would be very difficult. Even the placement of the gypsum pipelines above ground, the reason that we prefer to place them above ground, as I mentioned, gypsum is a very heavy material and with various booster stations, if you have a power failure, which they do occur frequently during storms, once your pumps shut down and the gypsum would just settle out in your pipeline. We've had these experiences in the plant. All you can do is open up the pipelines and try to flush the material out, out of the pipelines or rod the material out and then you would have to put your pipeline back together and start up again. So the transport, you're dealing with a solid liquid. You're all familiar with ammonia in transport of petroleum products. When you're dealing with a gas, like ammonia, natural gas, no problem. You're strictly dealing with gas and compressors, high pressures. This is very easily done. Petroleum products are transported many miles. But again, you're dealing with a liquid, and, again, very little difficulty. And these lines are generally buried below ground in the United States. So even the gypsum material, again, trying to keep it above ground, I can see some problems. If we bury the pipelines, then when you have failure, the line plugs, you're going to have to dig up the soil, the ground, unplug your lines and again, it's very hard to conceive this actually working from a practical sense.

You look at trying to rail the material twenty miles, talking with Coastline and they still want their sixteen million dollars. They go by the tonage and even though it's twenty miles, it still takes the same engines, maybe not as long, but again, the freight cost would be there.

So, those options, from an economic standpoint and the pipeline from practical, trying to conceive how it would actually operate, to me are not viable.

Q Mr. Cabina, when you and the Gardinier staff evaluated these alternative sites, did anyone try and evaluate them from a land use prospective? That is, did anyone try and determine whether the alternative sites had the appropriate zonings and were compatible with surrounding land uses?

A All our studies initially looked at the geotechnical, as I mentioned. We have the various documents, the studies made by Woodward Clyde, in 1974. All our studies started with the geotechnical investigations.

I think probably not until we finally found a site which was satisfactory from a geotechnical standpoint and engineering, environmental, then we would say, look at the site from a land use standpoint.

Q Was that done in this case for the proposed gypsum field?

A Yes. We made our studies. As soon as we were aware of the sink holes on the Goldstein tract, we immediately proceeded to investigate the tract north of the -- north of Archie Creek, the proposed site. These studies were made in 1979, started in, say, August of 1979. And once these studies were completed, this data was all compiled and we started our process of reviewing the data, the information with the federal government, of the EPA, DER, and EPC was aware of our findings and I mentioned the process whereby site visits were made by DER, EPA, Corp of Engineers. They looked at the Goldstein tract. They looked at the proposed site. They reviewed the information and concluded that the proposed site was the most suitable site for the proposed storage of gypsum.

Q Was the proposed site analyzed insofar as zoning is concerned? Did anyone look to see whether the proposed site had the appropriate zoning?

A We looked to the zoning, I would say, in the period of, say, 1980, '81. We felt that the land use was appropriate since we did have the water retention ponds east of Highway 41. We looked at the storage of gypsum very similar to the water retention ponds. The storage of the gypsum would be a passive type situation. Gypsum pile would create no noise, no smoke, no vibration. We feel we would be grassing the sides of the field, replacing trees around the perimeter of the area. Certainly, we feel that it would fit in with the appropriate surroundings. This was taken into consideration right at the site -- say, beginning in 1980.

Q Mr. Cabina, isn't it true that the Gardinier staff met with some of the Hillsborough County staff to discuss the zoning on the proposed site?

A There had been several meetings with the staff.

Q And wasn't it the conclusion of the County staff and the Gardinier staff that the proposed site should be rezoned as a M-1, heavy industrial use?

A I can't recall that being the conclusion.

Q You don't recall any internal memos that were circulated by Gardinier in which it was determined or suggested that the proposed site should be rezoned in the M-1 category?

A I can't recall any specific memos. There could be some correspondence, but I can't recall no specific letters.

MR. DEE: All right. I have no further questions.

COMMISSIONER COLSON: Mr. Reese?

CROSS-EXAMINATION

BY MR. REESE:

Q Mr. Cabina, the general procedure for mining phosphate is that the phosphate matrix mine in Polk County, generally, it's processed in Polk County? Is that not correct? That's the way most companies do it?

A Several of the companies process in Polk County and several process in Hillsborough.

Q Eastern Hillsborough?

A And western Hillsborough.

Q Western would be Gardinier?

A Correct.

Q Now, the companies that process their phosphate rock in Polk County have to transport their sulphur from Tampa, do they not? The sulphur comes in to Port Tampa and it's then transported to Polk County?

A Some of the sulphur comes in to port and certainly needs to be transferred to Polk County.

Q So, for many years now, Gardinier has been saving the cost of transporting sulphur to Polk County by having its chemical plant in east Tampa. You've been saving that cost of transporting sulphur, correct?

A There could be a slight savings. Also, I might add, we have the cost of transporting the rock to the facility whereby fertilizer plants in Polk County, say, the Nixon Mine would not have that cost.

Q They would have to transport their product to the Port and ship it out, wouldn't they?

A Correct.

Q Two years ago, Gardinier was proposing to put gypsum in mine cuts at its Ft. Meade mine in Polk County, was it not?

A We were doing some research regarding the utilization of gypsum, what we refer to as our phosphatic clay consolidation project.

Q You were proposing to transport that gypsum to Polk County by railroad cars?

A We actually were not proposing to transport the gypsum back to the mine. The project was a research project which was part of the project, main objective being the consolidation of phosphatic clays. We have pursued this project. In fact, we're hopeful this project could be viable and we would be able to build a facility to accomplish this task.

Q Well, if it is viable, you will have to transport the sulphur or the gypsum to Polk County.

A That's not correct.

Q How would you put gypsum into the mine cuts if you don't transport it from east Tampa to Polk County?

A I think we need an explanation of the project that we were pursuing. We're going back approximately, say, two years and twenty, twenty-six months in which the main objective was to take the phosphatic clays -- I think you're all familiar with the current practice, where the phosphatic clays from the mining operation are stored in settling grounds and these settling ponds have dike walls, ponding areas. Dike walls being forty and sixty feet in height.

In the mining process, the phosphatic clays come from the mining process, very low concentration. Three percent, say, solid volume and then the balance is water. So, all the phosphatic clays have been stored in the settling ponds.

Our research project was to see if we could consolidate the clays, remove the water, dewater, whereby we could compact the clays at a much faster rate and avoid building the high dam or settling ponds required for the storage of phosphatic clays. We worked with gypsum as well as sand to see if this would aid the compaction of the clays.

The gypsum was possibly tried in the laboratory, some small test cuts for a period of, say, two, three months. The results were not encouraging and it was discontinued.

In fact, we worked with sand to see if the sand would aid to the compaction and consolidation of the clays. In fact, the final process that we're pursuing is without the sand and just the compaction of the clays, using a flocculent which to aid the compaction of the clays. So the gypsum was never really considered. It was just an idea. And I think probably to help the Board of County Commissioners, when you work an industry, you have many ideas of recovering sulphur from gypsum. The idea has been tried four or five times. We have maybe spent to date three million dollars. In other ideas that come about. When I worked with the I. DuPont for sixteen years -- I was associate producer to development, the first week on the job, I was told we might have a hundred research projects, a hundred ideas. They all sound great, but only one would be successful and ninety-nine would fail. We needed a hundred projects to have one that would finally work on a commercial basis. I think Mr. Reese has taken that idea and I could give you ninety-nine hundred ideas and I can tell you one that was successful in our research over the years in a fertilizer. We did develop the process for producing dimonium phosphate where you can add the nitrogen to the phosphate. This is prior to, say, 1957.

The basic fertilizers made in phosphate plants were just triple super phosphate or single super phosphate. You utilize in fertilizer in Florida, you have NPK. You have phosphate. You have nitrate. You have pot ash. Prior to 1957, you would basically produce the phosphate with the product. We were able to develop in laboratory research development, come up with a product dimonium phosphate eighteen percent, 1946 phosphate.

The point I'm making, we certainly have looked at many ideas. Sometimes, we look at them for a month, two months, three months in the laboratory and then we see from a technical standpoint, or for other reasons, they're not feasible and the ideas drop. So I think this was the case of the gypsum. It didn't aid compaction. I might add, the gypsum, the small amount we utilized, was obtained right next door, U.S. AgriChemicals, which is adjacent to our Ft. Meade mine. They provided possibly a half truck load of wash, utilizing our research efforts.

Q Well, wasn't your proposal to mix gypsum, sand, and clay at a one to one ratio and if that had been feasible, you would have transported the gypsum from your east Tampa facility to Polk County, would you not?

A Again, I must say, that you're working with a research idea. The idea never really was proven out. It was immediately dropped after two, three months' work and, again, to further speculate what would happen, certainly, this was not considered by Gardinier at this time.

Q You testified briefly about the possibility of expanding existing gypsum pile. You would have thirty-five acres to the east and you would have some area to the north; is that correct?

A Yes. We did look at the possibility of adding to the existing field. I believe the area to the north, it's questionable, because, as I mentioned, we only have around two hundred and fifty feet and then we're approaching Archie Creek, if it would be feasible to utilize this area. And so I believe the area to the east is the area that would have the potential for, say, adding some short term additional life if we're able to get the necessary permits from the various agencies.

Q Well, if you added thirty-five acres to the east of the pile, you could also add to the heighth of the pile, could you not?

A If you were able to increase your base, that is correct. You possibly could add some additional heighth to the pile.

Q On December 15th, 1980, you wrote a memo to Bob Guthrie, which you attached a copy of a memo that Al Morrison had written you on December 9th, 1980. Mr. Morrison's memo listed the various permits that might be required for a gypsum field and he states that there were very strong possibilities that the following rules could be in existence prior to constuction and one that he listed was a hazardous waste permit for the gypsum pile.

In your letter to Mr. Guthrie, you stated that it was important to start the construction of the starter dike before 1983 in order that we can -- that that would put us ahead of EPA's future potential legislation with regard to hazardous waste.

Was it Gardinier's intent to try to get this pile started as quickly as possible so that they could avoid the hazardous waste regulation that EPA has in the process?

A That is not correct.

Q These letters seem to state that fairly clearly.

A I think you need to look at all the facts. We have, in all our projects, certainly the awareness of the environment in every project that we have proposed, the initial data. The first approach would be to approach the various environmental agencies to consider the ramifications of the project. As I mentioned, we did, in the summer of '79, put together the modernization program in which it was well stated that a proposed site, future storage of gypsum, would be required. It appears also in all the documents that I placed in the exhibits, the various Woodward Clyde documents. It mentions that the existing gypsum field would be approaching a final, useful capacity of life. I think they use the years 1985 and 1987. This goes all the way back to the year 1974.

So, we've always certainly recognized the need of a future site. We have been encouraged by the agency, the state, and the county to look for a site, say, east of Highway 41. We realize that the present stack is fifty years old and it certainly was not built to today's stringent engineering and environmental standards. So Gardinier has always wanted to look to a new site, a site that we could build, utilizing the state of the art technology, working with all the agencies to insure that we meet all the environmental requirements, certainly keeping in mind the community and the neighborhood as we try to project the placement of the gypsum in the proposed area.

Q Would you classify phospogypsum as a solid or a semi-solid industrial waste?

A No, I wouldn't.

Q Why not?

A As I mentioned, phospogypsum is used in agriculture. It's used throughout the world for insulation. It's being used for road building. Therefore, phospogypsum as we produce it in the fertilizer product, is a waste byproduct.

Q It's an industrial waste byproduct of a solid or a semi-solid nature?

Q It's a byproduct, semi-solid, which is being utilized to some degree in this country and throughout the world for other uses.

Q What is a gypsum filter pan residue from a phosphoric acid plant?

A The gypsum, as I mentioned, is generated from the process whereby we are separating the liquid phosphoric acid from the solid material gypsum. Part of the process we refer to as the filtration step. This would be the second step of producing phosphoric acid.

The first step, you take your phosphate rock. As I mentioned, we bring in sulphuric acid. You go into large vessels identified as digesters and you produce the phosphoric acid in the solid material gypsum, in the first step. And then the second step, the filtration step, we separate the phosphoric acid from the solid material gypsum and the gypsum is then transported and stored in our gypsum storage area.

In the process, you do have what we refer to as a scale build up within the equipment and we have a normal maintenance cycle for maintenance of this equipment. And you have some material that remains, and this material that is disposed of in this case, as Mr. Reese has mentioned, the crystal from the filtration process. We possibly have a generation of maybe a hundred pounds, a little over a hundred pounds a year. And this material is disposed of by us. It is disposed with the gypsum into the gypsum field. It comes under our operating license by HRS for the disposal of the crystal from the finishing process. We are permitted. We are licensed to carry on this procedure, as I've described.

Q This license that you refer to that the HRS provides for the filter pan residue, that's for the disposal of radiation waste?

A It is for the disposal of the scale material which I mentioned is disposed with the phosogypsum.

Q And the reason HRS issues a permit is because this scale filter pan residue is radiation, is radioactive waste?

A I wouldn't classify it as a radioactive waste. It's a material residue which comes from the process. It's a known material identified by HRS and it is, as I mentioned, disposed of by placing the material into the process. We place materials in what we refer to as the gypsum slurry tanks. We're pumping the gypsum, the slurry, very large volumes we're dealing with, six thousand gallons per minute, and the small amount of crystal that is being discussed is disposed of in this fashion.

Q But HRS wouldn't regulate this unless it was radioactive waste, would it not? This is a radiation disposal permit or license.

A It's our license to operate. You have scales of devices for weighing which would come under the HRS jurisdiction.

Q On what date did Gardinier buy the Goldstein tract? Was it November of '78?

A I believe November of '78 is correct.

Q And Gardinier purchased it and then found out that it had problems, that it couldn't be used for a gypsum pile?

A After purchase, we initiated the various investigations and found, as I mentioned, the presence of sink holes, wetlands, and was determined not to be satisfactory for the storage of gypsum.

Q Gardinier bought a six hundred acre tract of land before they found out whether it could be used for the purpose that they intended it for?

A The purchase of the property was certainly to -- if there was certainly a need of future utilization of property for any long range company plans, definitely, we did look at the property for the utilization of a gypsum storage pile because we proceeded to make the investigations.

MR. REESE: I have no further questions.

COMMISSIONER COLSON: Mr. Dawson?

MR. DAWSON: Thank you.

CROSS-EXAMINATION

BY MR. DAWSON:

Q Mr. Cabina, my name is -- Mr. Cabina, my name is Warren Dawson. I represent the people of Progess Village and I just have a few questions for you.

You have delineated that these sites -- you refer to a Goldstein site, is that correct?

A Yes, the Goldstein tract.

Q Goldstein tract. How many acres is that?

A The actual tract is approximately a thousand acres.

Q Approximately a thousand acres?

A Correct.

Q If I understood your testimony, this tract would be suitable save for the fact that you found sink holes that penetrated the hawthorn; is that correct?

A That's correct.

Q Let me understand this. Is there anything about the Goldstein tract other than the presence of the sink holes that you refer to that would be more -- more or less costly in utilizing that site as distinguished from the proposed site?

A No. It's in the same vicinity and so the use of that site would be fairly comparable.

Q All right. In all of the annuls, current annuls of dealing with technology to resolve problems concerning ground water protection, has there ever been anyone to devise a reasonably safe method for dealing with the existence of sink holes?

A In my experience, I feel that certainly when you're looking at a site or building, we'll say a half an acre, there are methods that are utilized to -- for, say, foundation work in which you can utilize, say, a half an acre site with, say, some sink holes and corrective measures could be incorporated to enable, say, the use of the site for saleability.

Q Why do you limit it only to a half acre situation? What's the importance of that?

A Because when you look at the storage of gypsum, we're looking at a very large base and it's very important that the clay liner, which is placed under the gypsum material be such that we have no fractures, such that it can be contiguous and function as we perceive it to function so that when you're working with, say, the base of the three hundred and eighty-nine acres in knowing that you do have sink holes on the property, to be able to mitigate or take corrective measures for the entire base and then assure Gardinier or the Board of County

Commissioners that, yes, we feel that there would be no potential for a sink hole failure. In my judgment, having worked with various engineering companies, my thirty years of experience, we would never get this type of assurance.

Q Let me ask you this. In the half acre situation, what is -- is it a very costly process to do the work on a half acre situation, to insure the integrity of the technology that is utilized to overcome the presence of a sink hole, say, on a half an acre tract?

A Yes, it would be quite costly.

Q Well, what do you call quite costly?

A Depending, of course, on the situation, you vary. As Mr. Gibson mentioned, that grouting was one method. There are other methods of piling excavation so that the situations do vary and you could be looking at a sizeable sum of money. Not knowing exactly what method would be, say, provided for the half acre, you have to certainly have a compete -- complete knowledge of the type of sink hole before you can really proceed with a corrective measure. So I couldn't even guess at a figure that would be utilized.

Q Well, let me ask you this. With respect to the Goldstein tract, how pervasive were the sink holes found?

A They could occupy seventy-five percent of the property.

Q So, seven hundred and fifty acres?

A Approximately.

Q Is that documented any place?

A We would have to go back into the very large Woodward Clyde reports to try to say, determine that. That number is in that specific report.

Q Well, when you alluded to the figure, were you doing it on the basis of your recollection that it stated somewhere that that was the extent to which there were sink holes on the Goldstein tract?

(To be continued on Page 122)

Q Were you doing it on the basis of your recollection that it is stated somewhere that that was the extent to which there were sink holes on the Goldstein tract?

A It's a calculated figure.

Q All right. Let me ask you this, then. So -- let me ask you this. Any -- is there any community located adjacent to the Goldstein tract as there is in the case of the proposed tract?

A You have private property-owners of commercial property joining the site.

Q But it's not -- you don't have a large residential, seven hundred and some residential homes and a school and that kind of thing located next to the Goldstein tract as you do with the proposed tract, do you?

A Progress Village is due north of the Goldstein tract.

Q Well, are you saying it's just as close?

A The distances aren't that great when you compare, say, the proposed site and the Goldstein tract.

Q Well, let me ask you this. Has anybody done anything in regard to the -- I take it no one has done anything in regard to the cost that would be required to undertake to repair these sink holes and utilize the Goldstein tract on a comparative basis between what is proposed to be utilized in the way of capital outlay by your company for the proposed site and I think the next -- the next most feasible site would be -- strike that.

I'm trying to get -- if you would, give me the next most feasible -- although, it doesn't maybe seem feasible to you -- in terms of capital outlay, say, between the utilization of either the Goldstein tract or the proposed site and, say, the shipping by pipeline back to Fort Meade.

A Of course, I mentioned --

Q Is there anything in between there in terms of cost to the company? I think that was eight million, eight million dollars combined operating costs per annum.

A For the pipeline, that's correct.

Q For the pipeline. Now, you say there's about a thirty-five million dollar, three million dollar per annum total cost to operate on the proposed site; is that right?

A If we are to compare, say, apples with apples, the pipeline costs that I gave, the, say, operating costs of, say, eight million dollars, you would need to add the capital costs when we compare total costs to total costs, the total cost would be eleven million dollars for the pipeline if it was feasible. As I mentioned, trying to visualize obtaining the right-of-ways and be able to engineer the pipelines above ground or below ground, a very difficult problem since we're working with a slurry, a solid liquid material, and I can't visualize any pipelines in Florida above ground, say, alongside roadways. We might have some booster stations where you have property set aside. So the pipeline option to me is, again, very, very difficult to conceive.

Q Please don't take me back through that. We've been through that. I just want to understand, there is -- what is the closest thing between utilization of the proposed site in the way of costs, what is the next closest alternative from the expense angle?

A We really don't have anything that we consider viable.

Q That's not my question. My question is not whether it's viable or not. What is the next closest in terms of expenditure per annum to the utilization of the proposed site?

3 A We have -- the closest thing is the pipeline

at eleven million dollars.

Q Well, maybe I took the notes wrong. I thought you said it was eight million for the pipeline and that it was eleven million for the rail transport.

A No, that is not correct. As I mentioned, you have to look at the total costs. In the pipeline situation, as I mentioned, the very highly costly pipe, the purchase of the pipe and installation, we're working with a capital cost of a hundred and twenty-eight million dollars.

Then, as I mentioned, the operating costs, booster stations, the power, the pumps, you're looking at the physical cost. The operating cost is the maintenance, the labor, the power, at eight million dollars. So, you need to get the total costs, add the capital costs to the operating costs and you have the eleven million dollars per annum and the railroad scheme, total cost is twenty-five million dollars.

Q Mr. Cabina, I get the impression from your analysis in your testimony that somehow or another you decided that the proposed site was the most economical one closest to the plant, cost less to get, and that the rest of your analysis, by and large, made ultimately the selection of that site the place to go because of the fact it was, in the

4

first instance, decided that it was the most economical without regard to the fact, of course, its relation to where Progress Village is located and the elementary school, et cetera. Is that true?

A That is not true.

Q So, in all of the alternatives under the sun that were available to you, the closest you could get in terms of alternatives, in terms of per-annum costs, for example, was eleven million dollars as contrasted with three million dollars to use this site; is that right?

A Yes. And I might add that we certainly have looked at all the sites, as I've gone through the exercise, where we did obtain denial, going north of the present gypsum field. We did make a very thorough, honest investigation of the found proposed site, reviewed by all the agencies. Certainly we feel, again, the placement of the gypsum material in the area, we definitely have the community in mind, certainly the citizens of Progress Village. I believe many of our workers do live in Progress Village and definitely we would not be recommending the storage of gypsum in the area if we felt there were any safety or health considerations.

5

Q I hate to throw it across to you, Mr.

Cabina, but we could be here all night. I would like for you to try to be responsive to the question. I noticed in your other examinations, that's what makes these hearings go on forever. If you would just try your best, if you would, and I don't want to cut you short, but to be a little responsive to the question. If you'll answer the question, I'll move on to another question and that way maybe we can expedite the matter.

MR. WARD: Let me say, Mr. Dawson, that if you might articulate your questions with a little more clarity, the witness might be able to likewise respond.

MR. DAWSON: I noticed in articulating his answer, he never asked that the question be repeated and if he didn't understand, that's a mighty long answer to a question he never understood.

THE WITNESS: I'm trying to give you an honest answer and tell you what we did, all the factors that were taken into consideration. And all I see is we looked at the proposed site in 1979, 1980. We have been living by the present gypsum field for fifty years. We have over two hundred workers that have over twenty-

6

five years service. I'm one of them. I've been on that gypsum field over a thousand times. I operated a plant for two years, six months right alongside the gypsum field.

BY MR. DAWSON:

Q What is this in response to? I didn't ask a question.

A What I'm telling you is that we have looked at, certainly, the alternate sites, the proposed site from all angles, all viewpoints, and we feel this is the most suitable site, not only our conclusion, but, as I mentioned, the agencies: DER, EPC, the Federal Government, and also the Tampa Bay Regional Planning Council.

COMMISSIONER COLSON: Let's get back to Mr. Dawson's question.

BY MR. DAWSON:

Q In terms of alternatives, Mr. Cabina, of course, the basic product, that is phosphate, comes from Polk County, in the first instance; isn't that correct?

A And some comes from other counties.

Q Where else?

A Hillsborough, Hardee, North Florida, Tennessee, North Carolina.

7

Q How much of it would you say comes from Polk County?

A I can't give you an exact figure, but --

Q Percentage?

A A sizeable tonnage.

Q Eighty percent?

A What was that again?

Q Eighty percent.

A Eighteen percent?

Q Eighty.

A Eighty percent, no, I don't think it's that high.

Q Well, is it more than sixty percent?

A I would say possibly fifty percent.

Q Fifty percent from Polk County?

A Correct.

Q And I take it that you have found it, the company has found it economically feasible to have that shipped in by rail car for all this time; is that right?

A We've been doing it for sixty years.

Q Now, you mentioned that there are other processing plants in Hillsborough County; is that right --

A Right.

Q -- that do roughly similarly the same thing that your company does with phosphate rock that they get?

A Correct.

Q How do they dispose of the gypsum? Do you know?

A They would store the gypsum in a specific area.

Q Here in Hillsborough County?

A Correct.

Q Is it true, then, that the major consideration was one of cost in terms of the selection of this site?

A That is not correct.

Q What was the major reason?

A As I mentioned, it's a number of factors, starting with the geotechnical, the engineering, the environmental, the land use and certainly, again, from a health and safety standpoint, this site is the best site that is available for the storage of gypsum.

Q Do you think you told me in that answer what the major reason was?

A You can't just boil it down to one reason. Unfortunately, life isn't that simple. And again, it's been a very tedious task of making all these studies and you just can't boil it down to one thing.

Q Well, can you give me two major reasons?

A I'll have to give you all the same reasons I gave you before because it's a combination of the geotechnical, engineering, the environment, the land use. Working with EPC and DER and EPA, they've asked us thousands of questions. We've answered all the questions. We've made numerous studies, as I've demonstrated with all the documents. These are just the engineering documents. So, in all honesty, it's been a very tedious study of trying to, again, to have the best site selected meeting all the parameters.

Q During your testimony, you indicated that gypsum is being utilized for certain purposes some place in the world now; is that right?

A It's being utilized in Japan, France. It's also being utilized in the United States.

Q What is it being utilized in France for?

A It's being used for insulation.

Q Is it being utilized for insulation in the United States?

A The phospho-gypsum is not being utilized in the United States for insulation.

Q But it is in France; is that correct?

A That is correct.

10

Q Well, why not ship this stuff -- can you sell it to somebody in France and let them use it over there in insulation?

A We wouldn't be able to compete.

Q Wouldn't be able to compete with who?

A With the producers in France and other phosphate companies that are in that vicinity, Tunisia, Morocco.

Q Isn't your company based in France?

A No, it is not.

Q It's not?

A That's correct.

Q Where is it based at?

A We are a U.S. corporation.

Q It's not incorporated in France?

A That is not true.

Q Well, my question to you is, is it?

A It is not.

Q Does it have any ties in France?

A No, it does not.

COMMISSIONER COLSON: What does that have to do with this site in Hillsborough County, whether it's incorporated in France?

MR. DAWSON: I appreciate the opportunity to answer that. It is, I might note --

11

COMMISSIONER COLSON: We've just got twelve minutes, so if you can answer it in that period of time.

MR. DAWSON: Whatever you request of me I'll do. I don't understand your inquiry at this juncture. I'm trying to question the witness, but whatever you desire of me, I will do.

COMMISSIONER COLSON: Well, I would like for you to try to keep the questions dealing with the situation in Hillsborough County, and I don't see a relationship of them being based in France, Switzerland or England making any difference about the stack in Tampa.

MR. DAWSON: Let me ask you this, then, if I may. My point of view on that, as to why I asked the question. First of all, I'll be frank with you. It is the first instance in which I learned, that is during his Direct testimony, that there is some use for this stuff. That's number one. I learned that from his Direct testimony. He says that, gee whiz, this stuff is being used in insulation in France. All right. I didn't think, but I had to ask him
12 whether or not it's being used for insulation

in the United States because I didn't think they would permit it to be used for insulation in the United States. But he does say, yes, it is being used in France.

Well, I'm not necessarily privy to all of the corporate entanglements of this corporation, but it is generally thought to be a corporation that has something to do with France. I don't think that's a misnomer.

Now, once you delved into the technical aspects of it, you may find, well, gee, when it's incorporated in the United States and maybe, as he says, it doesn't have anything to do with France at all. I don't know that unless he tells me. Of course, now he tells me it doesn't have anything at all to do with France. Well, if it did, as it is generally presumed to be, that is, that it has its base in France, and they can use it in France and are using it in France, then maybe we got some place where they could dispose of it through its connections in France where it's being utilized. I don't know if that makes sense to you or not, but that was the basis of my inquiry. And I get the impression that there may be other things.

13

COMMISSIONER COLSON: I don't think you need to make any more statements. I would love for you to direct your questions to the witness.

MR. DAWSON: Thank you.

Could you tell me where I was at that point? (Addressing the Court Reporter)

COMMISSIONER COLSON: You were just asking about France, whether they were based in France.

(Whereupon, the Court Reporter read back Mr. Dawson's last question and answer by the witness.)

BY MR. DAWSON:

Q Mr. Cabina, I'll try to make this my last question. Is it your testimony, then, that although there are uses for this, there is no way that you can dispose of it or sell it or -- and as I said, I learned for the first time that there are uses for it. There are no places that that can be done other than disposing of it in the manner that you do? Is that your testimony?

A That is correct.

Q What is it used for in the United States today, now? What is it being used for?

A Sure. As I mentioned, about a million tons per year is utilized in, say, agriculture. It's

k4

used, we know, in Georgia, Virginia, North Carolina, for, I believe, the sulphur additive for peanuts and some other crops. It's utilized in Arkansas and also, I know, in the western states; especially California, where the soil is alkaline and it's utilized to lower the PH of the alkaline soil. So, a million tons is being used in agriculture.

And I mentioned that it's being used in road work. Apparently, the State of Texas has made some considerable investigation into the use of phospho-gypsum for their road work and they are proceeding to build a state highway. We're in contact with the DOT of Texas. I believe Dr. Salak (Phonetic) has been working with this material for many years and corresponding with the people, nurse, in Miami along with Dr. Salak, and we're also working with the Florida DOT. As I mentioned, we hope to build a test road. We recognize that and we will work with DER, certainly, to insure that, if we utilized it, we monitor and definitely check all the environmental considerations with the utilization of the material, say, in road work. Extensive research in trying to recover the sulphur from the gypsum because all the sulphur that comes in and is utilized and used in the fertilizing process is sulphur. It winds up in

15

the gypsum piles. And certainly extensive work has been done in this area and certainly some projects, again, utilization of, say, the phospho-gypsum as insulation. As I mentioned, it's being used in France and in Japan. And so that, again, would be a very thorough type of research project, working with the appropriate agencies. That complete investigation would be made not only from its use technically, but because of the environment.

And I might have left out one or two other cases.

MR. DAWSON: I don't have -- I'm not going to ask any more questions, although I do have some more. I do realize that the Commission desires to ask some questions, number one. I realize the lateness of the hour, number two. And I want to at least not have the Commission look at me askance in terms of the time, in terms of how -- my questions are basically brief. You may not have thought they were relevant.

COMMISSIONER COLSON: Mr. Dawson, in all fairness to you, I'll admit that the time was getting late, but I'll also admit that it was not you that caused the time to get late and

16 certainly did not want to appear argumentative

with you on that. I think the only thing that spurred anything is when we left the continent of the United States, I thought we were getting a little far from the base of the thing. You did have a point that you wanted to make a connection in the use of France, so I can certainly accept that.

All right. Are there questions from other Board Members?

COMMISSIONER PLATT: I want to explore the -- I would like to explore with you the alternative of the property adjacent to the stack, that thirty-five acres. You mentioned that in 1980 Woodward Clyde had done a study on the possibility of using that adjacent land and also Mr. Gipson, who came and spoke as a hydrologist, said that he believed the existing stack could be expanded to the east on that land adjacent.

Before you get into that, would you tell us what is the nature of the environmental problem with the existing stack. Is that basically because of the runoff into the bay?

THE WITNESS: Of course, as I mentioned, the existing field is fifty years old and it

17

wasn't built for today's standards. So, to just take you, you know, to today's situation, we are working with the side slopes of the existing stack. We're installing peripheral drains and drainage systems similar to what we had in mind for the new stack, in which we would collect any of the acid water that would work its way to the side slopes because we have, in fact, had some of the acid water appear on the surface of the side slopes. When it does rain, the rain contacts the acid water and we've had some of the rain combination acid water run into Hillsborough Bay. So we're working with DER and we have an ongoing program for side slopes, that's correct.

COMMISSIONER PLATT: But did the study of Woodward Clyde indicate that you could, rather than expand off to another land area, environmentally expand to the east and deal effectively with the major environmental concerns?

THE WITNESS: No. Woodward Clyde only does the engineering geotechnically. They look at the ground, the geology. So they don't really take the environment --

COMMISSIONER PLATT: When they did that,

18

did they indicate that you could, in fact, expand to that land immediately to the east, that would be west of 41?

THE WITNESS: Correct. They felt from an engineering standpoint, they felt it was feasible.

COMMISSIONER PLATT: All right. Then why haven't you gone further to explore that possibility?

THE WITNESS: Okay. As I mentioned, we are working. We do have the seepage problem which we are working to correct on the present field. As we work with Hillsborough County EPC and DER, they felt, again, knowing that the stack is fifty years old, -- they visit. We go up on the stack monthly -- they feel that the best solution would be to get a new site in which we could properly engineer the storage of gypsum.

COMMISSIONER PLATT: Well, I know the stack is fifty years old and they're concerned about the seepage and the seepage is already there, the seepage that goes down. And isn't it salt water, basically, down underneath that stack, the current stack?

19

THE WITNESS: Yes. Correct.

COMMISSIONER PLATT: The major problem with the current stack is the runoff that goes into the bay?

THE WITNESS: Yes. That is the current problem.

COMMISSIONER PLATT: And can that be taken care of? Can you correct that problem?

THE WITNESS: Yes.

COMMISSIONER PLATT: Yes, you can?

THE WITNESS: Yes.

COMMISSIONER PLATT: If you can correct that problem and then if it's engineeringly sound to expand to the east and possibly go higher with the current stack, why is that not a viable alternative, understanding that we already know that there is seepage and it's my understanding that in that particular area, that's already salt water? Is that not so?

THE WITNESS: Correct, but it's against the law to discharge any affluent contaminants into any waters of the state.

COMMISSIONER PLATT: It was my understanding that you said you would be able to take care of the runoff of the existing stack.

THE WITNESS: That currently is correct. That's true.

COMMISSIONER PLATT: And you said you could do that?

THE WITNESS: Yes.

COMMISSIONER PLATT: So, if you can do that, why have you not explored it further?

THE WITNESS: The expansion, I mentioned, the present stack is a very small amount of storage. In other words, we would have to sit down with DER and EPC and see how much of that thirty-five acres could be utilized. Again, we're dealing with a very small time period and as I mentioned, our objective always, from 1979, was to look for a new site, large enough. We made an expenditure of a hundred million dollars to modernize the plant. Again, as I mentioned, we're following the guidelines of the Federal Government with the present plan, improving the environment. So we made the expenditure, always up front stating that we feel that we should locate a new site for the gypsum, again, from a business standpoint, certainly where we could have a life of around forty years. This was always our objective.

21

So, that small amount of expansion around the present stack is very small and certainly would not --

COMMISSIONER PLATT: Even if you could not -- let me just finish this, because if you expanded, couldn't you go higher?

THE WITNESS: A little higher, but the thirty-five acres, we're not -- see, we're already approaching a point of a pyramid. So it's getting very small up top and thirty-five acres on the base is going to add a few feet to the height. It's not that significant.

COMMISSIONER COLSON: Commissioner Paulk.

COMMISSIONER PAULK: My question, I think, supports Commissioner Platt's line of questioning. I drive by that pile a couple times a day, and, of course, we've all been thinking about it and I'm not an engineer, but common sense says -- you know, regardless, you never answered the question. You want to do it as cheap as you can. You want to do it as environmentally safe as we can. If we can expand that existing pile, to me, that's the best way to do it. Commissioner Platt has just talked about to the east. There is two or three hundred feet to the north. I've

22

been out on top of the pile, you gave me the tour and I saw it. Why couldn't we go three or four hundred foot to the west. There is some land to the southwest. Why not go all the way around the pile. There would be some engineering problems, there would be some equipment problems, plant problems. You would have all kinds of environmental problems. I appreciate that. But there are things that you can do to mitigate these kind of things, the impact that you would have.

To me, the simple thing to do would be to go out there and increase the size of that pile all the way around, work with the environmentalists. I know that's not that easy. But if you're going to build that fence around the other pile, we need one around the existing pile. Let's spend all that money building this great big fence all the way around the existing pile and when you go around a pile as big as that one, you're going to pick up much, much more than thirty-five acres. You might pick up a hundred acres or more. I don't know. That's not a simple question to answer and I don't know that you can answer it here, but that is the thought that I have. As anybody testifies, I would like to hear them comment on that.

My real question is, environmentally, can you go further than Commissioner Platt said? Could you go to the north three or four hundred feet? Could you go to the west three or four hundred feet? Can you go to the southwest a thousand feet?

THE WITNESS: It would be very difficult because, as I mentioned, we have Archie Creek and I would say only two hundred and fifty feet to place a dike wall right against the creek with no setbacks, no areas. See, the storm water is running off the sides and you would be sheeting right off into Archie Creek. We have, you know, the five-hundred-foot room to work on the proposed site where the water would run off. We're committed to monitor that water, to insure the water quality.

COMMISSIONER PAULK: Let's talk about the west. You already destroyed the mangroves to the west. Why not get out there a thousand feet or so and put a fence and we stop the runoff?

THE WITNESS: The area to the west is a

24

very small area. The bay is being restored. We did make the study in 1981. In fact, Commissioner Platt requested it in August of 1980, that we look at the bay because we know there was environmental damage in the seventies. We did make a one-year study, using mangrove systems and utilized the -- the same individual made the study in '76, Ernie Escovitch. They did document. It was like a fifty-thousand-dollar study for a year. I think after nine months they were finding the biota, the restoration in the bay -- this is right adjacent to our gypsum field -- that they came back and asked for another $20,000.00 because they were counting all these little creatures and they needed another twenty thousand to count all these little creatures. So we went ahead and the document's been submitted to all the agencies. So the bay is being restored on the west side. And again, the area is so small to try to get some additional storage there and insure that you're not going to runoff into the bay is a very difficult, technical and environmental problem.

COMMISSIONER COLSON: Commissioner Jetton.

COMMISSIONER JETTON: I think just on that same course of discussion, we are mitigating or relocating Archie Creek, you know, in the proposed site. I wonder if any study has been done maybe of that type of action on the existing site, to increase that acreage much stronger than your thirty-five acres. My thinking -- and the other thing, just an observation would be that there are some maybe minor structures that are not connected with your plant at the existing site.

Has a study been done to see just how much -- I guess this is really the question -- just see how much that thirty-five acres could be enlarged with the aid of agencies, et cetera? Has a study been done to do that?

THE WITNESS: I think on your first question, possibly my explanation, you refer to Archie Creek being altered is -- I mentioned we have no plans for changing the course of Archie Creek. The creek flows eastward -- I'm sorry -- westward toward the bay. This is the actual creek. It's north of the retention ponds and we have this wet land area and then it flows right into Hillsborough Bay. So there are no

26

plans. Possibly, I think we did mention a north canal, which you see right up here. This one would be relocated and we have no plans to alter Archie Creek.

COMMISSIONER JETTON: I understand.

THE WITNESS: Your second question regarding the other, say, if you can remove some other buildings, we do have along Highway 41 -- the marshalling yard's right along Highway 41. This is where you have around at least seven thousand feet. You need a straight run of tract where you have, say, ten rail tracks where the Coast Line would bring in all the rock cars, the empty cars for product, and we use the other tracks for product going out, the empty rock cars with phosphoric acid. So, you need at least a seven-thousand-foot stretch. The Coast Line comes across Highway 41. They block the traffic, maybe, twice a day and sometimes in the evening. And so to relocate that marshalling yard, you need this length and when you look at the plant, there's no other area you can get this long seven thousand feet. We would have to go on the, say, east side of Highway 41. And then if you had all your cars

27

on the east side of 41 -- see, we pick up all the cars within that marshalling yard with our own engines. We have, say, three engines. We wouldn't be allowed to cross Highway 41. We go out to the marshalling yard at every hour and pull in some rock cars, bring in some empty cars for product. We load the tracks. And then when the next train comes in from the Coast Line, they pull the cars out, the empty rock cars.

So, if we were crossing 41 a lot, if DOT allowed it, we would be blocking traffic twenty-four hours a day. So, the marshalling yard is the major problem. I know you've mentioned this to us when we made the site plan. I've looked at it. I had the engineers look at it. I talked with our plant personnel, our plant manager, Frank Gonzalez, who's been in the plant twenty-five years. There's nowhere we can come up with seven thousand feet east of 41 for that marshalling yard, for all these cars. We're dealing in hundreds of cars when you look at the product we load. So that, we just can't relocate it. We would have to shut down if we didn't have that marshalling yard.

COMMISSIONER COLSON: Commissioner Platt.

COMMISSIONER PLATT: Well, but you said that you could -- one of your alternative sites would be that that cooling pond area to the south of your current proposed gypsum stack, plus the land that is south of that, why couldn't that be utilized for the marshalling yard? Aren't there tracks already on the west -- on the east side of 41? There's tracks on both sides of that.

THE WITNESS: Correct. What you have is the Seaboard Coast Line --

COMMISSIONER PLATT: Why can't you move that over to that land that you said could be a viable alternative?

THE WITNESS: As I mentioned, we have a total of, say, ten tracts, seven thousand feet in length, which the Coast Line pushes in all the cars. You move all those tracks on the east side of Highway 41, then our engine would have to be crossing Highway 41 to get the rock cars, to bring or get the empty rock cars --

COMMISSIONER COLSON: Crossing is the only problem you see in that particular situation?

THE WITNESS: The crossing, yes, of

29

Highway 41 with our engines.

COMMISSIONER PLATT: I think you're intelligent enough to figure that one out.

COMMISSIONER PAULK: Well, my reaction to that is, this is not a facetious one because I have to make the ride every day, about two times. Why don't we relocate 41 and relocate the tracks and relocate 41 and build us an overpass. You might get some DOT funds. I don't know.

THE WITNESS: If the Board of County Commissioners will commit to help us, I can't object.

COMMISSIONER PAULK: I'm serious. Has that been studied? What would it cost? You know, you make these way-out costs for a hundred million dollars for pipelines. So, why not relocate 41 and those railroad tracks and give yourself some space right next to the pile?

THE WITNESS: Again, I think, as you can tell from the drawing, you're right up against the edge of the retention pond. I think from Highway 41 to this point, possibly no more than two hundred fifty feet.

COMMISSIONER PAULK: Your pile is south

30

of that.

THE WITNESS: Right. But we're considering the relocation of Highway 41.

COMMISSIONER PAULK: You wouldn't have to relocate it on that end.

THE WITNESS: Pardon?

COMMISSIONER PAULK: You haven't considered it. My question is, have you considered that?

THE WITNESS: I've given it some thought, but the feasibility, because we're working in this very narrow strip, you have the railroad track, which again, would have to make its way. This is the Seaboard Coast Line track. Then you have -- this is Old 41. If you came and tried to utilize Old 41, we would have the railroad track and then you could pick up and shove your marshalling yard further to the east. You pick up another three hundred feet, but again, that's a very small area, possibly another ten or fifteen acres at the most.

COMMISSIONER COLSON: Well, when you mentioned the use of the cooling ponds and the hundred and sixteen acres south of there, your basic reason for saying that that was an

31

option but not as viable as an economic thing because of the relocation of the cooling pond and the size of the project?

THE WITNESS: Correct. That was the basis.

COMMISSIONER COLSON: But it is a viable -- it would be a reduced size and more expensive?

THE WITNESS: That is correct.

COMMISSIONER COLSON: Commissioner Jetton.

COMMISSIONER JETTON: The bottom site there, the cooling pond of a hundred and sixteen acres, a portion of the southern part of the big site -- well, no, I'm talking about the present portion of the proposed site.

COMMISSIONER COLSON: The southern portion

COMMISSIONER JETTON: -- that could get you the like acreage. How far away would that put you if you approached it that way? How far away would that put you from the residential community? I wish we had a big aerial where I could relate to -- I can't relate to that.

THE WITNESS: Sure. I think I can follow what you're saying, Commissioner, where we could, say, slide the field downward if we would conserve, say, somehow re-route Archie Creek and just try to encompass a hundred and seventy-two acres and then if you try to work your configuration as such, you would be looking then at the re-routing of, say, Archie Creek. We know we couldn't go in a northern direction. We've looked at that consideration.

Your elevations, of course, increase in height. So, we would be looking at a southward relocation of the creek into, say, the Alafia River and then we would have to look at, you know, the impact. You would stop this flow and, again, you would have to work with the biologists. What does it do to Archie Creek since you don't have this flow, again.

COMMISSIONER PAULK: When you shift to the southwest, there is housing on the west side of 78th Street and on the north side of Riverview Drive there.

THE WITNESS: Yes, you have housing, definitely, in this area. The housing is already -- I'd say, the property line is -- the housing commercial property, eleven hundred feet from the base of our retention pond. You have a distance of, say, eleven hundred feet,

33

and you have your property-owners right in this direction.

COMMISSIONER JETTON: Mr. Chairman, I think the next time, whenever we get back on this subject, it would be very helpful to have a large aerial so we can kind of follow you. I know you know it by heart and we don't.

THE WITNESS: Sure, I follow you and that certainly can be done.

COMMISSIONER COLSON: Commissioner Bing.

COMMISSIONER BING: Yes. I just have two small questions, quickies.

In your testimony, you mentioned the fact that in terms of uses of gypsum that it is being used for insulation. Did I understand you clearly that it is actually used in road construction or it's being researched for use in road construction? The reason for my question is, I've always heard the reason for not using gypsum as a road base was that it held water, number one, and, secondly, it was radioactive.

Did I understand you to say it is presently used in road construction in Texas or it's being experimented and researched in Texas?

THE WITNESS: They have built some

secondary roads in Texas and now they're proceeding or proceeding with, as I understand, a state highway to be built with the phospho-gypsum. I believe they have to combine it with flyash to insure the compactness. I believe certainly the moisture is a feature and it has to be compacted.

COMMISSIONER BING: What about the radioactivity?

THE WITNESS: And then we recognize that the phospho-gypsum has the level of radiation, a very small amount, but it's there.

COMMISSIONER BING: I just have one other quickie.

In your testimony, you testified that the proposed gypsum pile is anticipated to last forty years. Also, in your testimony, you testified that presently you'll have a hundred years. At your present rate of operation, you have a hundred years of inventory in terms of phosphate rock in Polk County.

THE WITNESS: That is correct.

COMMISSIONER BING: At the end, assuming that there is no technology that would come forth on the utilization of gypsum, there's no new advances in the use of the stuff and with the anticipation of this pile lasting only forty years, you still are left with sixty years of inventory. What will you do then for another stack because you'll need another stack in forty years if there's no new technology developed? So, at the end of forty years, you're going to need another stack because you still have sixty years of inventory. Now, what will you do at that time?

THE WITNESS: I would only be, say, guessing, but, definitely, if you have no new technology, we've used it forty years, certainly we know the area with the growth, then, we definitely would have to shut down and the rock would have to be utilized in Hillsborough County.

COMMISSIONER BING: It comes to all the alternatives that you have now that you said are not viable, even though those alternatives won't be available then.

THE WITNESS: Yeah.

COMMISSIONER BING: So, you would have to shut down in forty years.

THE WITNESS: In forty years, trying to be practical, yes, I think in forty years, if we

36

have no way of disposing of the gypsum, then, yeah, I can't visualize where else we would be able to place it.

COMMISSIONER BING: But you wouldn't really shut down because you've still got sixty years of inventory.

THE WITNESS: Sir, we would be in Polk County, hopefully, with our mining operation. I would be retired.

COMMISSIONER COLSON: Do you have any idea what the cost of your plant for construction would be?

THE WITNESS: I'm sorry. What was that?

COMMISSIONER COLSON: The plant facility that handles this --

COMMISSIONER PAULK: The capital investment.

COMMISSIONER COLSON: The capital investment?

THE WITNESS: Let me ask my counsel that. Again, from a competitive standpoint, to make any financial numbers -- but I can answer.

COMMISSIONER COLSON: I don't really want to know the cost of the plant. What would it cost to relocate it?

37

THE WITNESS: I know we're working with a total capital cost facility of four hundred, five hundred million dollars.

COMMISSIONER COLSON: Any other questions by the Board Members?

COMMISSIONER BING: No, sir.

COMMISSIONER COLSON: Time is up tonight. Mr. Varn, is this a situation where we'll come back and we'll start with Redirect the next session?

MR. VARN: Assuming they have Redirect. If Counsel has Redirect, it would be appropriate at our next hearing to start at that point. Of course, if they have no Redirect, they may want to excuse Mr. Cabina as a witness. That is up to them, at this point.

MR. WARD: We will determine that tomorrow. Mr. Cabina will re-appear and be recalled for other subjects that are to follow in the hearing. So we reserve the right to recall him at a later time for that.

COMMISSIONER COLSON: We'll conclude the meeting tonight and pick up at this point tomorrow in whichever direction you want to go.

(Whereupon, the hearing was concluded at 9:50 o'clock p.m.)

C E R T I F I C A T E

STATE OF FLORIDA)
)
COUNTY OF HILLSBOROUGH)

I, BETTY M. LAURIA, Official Court Reporter for the Circuit Court of the Thirteenth Judicial Circuit of the State of Florida, in and for Hillsborough County,

DO HEREBY CERTIFY that I was authorized to and did, through my undersigned Deputy, report in shorthand the proceedings and evidence in the above-styled cause, as stated in the caption hereto, and that the foregoing pages, numbered 1 to 160 inclusive, constitute a true and correct transcription of my said Deputy's shorthand report of said proceedings and evidence.

IN WITNESS WHEREOF, I have hereunto set my hand in the City of Tampa, County of Hillsborough, State of Florida, this 8th day of March, 1984.

BETTY M. LAURIA, Official Court Reporter,

By: ______________________, Deputy

39

HEALTH RISK ASSOCIATED WITH RADON
FROM A PROPOSED GYPSUM FIELD

For

Gardinier, Inc.
P. O. Box 3269
Tampa, Florida 33601

P. J. Walsh, Ph.D.
16 Monaco Lane
Oak Ridge, Tennessee 37830

TABLE OF CONTENTS

SECTION	PAGE
SUMMARY	1
INTRODUCTION	5
BACKGROUND	7
Ionizing Radiation from Naturally Occurring Materials .	7
HEALTH RISK FROM RADON PROGENY	10
Extrapolation of Mining Experience to the General Population	11
Range of Risk from Background Exposure	12
EXPOSURES FROM THE GYPSUM FIELD	16
HEALTH RISK FROM THE GYPSUM FIELD	21
Number of Cases in the Population Near the Gypsum Field	25
REFERENCES	27
APPENDIX I	29
APPENDIX II	43
APPENDIX REFERENCES	60
APPENDIX IIA	61

SUMMARY

Gardinier, Inc. proposes to construct a gypsum field near East Tampa, Florida. They have contracted with the writer to assess the significance of exposures to air-borne radon and radon progeny from the field. They were referred to me because of my experience and publications on risk assessments for toxic materials and particularly because of my experience with radon progeny assessments during my tenure at the National Institutes of Health and at Oak Ridge National Laboratory. I have not been associated with Gardinier, Inc. before and assist them with the present assessment as an independent consultant.

The health risk associated with radon progeny resulting from radon emissions from the proposed gypsum field is insignificant. This conclusion is based mainly on a comparative assessment of risk from the gypsum field with risk from other natural sources of radon. It is also based on a comparison of potential exposures from the gypsum field with existing guidelines and standards some of which the writer helped to develop. The elements of the assessment were:

- A comparison of radon progeny exposures from the gypsum field with background exposures in Florida, the United States and Canada.

- A comparison of radon progeny exposures from the gypsum field with guidelines and standards recommended by the Surgeon General of the United States, the Environmental Protection Agency and the International Commission on Radiological Protection.
- Development of a risk factor for radon progeny based upon epidemiological studies of U. S. uranium miners and other underground mining groups.
- Use of the risk factor along with gypsum field exposures to estimate the potential lung cancers produced in the surrounding population.

In addition a background section is provided which summarizes ionizing radiation fundamentals and the nature of exposures to background radioactivity.

The results relating to exposures were:

- The average exposure near the gypsum field is about an order of magnitude less than average background exposures (i.e., less than one tenth of average background exposures).
- Exposures near the gypsum field are almost an order of magnitude less than the standard deviation in background exposures.

- Exposures from the gypsum field are more than an order of magnitude below existing standards and guidelines.

It is reasonable to conclude that exposures within a standard deviation of background exposures will make an undetectable and insignificant contribution to increased risk. Since exposures from the gypsum field are even much lower than the standard deviation due to background, it is concluded that such exposures are insignificant.

The results relating to risks were:

- The annual risk associated with maximum exposures near the gypsum field based on linear nonthreshold extrapolation and after continuous exposure for 70 years is about 4 deaths per million population exposed (4×10^{-6}). This would be the risk to the maximally exposed individual and thus represents an upper limit.
- If all the people (not more than 100) who may live very near the gypsum field were exposed continuously during their entire lifetimes at the maximum level, 0.0004 lung cancers per year or 0.028 cancers per 70 years would theoretically be produced.
- Over the lifetime of the population in Progress Village about 84 cancers would be expected from

normal causes. If the cancers did occur, the probability that it would be due to causes other than radon progeny from the gypsum field is greater than 99.99%.

Compared to annual "normal risks of living" which range from about 1 x 10^{-5} from tornadoes, hurricanes and lightning to 10^{-2} from disease, risks of less than 10^{-6} are considered to be insignificant. Although risks from the gypsum field are not directly comparable to other types of risks associated with life, a perspective may be gained on their significance.

In any case, comparisons based both on relative exposures and relative risks lead to the conclusions that no lung cancer caused by radon progeny will occur in the population surrounding the gypsum field.

HEALTH RISK ASSOCIATED WITH RADON FROM A PROPOSED GYPSUM FIELD

INTRODUCTION

This assessment addresses the health risk associated with radon releases from a gypsum field proposed by Gardinier, Inc. near East Tampa, Florida. The principal health risk is lung cancer due to alpha particle emissions from short-lived radon progeny (Po-218 and Po-214) inhaled into and deposited in the lungs. Exposure to radon progeny is associated with lung cancer in several underground mining groups, particularly uranium miners whose exposures were much higher than exposures to the general population. Exposure of the general population to radon progeny is continuous because radium, the radioactive parent of radon is ubiquitous in the earth's crust and thus in building materials, soils and water. It is, therefore, a matter of degree of exposure and/or relative exposure that can be assessed and perhaps controlled - it is impossible to avoid exposure.

In most cases people make choices unknowingly such as location, housing type, water supply, etc., that have an influence on their radon progeny exposures. Possible variation in such exposures are large and can far outweigh any small increment in exposures due to technological activity.

The purpose of this assessment is to put the health risk associated with radon from the gypsum field into perspective. Indoor radon and radon progeny exposures from the gypsum field taken from the work of Roessler et al. will be compared with indoor background exposures in Florida, the U. S. and Canada. Gypsum field exposures will also be compared to existing guidelines and standards. Risk factors based on the mining experience will be used to compare risks of exposures from the gypsum field with risks from other sources of exposure and indirectly with "normal risks of living."

BACKGROUND

Ionizing Radiation from Naturally Occurring Materials

More complete discussion of ionizing radiation, radioactive materials, units of exposure and dose and general biological effects is given in Appendix I. This discussion will be restricted to the major radioactive materials associated with the proposed construction of the gypsum field.

The fact that certain naturally occurring materials emit ionizing radiation was discovered by Madam Curie in the late 19th Century. In fact the material used, Radium-226, is the one occurring in gypsum that is the potential concern in this analysis. Radium-226 occurs in the uranium series (see Table 1, Appendix I) and thus has been present in the earth's upper crust for millions of years. Radium-226 and its progeny Radon-222, Polonium-218, Lead-214, Bismuth-214 and Polonium-214 are major contributors to human background exposure. Background exposure is that resulting from radioactive materials in their natural state. Additional exposure may be incurred through addition of manmade radioactivity to the environment or through redistribution of natural radioactive materials. Redistribution of radioactive materials is the case for the proposed gypsum field. The radioactive materials are those naturally occurring in the ores. They have only been moved from one site to another. The question is thus whether exposure has been increased or decreased by the action.

Any assessment of the hazard associated with a certain level of radiation must be made from the results of the many experimental studies that have been made of the biological effects of radiation (see Appendix I). When this is done, it is apparent that most experiments which correlate definite biological effects with radiation dose are at high radiation levels with respect to background or natural radiation levels. Although it is difficult to extrapolate to levels slightly above the natural baseline, the average exposure man receives from natural radiation along with the wide variation in that exposure serves as a baseline from which the effects of additional exposures may be judged. One may gain some understanding of the possible significance of exposures in this way without the confounding details of ionizing radiation units and dosimetry. All life has been exposed to these background levels throughout evolution. Exposure is unavoidable and varies widely depending upon geological, meteorological and lifestyle factors.

An analysis of potential exposures due to the proposed gypsum field was provided by Roessler et al. Thus, a detailed analysis will not be given here. However, based on experience and studies of uranium mill tailing piles - an analogous situation - Roessler's analysis is reasonable and tends to overestimate exposures to people near the gypsum field.

In addition to exposure analysis, a health effects assessment is needed to complete a risk assessment for the proposed gypsum field. The reason for going beyond relative exposures to conduct a risk assessment is to put the risk from the proposed gypsum field into perspective with respect to other sources of risk. A discussion of the health risk associated with radon progeny exposures is given in the next section. The critical concern is the potential lung dose and associated risk of lung cancer due to inhalation of radon progeny. Other radioactive materials (e.g. Thorium, Uranium, Actinium, etc.) are of less concern as are other potential exposure routes such as the food chain or drinking water. The proposed gypsum field is specifically designed to prevent groundwater contamination and wind erosion of gypsum appears to be minimal according to Roessler et al. and a study referenced in Roessler et al. by Dames and Moore.

HEALTH RISK FROM RADON PROGENY

A more detailed review of health risk from radon progeny is given in Appendices II and IIA. Only the highlights are given here.

The risk due to radon progeny exposures from the gypsum field may be calculated, in simplified terms as

> exposure from gypsum field x number of lung cancers per unit exposure (risk) = number of lung cancers due to the gypsum field.

Exposures from the gypsum field are discussed in the next section and health risk from the gypsum field in the last section. First, the risk per unit exposure for radon progeny must be obtained.

The only epidemiological data (data on humans) available that may be used to obtain risk per unit exposure for radon progeny is that developed in studies of underground mining groups, especially uranium miners. Although the levels of exposure for underground miners were much higher than background exposures, the same radioactive materials are involved. Uranium miners were also exposed to relatively high levels of other carcinogenic materials such as uranium ore dust, diesel exhaust fumes and most miners were heavy cigarette smokers. They were also exposed to other dusts and natural aerosols. In addition, they were exposed to the same materials as the general population after they left the mines. Uranium miners have exhibited a statistically significant increased risk of lung cancer at relatively high exposure levels.

One may obtain an estimate of the increase in risk per unit exposure by assuming that all the excess risk is due to radon progeny exposures. In other words, potential contributions of exposures to uranium ore dust, diesel exhaust fumes, cigarette smoking, etc. are ignored. The risk estimates for 10 underground mining groups are given in Appendix II and discussed further in Appendix IIA. If exposures are given in working level months (WLM) (see Appendix II) the increase in excess relative risk is about 1% per WLM. Thus, the amount of exposure necessary to double the risk of lung cancer would be about 100 WLM.

<u>Extrapolation of Mining Experience to the General Population</u>

The general population is exposed to much lower levels of radon progeny than were the uranium miners. However, if one assumes that the risk/WLM for the general population is the same as for miners (assumption of linear, non-threshold exposure response relationship, see Appendix I) then a theoretical risk may be calculated for the general population. Since uranium miners were exposed to other carcinogens, this is likely to result in an overestimate for the general population. Other differences between miners and the general population such as work state (breathing rate), nature of aerosol distribution, population characteristics such as age and sex and relative lung physiology also may lead to differences in effects. These factors are discussed further in Appendix II. They generally influence the extrapolation in opposite directions and have less effect than the potential influence of other potential cocarcinogens, cofactors, or promoters (e.g., uranium ore dust, cigarettes, etc.)

The 1%/WLM increase in excess relative risk agrees reasonably well with risk estimates for radon progeny derived by other groups as discussed in Appendix II. However, Cohen and Cohen (1) present an analysis which indicates that these risk factors may represent an overestimate of at least a factor of 10 when extrapolated to background exposure levels. Nevertheless we will use a direct extrapolation in accord with conventional practice. We will overestimate rather than underestimate impacts.

Range of Risk from Background Exposures

Ambient outdoor levels of radon and radon progeny are discussed in Appendices I and II. Outdoor levels of radon in the U. S. range from about 0.1 to 1 pCi/l and average about 0.3 pCi/l. Outdoor levels of radon progeny range from less than 0.0005 to 0.005 WL with an average of about 0.0015 WL. These levels are only representative. Actual levels can vary over a much wider range depending upon meteorological factors, soil, content of radium in soil, water content, etc.

Indoor levels of radon and radon progeny are about ten times higher due primarily to lower air turnover that tends to allow radon from the underlying ground to accumulate to higher levels. Radon from outdoor air usually makes only a small contribution to indoor levels. Indoor radon levels range from about 0.5 to 8 pCi/l with a mean of around 2 - 3 pCi/l. Indoor levels of radon progeny on main floors in the United States and Canada range from about 0.002 to 0.02 WL with a mean of about 0.007 WL. The range in basements is from about 0.004 to 0.04 WL with a mean of about 0.013 WL. The mean for the U. S. alone is about 0.005 WL but ranges from 0.0017 to 0.15 WL. According to the Roessler et al. report, the mean indoor levels in Florida are lower - around 0.004 - 0.005 WL. These levels are used in the next section to put levels from the gypsum field into perspective. Since the mean levels may be typical of exposures to the entire population, they are used here to estimate the risk theoretically associated with background exposures.

Under conditions of continuous exposure, the cumulative exposure for a 0.007 WL concentration would be about 50 x 0.007 WL = 0.35 WLM/y (see Appendix II) or about 25 WLM in 70 years. If, as is commonly reported, about 80 - 90% of the 24 hour day is spent indoors, then lifetime exposures would amount to about 20 - 22 WLM. Outdoor exposures would be a factor of 20 or more lower (especially if only 10% of the time is spent outdoors) and do not make a significant contribution to total exposure. Spending more time outdoors or increasing indoor ventilation could significantly lower exposures.

Using the risk estimate based upon the uranium miner experience of 0.4 - 1%/WLM, lifetime exposure at mean indoor radon progeny levels may represent an 8 - 20% increase in excess relative risk. This would probably represent a maximum increase for the general population. No account is taken for the uranium miner's exposure to other carcinogens.

Exposure estimates for uranium miners did not include background exposures. For groups in the lowest exposure categories, the WLM exposure would be underestimated and thus the risk per WLM would be overestimated. This problem with the lowest exposure categories as well as large uncertainties in exposure estimates for individual cases, the small number of cases involved, and the role of exposure to other carcinogens, requires further study. The uncertainty in uranium miner exposure means that each exposed group of miners was actually exposed to a wide range of exposures. Since the higher exposed miners would have a higher risk of developing lung cancer, use of the average exposure for the group would also tend to overestimate risk per WLM. Although the effects of all factors are not presently amenable to accurate analysis, an upper limit of 10% increase in excess relative risk after lifetime exposure to mean indoor radon progeny (0.007 WL) may be appropriate for assessment purposes. It must be kept in mind that radon progeny are used in the sense of a surrogate for the total exposure complex. According to Cohen and Cohen (1) actual risks could be more than a factor of 10 lower. Their study confirms that the risk estimates for uranium mines should provide an upper bound for general population exposures at background levels.

EXPOSURES FROM THE GYPSUM FIELD

Exposure levels from the proposed gypsum field were estimated in Dr. Roessler's report "Assessment of Potential Airborne Radioactivity Emissions from a Proposed new Gypsum Field." For five nearby receptor locations, the contribution of the complete pile to airborne radon concentration was estimated to range from 0.03 to 0.1 picocuries/liter. It was estimated that indoor radon progeny concentrations attributable to the gypsum field would range from 0.0002 to 0.0009 WL. These exposure levels are compared to Florida, U. S. and Canada background exposures and various standards and guidelines in Figure 1. Roessler's estimates would appear to be high since at 50% equilibrium (See Appendix II), the 0.1 picocuries/liter would produce about 0.0005WL of radon progeny.

Comparison of the exposure near the gypsum field with background exposures and exposure guidelines helps to put the gypsum field into perspective. The average exposure near the gypsum field (0.0005 WL) is about an order of magnitude (factor of 10) less than mean background levels (0.005 WL). The entire population is exposed to background levels while only a few people would be exposed to the maximum level from the gypsum field. The exposure from the gypsum field is also well within the variation of background

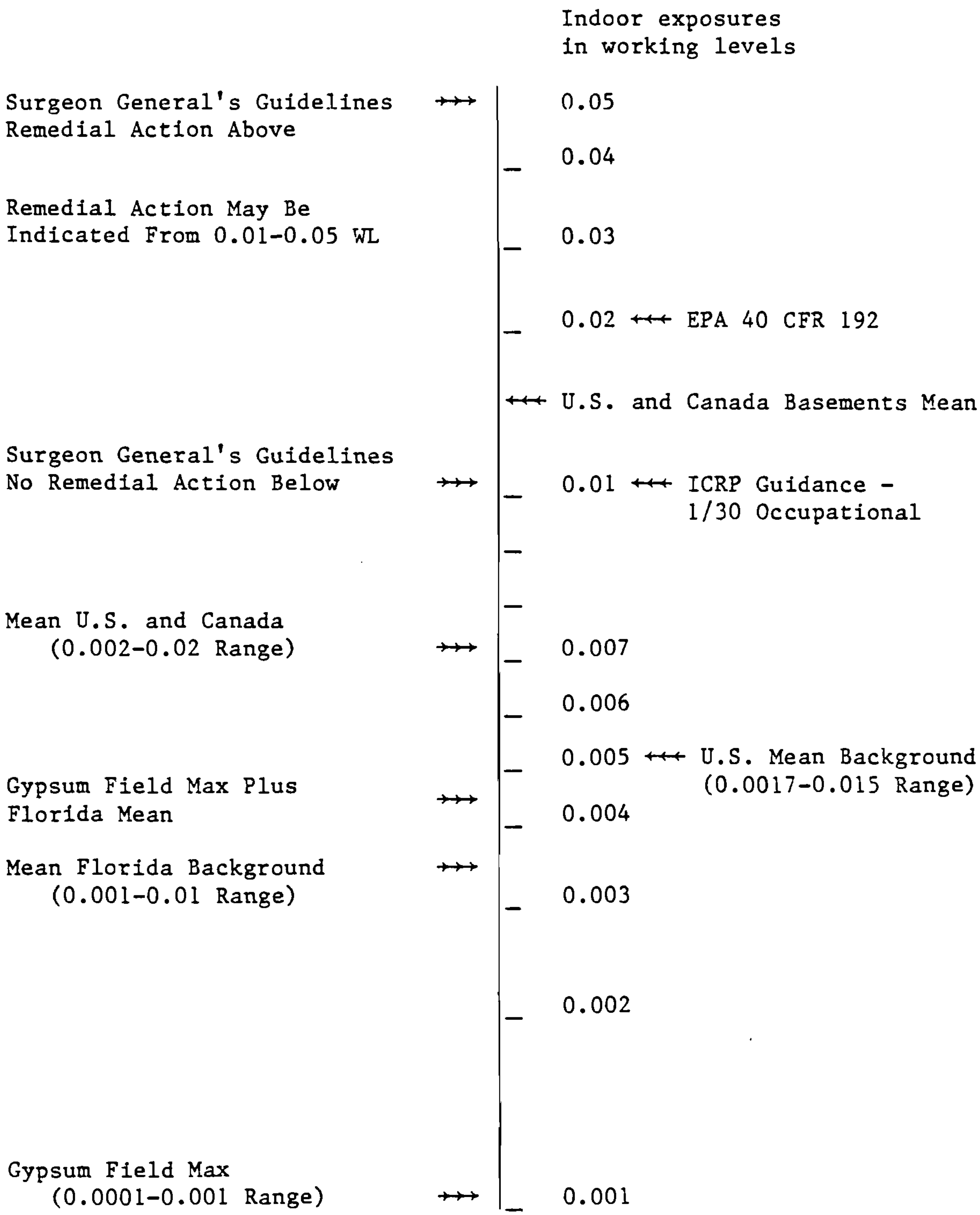

FIGURE 1. Comparison of Gypsum Field Maximum Exposure with Background Exposures and Guidelines

exposures. The standard deviation in background measurements at a particular location is often as large as the average level itself. Thus exposure from the gypsum field is almost an order of magnitude less than the standard deviation in background. This means that it would not be practically possible to measure the exposure from the gypsum field. But it also has more important implications with respect to de minimis exposures.

Several researchers (2,3) have suggested that although the existence of a threshold can never be proven, there are sufficiently low levels of exposure that should be considered insignificant (de minimis). It has been suggested that if exposure in a particular situation is less than the standard deviation due to background, then that exposure should be considered de minimis, i.e., low enough to be of no concern. Maximum exposures from the gypsum field are clearly in the de minimis category.

As shown in Figure 1, exposures from the gypsum field are also more than an order of magnitude less than existing general population exposure guidelines. The Surgeon General's guidelines were developed in response to a request from the State of Colorado for guidance in connection with remedial action being considered for buildings where uranium mill tailings had been used as fill material. The Surgeon

General's Committee recommended that no remedial action was indicated for exposure levels below 0.01 WL.

The Environmental Protection Agency (EPA) recently developed guidance for exposures from uranium processing sites including uranium mills. An environmental impact statement (EIS) for remedial action standards was prepared for inactive uranium processing sites. After extensive review of the EIS and some revisions of initial proposals, the standards were published in the Federal Register (40 CFR Part 192) on Wednesday, January 5, 1983 (Vol. 68, No.3). For indoor radon progeny, the standard is that exposure shall not exceed 0.03 WL and to the extent possible achieve 0.02 WL. If these levels include background, then the EPA standard is close to the Surgeon General's guideline of 0.01 WL above background.

Another conventional practice for derivation of public exposure guidance is to reduce occupational exposure guidance by a factor of 30. Since present occupational exposure guidance is 0.33 WL, conventional practice would also indicate public exposure guidance of around 0.01 WL.

It would appear that 0.01 WL should be considered as "official" guidance with respect to allowable exposures to indoor radon progeny. The maximum projected exposures from the gypsum field (0.001 WL) are thus an order of magnitude less than allowable exposures. The conclusion is that based on comparison of potential gypsum field exposures to existing guidelines and standards, the gypsum field exposures are of no concern. An assessment of gypsum field exposures on the basis of health risk is given in the next section.

HEALTH RISK FROM THE GYPSUM FIELD

In the section on health risks from radon progeny, an upper limit of 10% increase in excess relative risk of lung cancer due to lifetime exposure to mean indoor radon progeny concentrations was estimated. Since exposures due to the gypsum field and near the gypsum field are about an order of magnitude lower than mean background levels, an upper limit of about 1% increase in excess relative risk applies for the population near the gypsum field. This level of risk is applicable after a lifetime (70 year) exposure near the gypsum field. One year after start of exposure the risk would be 1/70 x 1%. Two years after start of exposure, the risk would be 2/70 x 1%, etc. At age n or after n years of exposure the risk would be n/70 x 1%.

In order to gain a better perspective in the significance of these levels of excess relative risks, they may be converted to annual deaths per population exposed and compared to annual mortality from "normal risks of life." Risks from the gypsum field are not directly comparable to normal risks of life, because they are not the same types of risks and do not operate over the same time frame. Also the calculated risks from the gypsum field are theoretical risks while other types are real and are based on actual vital statistics. However, in the assessment context, the magnitude of the calculated risks from the gypsum field may be considered for their significance on a comparative basis with the normal risks of living. The comparisons are discussed further below.

The excess relative risk is defined as (See Appendices II and IIa)

$$\frac{O - E}{E}$$

where O is the number of cases in the exposed population and E is the normal or background number of cases (called expected cases) in a comparable control population not exposed to the excess radiation. Thus, the number of excess cases (O-E) is given by (O-E)/E x E. The number of expected cases of lung cancer in the general population is about 40 cases per hundred thousand people per year (4×10^{-4})([4]). Thus, the maximum annual excess cases for a 1% increase in excess relative risk is

$$(1 \times 10^{-2}) \times (4 \times 10^{-4}) = 4 \times 10^{-6}.$$

For people less than 70 years old, annual risks would be less than calculated above. Recall that the 4×10^{-6} annual risk applies after a lifetime exposure (70 years). The same considerations apply for annual risks or for excess relative risk. Thus, for a person of age n, the annual risk after n years of exposure would be $n/70 \times 4 \times 10^{-6}$. The annual risk due to the gypsum field for a child of age 12 exposed for his entire life near the gypsum field would be

$$12/70 \times 4 \times 10^{-6} = 7 \times 10^{-7}$$

For children attending the elementary school (See Roessler et al report), the annual risk due to the gypsum field after 6 years continuous exposure would be

$$6/70 \times 4 \times 10^{-6} = 3.5 \times 10^{-7}$$

An annual risk of 10^{-6} (one death per million population) or less is often considered as an insignificant risk by comparison with "normal risks of life" (2,3). For example, the average risk of death from disease over all ages is about 10^{-2} (one death per hundred population); this would be considered a high risk. Risk of death per year from automobile accidents is about 2×10^{-4}, (two deaths per ten thousand population), a moderate risk. Risk of death per year from tornadoes, hurricanes and lightning in the U. S. is about 1×10^{-5}. Risks of this order of magnitude might be considered low. Annual risks of 10^{-6} and lower might be considered negligible. Another way this is viewed in the assessment context is that when risks are less than 10^{-6}, the assessment can stop because they are an order of magnitude less than low "natural" risks.

Annual levels of risk due to the gypsum field are compared to other types of risk in Figure 2. They are

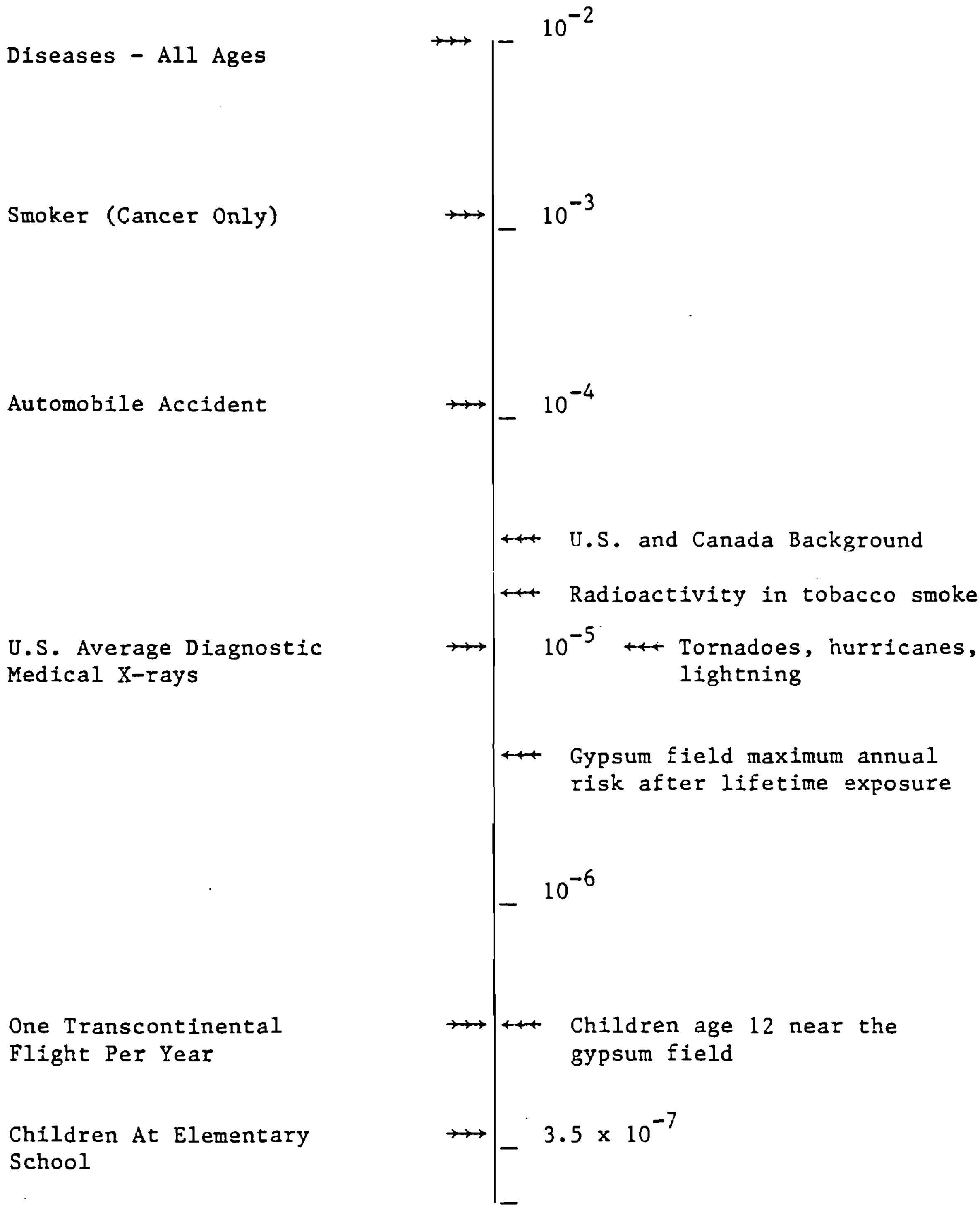

FIGURE 2. Annual Risk of Death from Gypsum Field Compared to Risk from Other Sources

clearly near or below levels of risk considered to be insignificant as discussed above. This is especially true since the risks calculated for the gypsum are upper limit risks as discussed previously.

Number of Cases in the Population Near the Gypsum Field

If all the people (not more than 100) near the gypsum field were exposed continuously at the maximum level for their entire lives, the number of excess lung cancers would be

$$4 \times 10^{-6} \times 100 = 4 \times 10^{-4} \text{ cases/year}$$

$$\text{or} \quad 4 \times 10^{-4} \times 70 = 0.028 \text{ cases/lifetime}$$

Thus, no cancers are expected to occur due to the gypsum field.

This calculation is based on the assumption that all the 100 people reside at the maximum exposure location, 24 hours per day for 70 years. (We have assumed that not more than one hundred people live close enough to the gypsum stack to be subject to the maximum exposure estimates used in the analysis.) The exposure to people in Progress Village would be less than 0.0001 WL since the exposure at the residences nearest to the field ranged from 0.0001 to 0.001 WL. Most Progress Village residents live farther away from the field. Thus, individual risks would be on the order of 1 x

10^{-7}. There are about 800 homes in Progress Village (around 3,000 people). Thus, the excess lung cancers would be

$$1 \times 10^{-7} \times 3000 = 3 \times 10^{-4} \text{ cases/year}$$

$$\text{or} \quad 3 \times 10^{-4} \times 70 = 0.02 \text{ cases/lifetime}$$

Over the lifetime of a population of 3,000 about 84 cancers from normal causes would be expected ($4 \times 10^{-4} \times 3 \times 10^{3} \times 70 = 84$). If the cancers did occur, the probability that they would be due to causes other than radon progeny from the gypsum field would be greater than 99%. This result is based on the risk estimator called fractional relative risk or fraction of observed cases due to exposure discussed in Appendix I. The quantity (O-E)/O is also referred to as relative attributable risk. Since the calculated excess number of lifetime excess cases is 0.02 in a population of 3,000 and the observed number of cases is about 84, the fraction of observed cases that could be attributed to exposure is about 0.02/84 = 0.00024. Thus, one concludes that for cancers that do occur, the probability that they are due to causes other than the gypsum field is greater than 99.99%.

REFERENCES

1. Cohen, A.F. and Cohen, B.L., Tests of the Linear Assumption in the Dose-Effect Relationship for Radiation-Induced Cancer, Health Physics 38, pp. 53-69, 1980.

2. Richmond, C.R. The Science of Risk Assessment, ORNL Technical Seminar Series, August 9, 1979.

3. Wilson, R., The Role of Health Risk Assessment in Decision Making, pp.79 In: Health Risk Analysis, Proceedings of the Third Life Sciences Symposium, Richmond, C.R., Walsh, P.J. and Copenhaver, E.D. (Eds.), The Franklin Institute Press, Philadelphia, 1980. See also pp. 7 and 49 for other comments on de minimis risk.

4. National Center for Health Statistics, 1980. Vital Statistics of the United States, 1976. Volume II - Mortality, Part A. Table 1-23, U.S. Department

of Health and Human Services,

Hyattsville, Maryland.

APPENDIX I

BACKGROUND[a]

IONIZING RADIATION

In the late 19th Century, the fact that certain naturally occurring materials emit radiation was discovered and the first manmade radiation, X-rays, was produced. Fairly soon, investigators realized that these radiations were dangerous and began to take precautions against their harmful effects. It was not until the 1930's, however, with the discovery of the neutron and nuclear fission - highly excited (in energy terms) atoms splitting in two - that man became capable of adding significant amounts of radioactive material to the environment.

Today the principle sources of manmade radioactive materials are fission processes, most commonly associated with weapons production or electric power production. The hazards associated with these uses led to large programs to study the interaction of radiation with matter and resulting biological effects. Safety precautions developed for man-made materials make the human radiation exposures caused by

a For more detail than can be given here, see references, particularly references 1 and 2 for introductory discussions.

fission processes much less than the exposures caused by other manmade sources such as X-rays, and on the average, even less than the background level caused by natural radioactive materials. It is the background materials that are of concern here but the knowledge developed in connection with manmade radiation applies.

Atoms are often compared to our solar system. They consist of a relatively massive nucleus surrounded by rotating electrons. The nucleus consists of protons and neutrons. The number of protons in the nucleus designates the atomic number (Z) and is used to uniquely characterize the elements. Elements of the same atomic number Z can have different numbers of neutrons. Elements with differing numbers of neutrons are called isotopes. Both the electrons surrounding the nucleus and the particles in the nucleus are constantly in motion and the particles collide with each other. The particles in the nucleus are held together by forces that result in a certain binding energy to hold the particles in the nucleus. Radioactive isotopes, on the other hand, have excess energy that they release by either ejecting particles, or high energy electromagnetic rays. The particles are usually helium nuclei (called alpha particles) because helium (2 neutrons and 2 protons) has a highly stable configuration (high binding energy) or negative or positive electrons (called beta rays or beta particles).

Particle emissions change the atomic number of the nucleus and thus a different element results. High energy electromagnetic radiation (called gamma rays) does not change the element but results in a more stable nuclear configuration.

Most naturally occurring radioactive isotopes occur among the heavier elements (large numbers of protons and neutrons) although they occur throughout the periodic chart (e.g. tritium, carbon-14 and potassium-40).

While it is not possible to determine when a particular atom will decay, a statistically large number of radioactive atoms will decay at a characteristic rate and characteristic energy. The time required for half the atoms to decay is called the half life. The number of atoms decaying per unit time is called the activity of the isotope. A special unity of activity called the curie (named after Madam Curie) has been defined - 37 billion (3.7 x 10^{10}) decays or disintegrations per second. The curie is a large amount of activity and, in common practice, fractions of a curie (10^{-3}-millicurie, 10^{-6}-microcurie, 10^{-9}-manocurie, 10^{-12}-picocurie, etc.) are used.

The concentrations of radioisotopes in environmental media (air, land and water) represent potential human exposures. Concentrations may be expressed as activity per unit volume or unit mass. For example, the higher the activity per unit volume (e.g. picocuries per liter) the higher the exposure if inhaled into the lungs. However, as discussed below, biological effects are related to the amount of energy deposited in biological tissues (called dose) and equal exposures do not always result in equal doses.

The patterns of energy deposition of particulate (e.g. alpha particles) and electromagnetic radiation differ dramatically. Ionizing radiation releases energy in matter by collisions with atoms of the absorber. In most cases collisions will result in the ejection of electrons from the atoms leaving an ionized atom. These ionized atoms may be part of or may subsequently interact with biologically important molecules. Other types of interactions occur but are not important for this discussion. Although the sequence of events between initial interaction and subsequent biological effects has not been worked out, a large body of experimental data at high doses has convincingly demonstrated that effects do occur.

Differences between the effects of particles such as alpha particles and gamma rays or X-rays are expected because of their patterns of energy deposition. For example alpha particles produce ionized atoms along short paths in dense clusters. By contrast electromagnetic radiation leaves longer paths of damage with wider spaces between ions. The amount of energy deposited per gram of material is termed dose and is expressed in units of rads (100 ergs/g). However, the differing spatial distribution of doses and subsequent interactions leads to different degrees of biological response for the same dose of two types of ionizing radiation.

One concept that has been developed to partially account for different spatial distributions of dose is termed linear energy transfer (LET). Alpha particles have higher LET because the ions produced are spaced more closely. Biological effects have been shown to be dependent on the LET of the radiation. High LET radiation is usually more potent. The higher potency is thought to be because higher LET radiation is much more likely to damage both strands of the genetic material making up the DNA double helix. Many cells can repair damage involving only one strand of DNA by taking advantage of the complementary character of the two strands. Double strand damage on the other hand is more difficult to repair and more likely to be repaired incorrectly.

In order to compare various types of ionizing radiation on a common scale, the concepts of relative biological effectiveness (RBE) and dose equivalent (DE) were developed. The dose equivalent in units of rem is related to a particular degree of biological response. This concept is very useful because if the risk of a particular biological effect can be related to the DE in rems then determination of the DE in rems for any type of ionization can be related to that particular degree of biological response. The determination of dose and DE for radon progeny will be discussed in the section on health effects of radon progeny.

The biological effects of ionizing radiation are better known than the effects of any other toxic material. Yet controversy still exists among scientists about how to extrapolate results from high level doses used in most animal tests to predict the effects of low level doses comparable to doses from background radioactivity. There exist, however, both evidence and a good theoretical basis for believing that, on the molecular level, the amount of initial (if damage is defined as ionization) increases linearly with increasing radiation dose; that is no cutoff or minimum "threshold" exists with respect to radiation interaction with molecules.

The scientific community agrees on the question of thresholds for effects on a single atom or molecule, but serious differences of opinion exist concerning the presence of a threshold for effects on organs or on whole organisms. Because cells and organs have some ability to repair radiation effects, such repair could yield an effective threshold for the particular type of radiation effect in question.

Also, in some organs or organisms containing many billions of cells - each containing thousands of types of molecules, the continuous death or alteration of a small fraction of these cells occurs naturally and with large variation. A small increase well within natural variation is probably unimportant to the functioning of the organism. However, because a threshold cannot be practically demonstrated, the conservative assumption of a linear, non-threshold dose response relationship is usually adopted for regulations and assessment purposes.

The health effect of most concern at the low levels of dose considered here is cancer. The assumption of linear non-threshold dose response is adopted. The assumption is made to be conservative even though it is quite clear that if repair mechanisms and/or other defense mechanisms did not exist, life spans would be dictated by the latency period for cancer. The latency period is usually defined as the time from onset of exposure until diagnosis of cancer. For most types of cancer the latency period is not more than 30-35 years at levels of exposure where effects have been seen.

NATURALLY OCCURRING MATERIALS AS SOURCES OF RADIATION EXPOSURE

Any assessment of the hazard associated with a certain level of radiation must be made from the results of the many experimental studies that have been made of the biological effects of radiation (3). When this is done, it is apparent that most experiments which correlate definite biological effects with radiation dose are at high radiation levels with respect to background or natural radiation levels. Although it is difficult to extrapolate to levels slightly above the natural baseline, the average exposure man receives from natural radiation serves as a baseline from which the effects of additional exposure may be judged. All life has been exposed to these background levels throughout its evolution.

Natural radiation may be divided into two categories: That produced by the radioactive isotopes that have been present in the upper crust of the earth for millions of years (primordial) and cosmic radiation that bombards the earth each day and also creates new radioactive materials.

It is estimated that the total average wholebody dose from natural radiation in the United States due to terrestrial radiation is 85 mrem/yr and that due to cosmic radiation is 45 mrem/yr. Of the 85 mrem/yr terrestrial radiation, 25 mrem/yr is estimated to be from internal radiation (3). In this report we shall be primarily concerned with the internal dose to the lung from inhaled radionuclides. Doses to the lung are higher than whole body doses. Factors that determine these doses will be discussed in the next section.

The most important radioactive elements in the earth's crust contributing to man's dose from natural radiation are the isotopes potassium-40 and isotopes of the uranium and thorium series. The actinium series and other primordial radioisotopes in the earth's crust contribute very little to man's radiation dose. The isotope potassium-40 contributes about 17 mrem/yr of the 25 mrem/yr average internal whole body dose.

Isotopes of the uranium and thorium series are listed in Table 1. Uranium occurs in the earth's crust at a concentration of about 3-4 ppm and thorium at 11-15 ppm. By contrast, the actinium series starts with U-235 (less than 1% of U or less than 0.03 ppm) and therefore the percentage abundance of isotopes in the actinium series is small. Many of the other primordial isotopes have long half-lives resulting in low specific activity (the specific activity of an isotope depends inversely on the half-life). For example La-138 has a half-life of 1.2×10^{11} yr. which results in a specific activity of 2.3×10^{-2} microcuries per gram.

If we make a somewhat arbitrary cutoff at a half-life of 10^{11} yr., then the only other primordial radionuclides left for consideration are Re-187, Lu-176, and Rb-87. The concentrations of Re-187 (0.001 ppm) and Lu-176 (0.01

TABLE 1. Isotopes of the uranium and thorium series

Uranium series		Thorium series	
Isotope	Half-life	Isotope	Half-life[a]
U-238	4.51×10^{9} yr	Th-232	1.47×10^{10} yr
Th-234	24.10 day	RA-228	6.7 yr
Pa-234m	1.18 min	Ac-228	6.13 hr
Pa-234	6.7 hr	Th-228	1.91 yr
U-234	2.47×10^{5} yr	Ra-224	3.64 day
Th-230	8.0×10^{4} yr	Rn-220	55.3 sec
Ra-226	1.62×10^{3} yr	Po-216	0.145 sec
Rn-222	3.82 day	Pb-212	10.6 hr
Po-218	3.05 min	At-216	3×10^{-4} sec
Pb-214	26.8 min	Bi-212	60.6 min
At-218	1.5-2 sec	Po-212	3.04×10^{-7} sec
Bi-214	19.7 min	Tl-208	3.10 min
Po-214	1.645×10^{-4} sec	Pb-208	Stable
Tl-210	1.32 min		
Pb-210	20.4 yr		
Bi-210	5.01 day		
Po-210	138 day		
Tl-206	4.19 min		
Pb-206	Stable		

[a] Half-lives obtained from Radiological Health Handbook (see Reference 3).

ppm) in the earth's crust are small compared to those of uranium and thorium. Rubidium-87 (75 ppm) is the most abundant of the natural radioactive nuclei but has a long half-life (5 x 10^{10} yr) and has a single beta emission (0.024 Mev) so that the expected dose is small. It is estimated as 0.6 mrem/yr whole body.

RADON AND PROGENY

Those isotopes listed in Table 1 which become airborne are of particular interest. Obviously the radioactive gases and their decay products must receive primary consideration. In trying to determine those isotopes which potentially would be of more harm to the lung, it is recognized that almost any isotopes can become airborne either as a gas or on dust particles and delivery doses of radiation to the lung. The uranium and thorium series both contain gaseous isotopes of radon. Radon-222 of the uranium series has a half-life of 3.82 days and has a large number of daughter products, some with long half-lives. For example, Pb-210 has a half-life of 20.4 years, Po-210 of 138 days, and Bi-210 of 5 days. In the thorium series, Rn-220 occurs with a half-life of 55.3 sec. The longest lived progeny product of Rn-220 is Bi-212 with a half-life of 60.6 min. The actinium series also has a radon isotope (Rn-219) with a half-life of 4.0 sec and the longest-lived progeny product is Pb-211 with a half-life of 35.1 min. Therefore, the thorium and actinium series will contribute very little to man's lung dose from gaseous products except for strictly local conditions where high concentrations of uranium and thorium exist (as in mines). Even here the principal gas for consideration will be Rn-222. Measured concentrations at various locations show Rn-222 to be 50 to 100 times more concentrated than Rn-220.

Atmospheric concentration of radon depends on many geological and meteorological factors. Such factors as proximity to uranium and thorium ore deposits, porosity of the soil, effect of temperature on diffusion rates, snow cover to prevent the escape of radon gas from the ground, and wind conditions play an important role in the concentrations observed for radon. Osburn, see reference 3, considers migration of radon out of soil where it is formed to occur in four steps: recoil of radon precursors, diffusion through the mineral grain, movement through permeable rock or soil and release to the environment. Depending on soil surface, much of the gas may be absorbed. For example, if charcoal is present as in the case of ground covered with a burned forest, then much gas is absorbed. Since radon gas is heavy, it also tends to accumulate in valleys. Rain may cause radon progeny to return to ground and increase ground radiation temporarily; in other cases wet ground may prevent the escape of the gas and thus reduce ground radiation.

When Rn-222 decays with emission of an alpha particle (5.47 MeV), the newly formed atom (Po-218) has a recoil energy of 0.11 MeV which is enough to give most atoms a positive charge. These atoms may later become neutralized by electrons or may attach to aerosol particles from dust, smoke, ocean spray or pollen. Gold et al., see reference 3, find that the major fractions of radon progeny are associated with particles of 0.005 to 0.04 micrometers size. Others find most of the activity on 0.2 - 0.084 micrometer size particles. Raabe finds that the attachment of activity to an aerosol particle is proportional to the surface area of the particles for all particle sizes except at extremely high radon concentrations.

Gold et al., in a 1953 Cincinnati study, found the average annual Rn-222 concentration to be 0.26 picocuries per liter. Lockhart reports Rn-222 concentrations studies for various sites showing concentration values of 0.00047 picocuries per liter at the South Pole up to 0.122 picocuries per liter in Washington, D. C. In Czechoslovakia, ground level values for Rn-222 were observed from 0.026 picocuries per liter to 0.106 picocuries per liter. Shearer has evaluated Rn-222 concentrations near uranium mill tailings in Colorado and Utah. At Grand Junction, Colorado, the level recorded was 0.8 picocuries per liter, whereas directly over the tailings, levels of 3.5 to 16 picocuries per liter were observed (ICRP recommendation for the maximum permissible concentrations for the general population is 1 picocurie per liter). Indoor levels of radon and radon progeny are reviewed in the next section.

The hazard of naturally occurring radioactive materials to the lungs of the general population therefore reduces to much the same hazard as for uranium miners, except exposure is less per individual but to a greater number of individuals. The problem of uranium miners has been extensively studied and many lung models and dosimetry calculations have been made in connection with the problem encountered in uranium mining. These will be discussed briefly in the next section.

Exposures from the gypsum field do not represent a new or unique situation. They arise from natural radionuclides. The radionuclides have only been moved from one site to another. The assessment can thus concentrate on whether a significant increment in exposure is produced because the radionuclides may have been made more accessible to transport.

APPENDIX II

HEALTH RISK FROM RADON PROGENY

SPECIAL EXPOSURE UNITS

Discussion of the health risk from radon progeny per unit exposure or per unit dose will require the introduction of special exposure units developed for radon progeny during studies in uranium mines (4).

The definition of activity and concentration was given in Appendix I. However, most of the respiratory tract dose from the inhaled progeny is due to alpha particles from Po-218 and Po-214. For each atom of Po-218 deposited in the lungs, two alpha particles will be emitted as the various short lived progeny decay. For each atom of Pb-214 or Bi-214 deposited only the Po-214 alpha results. Another way to state this is that three Po-214 alpha particles and one Po-218 alpha particle will result when Po-218, Pb-214, Bi-214 and Po-214 are deposited in the lungs. If the alpha energy potentially released by activity concentrations of the progeny is evaluated then one has a quantity more closely related to the lung dose.

In studies of underground uranium miner exposure, the U. S. Public Health Service developed such a quantity called the working level (WL). One WL is defined as any combination (of activity concentrations) of radon progeny so that the total alpha particle emission in one liter of air is 1.3×10^5 MeV in the complete decay through Po-214. Activity concentrations of 100 picocuries per liter of Po-218, Pb-214 and Bi-214 will result in an alpha emission of 1.3×10^5 MeV. These concentrations thus result in 1 WL exposure - which was the occupational exposure limit recommended at the time. Cumulative exposure is given in working level months (WLMs) which is defined as exposure to 1 WL for 170 hours (an occupational month). Continuous exposure to 1 WL for a year (8760 h) would corresond to a cumulative exposure of about 50 WLM.

BACKGROUND EXPOSURE LEVELS

Much of the worldwide data obtained on indoor radon and progeny concentrations is summarized in the UNSCEAR reports (see reference 4). A comprehensive review of reported radon and radon progeny exposure conditions in houses and other buildings by Goldsmith et al. has been summarized by Ryan (see reference 4). Measurements were included for buildings on soils considered to contain typical background Ra-226 concentrations (less than 5 picocuries per gram and an average of 1 picocurie per gram). The measured radon and radon progeny concentrations each appear to be lognormally distributed. The geometric mean radon concentration on main floors was 2.4 picocuries per liter with a geometric standard deviation of 4.24 (296 measurements). Working level concentrations of radon progeny have also been measured and compiled by Goldsmith et al. As summarized by Ryan, the average concentration of radon progeny on main floors was 0.0066 WL with a geometric standard deviation of 3.45 (403 measurements). The mean concentration in basements was 0.0127 WL with a geometric standard deviation of 3.41 (298 measurements). These results illustrate the main phenomena, but there may be inherent biases in this data base due to insufficient sampling periods and the choice of interesting areas of study. A large-scale, carefully planned survey that would yield a reliable distribution of long-term radon exposure levels in U. S. housing is still lacking. Such surveys are presently being conducted in Sweden and West Germany.

These wide ranges in background concentrations of radon and radon progeny in typical structures indicate the need for measurements in particular situations to determine the degree to which exposures may be elevated above background. It is clear that indoor radon concentrations can often be a factor of 10 or more higher than outdoor concentrations. However, it is difficult to establish whether exposures are atypical for a particular situation such as houses built on reclaimed mining land. For example, the average radon progeny concentration in structures built on reclaimed lands (including reclaimed phosphate and uranium mining lands) was 0.0124 WL, which is about the same as levels found in basements of typical buildings. It is clear that background exposures to radon and radon progeny need to be better defined for various population groups in order to provide a basis for assessing the risk associated with a particular action that may increase exposures.

URANIUM MINING EXPERIENCE

The data on lung cancer introduction by radon progeny arises from epidemiological studies on underground miners, particularly uranium miners. We will provide a brief discussion of risk estimates from the uranium miner experience, dosimetry for radon progeny, and the uncertainties involved in extrapolation to the general population.

Uranium miners are exposed to a complex atmosphere. Uranium ore dust, silica dust, diesel exhaust fumes, natural aerosols, radon, and radon progeny are present in most mine atmospheres. Although possible effects from one or all of these components in combination are not ruled out, an association between incidence of lung cancer and cumulative exposure to radon progeny has been established. Cumulative exposure to radon progeny may be serving as a surrogate for the complex mixture, and it is possible that the nature of exposure response relationships will vary with the nature of the complex mixture. Thus, it is difficult to extrapolate the results from mining groups to the general population where different complex mixtures are prevalent and different spatial, temporal, age, and sensitivity distributions characterize the exposed population.

Epidemiological data on the induction of lung cancer have been used by Walsh (see appendix II A) to derive dose conversion factors for radon progeny. After discussing several possible ways of expressing the risk of lung cancer, excess relative risk was selected as an appropriate quantifier. Excess relative risk is the rate or number of cases observed in an exposed population (O) minus the rate or number of cases in a control population not so exposed (E) divided by E. Thus, excess relative risk is (O - E)/E. The results for ten different population groups exhibiting radiogenic lung cancer are given in Table 2. The percent increase in excess relative risk per WLM for uranium mining groups varied from 0.4 - 1.2%WLM. For all mining groups, the range was 0.4 - 3.2% WLM. If radon progeny do not account for all the lung cancer induction, then these risk estimates would overestimate the carcinogenic potency of radon progeny. The higher estimates for nonuranium mining groups where the cumulative exposures to radon progeny were lower

TABLE 2. Excess relative risk (in percent) of radiogenic lung cancer in groups exposed to alpha particles, x-rays, gamma-rays and neutrons[+]

Exposed Group	Type of radiation	Percent increase in excess relative risk		
		per WLM	per rad	per rem
Uranium miners				
U.S. (white)	Alpha	0.9		
U.S. (Indian)[#] WLM >300	Alpha	0.4		
U.S. (15 years after start), WLM <500[#]	Alpha	0.9		
Canada[$]	Alpha	0.9		
Czechoslovakian[¶]	Alpha	1.2		
Fluorspar miners	Alpha	3.0		
Metal miners	Alpha	0.5		
Swedish metal miners	Alpha	3.2		
Thorotrast (Portuguese)	Alpha		1.0	
Atomic bomb survivors	Gamma		0.3	0.3
	Neutron		1.0	0.2
Spondylitics	X-rays		0.2	0.2

\+ Data from BEIR report unless indicated otherwise.

\# Data from Archer et al.

$ From data tabulated by Archer, personal communication.

¶ From Sevc et al.

See reference 4 and Appendix IIA

and other agents may have been responsible for a greater proportion of lung cancer would indicate that radon progeny become a poor surrogate for total exposure as exposure decreases.

Using the single estimate for thorotrast patients given in Table 2, an epidemiological-based dose conversion factor for radon progeny was calculated to be about 1.4 rad/WLM using the average value of 1.4% per WLM for all mining groups. The range for uranium miners referenced to the thorotrast estimate would be 0.4 - 1.2 rads/WLM. A dose conversion factor of 6 rem/WLM and an average rem/rad factor of 4 was also derived by using the gamma- and x-ray data in Table 2 as a reference. The dosimetric meaning of these rad and rem values are discussed below.

DOSIMETRY FOR RADON PROGENY

Estimated rad/WLM and rem/WLM conversion factors are important in order to relate the information on uranium miners (exposure in WLM) to the total body of information on radiogenic lung cancer (risk expressed per rad or per rem) and to identify those parameters (and uncertainties) which are important in extrapolating the results for uranium miners to low exposure rates and to general population groups.

The absorbed does (rad) is simply a physical energy absorption (100 ergs/gm) and does not necessarily relate to any biological response. According to the International Commission on Radiological Protection (ICRP), the absorbed dose is to be multiplied by appropriate conversion factors to obtain the dose equivalent. Thus, the dose equivalent (DE) is

$$(DE) = D(QF)(OMFs) \qquad (1)$$

where D is the dose in rads, QF is the quality factor or relative biological effectiveness of OMFs and other modifying factors such as spatial distribution of dose (DF) or relative biological sensitivity (RBS). The unit of DE is the rem. The DE relates to a given degree of biological response and was developed to enable comparisons of biological effect to be made on a common scale regardless of the type of ionizing radiation involved. Therefore, the dose in rems will be the same for any type of ionizing radiation producing that degree of a particular biological response. The physical rad doses and conversion factors can and will differ for different types of radiation but when multiplied together, all will converge to the same rem dose. The practical implications of the definition of DE for radon progeny dosimetry have been discussed by Walsh (see appendix II A).

Given a WLM exposure, calculation of a corresponding rad dose can be made if enough is known about aerosol characteristics, deposition models, clearance of deposited material from the lung, critical tissue or cells and depth-dose curves for the alpha particles. Such dose calculations have been discussed extensively. Formulation of the methods for dose calculation and an expression for the dose per WLM were given by Walsh (see references in appendix IIA). Much of the variation in dose per WLM calculations have been due to assumptions regarding aerosol characteristics, lung morphometry and physiology, and the portion of the lung (e.g., a particular generation in the tracheobronchial tree versus the whole lung) for which doses were calculated. Some of the more important factors will be discussed further in connection with extrapolation of results for miners to the general population.

A review concluded that a detailed site-by-site (e.g., an area as small as a bifurcation in the tracheobronchial tree) dose calculation was not possible, and such calculations are still not feasible with any degree of certainty. The average dose to each region (Weibel model, 17 generations) of the tracheobronchial tree was calculated, and showed that the highest doses to particular regions were not much higher than the average dose to the entire tracheobronchial tree. The average dose to the tracheobronchial tree was about 1.4 rads/WLM and the dose to the basal cells of the bronchial epithelium (thought to be the critical cells) located at variable depths below the surface of the bronchial epithelium was estimated to be less than

1 rad/WLM. Later calculations by Harley and by Jacobi have tended to confirm that dose to basal cells is less than 1 rad/WLM. These calculations are in surprising good accord with the dose conversion factors based on the epidemiological data given above (see appendix II A for more detail).

A calculated dose of less than 1 rad/WLM (say 0.5 rad/WLM), along with the data in Table 2, would indicate that the factor for rem per rad is about 12. Since the risk per rem must be approximately invariant by definition, such results indicate that the basal cells are more sensitive than the entire bronchial epithelium on a rad dose basis, as would be expected. Higher rad/WLM (e.g., 5 rad/WLM) would lead to rem per rad factors less than unity; thus, the basal cells would appear to be less sensitive than the entire bronchial epithelium. Such a result would clearly not be in accord with rem per rad factors for alpha particles. Walsh (see appendix IIA) also showed that the ICRP models can provide an adequate basis for radon progeny dose calculations; and he also concluded that animal toxicological studies tend to support a rem/rad factor less than 10, the value generally used at the time for alpha particles.

EXTRAPOLATION OF MINING EXPERIENCE TO THE GENERAL POPULATION

The general population is exposed to much lower levels of radon progeny than were the uranium miners. Uranium miners were also exposed to other materials including cigarette smoke that could have influenced lung cancer induction. Other differences relate to work state (e.g., breathing rate), nature of aerosol distribution, population characteristics such as age and sex and relative lung physiology. Thus, extrapolation of the results for uranium miners to the general population is complex and highly uncertain. Only the general features are discussed here.

The infuence of potential cocarcinogens, cofactors, or promoters on the induction of lung cancer in uranium miners probably contributes the greatest uncertainty in extrapolations to low level exposures. If these factors are absent in cases of exposure of the general population, then risk estimates based on uranium miner data will almost certainly overestimate impact on the general population. If these factors were to make a constant contribution over all radon progeny exposure categories, then their relative contribution would increase as exposure to radon progeny decreased. For example, if risk of lung cancer were doubled (100% increase) at a 100-WLM exposure and 10% of the increase was due to other exposures (chemicals, dusts, cigarettes, promoters, etc.) then at 1 WLM the total increase would be about 11% but only about 1% could be attributed to radon progeny. The risk per WLM for radon daughters would be overestimated by an order of magnitude if these cofactors are not present in another exposure situation. If there is interaction between radiation and these other exposures, then the overestimate would be even greater. If exposures to other materials decline in proportion to radon daughter exposures, there would still be an overestimate, but of lesser magnitude.

Although a linear dose-response relationship for high linear energy transfer radiation (LET) such as alpha radiation is generally assumed, there is no way to confirm such an assumption unless the effects of other potential contributors can be separated out. Stewart and Simpson and Myers and Stewart as cited in Evans et al. (see reference 4) have evaluated the American and Czechoslovakian data using various statistical techniques. Their work indicates, according to Evans et al., that the incidence of lung cancer can be accounted for by a linear relationship with exposure, allowing a constant factor for non-radiogenic lung cancers. They also found that estimates of risk for low-level exposure may include zero as a lower bound. Evans et al. judge from the available epidemiological evidence that an upper bound for the lifetime risk to the general population is about 10^{-4} per WLM.

The main factors that may differ between uranium miners and the general adult population in terms of the physical dose conversion factor are the fraction of activity deposited in the lung and breathing rates. The fraction deposited in the respiratory tract, f_R, for the general population may be higher because the particle size distribution may be different than was the case for miners. The breathing rate for the general population will, however, be lower perhaps by a factor of 2 or more because of a lower level work state.

The factor, f_R, is influenced strongly by the aerosol characteristics. Although radon progeny will attach to a distribution of particle sizes, dose calculations have emphasized a single particle size for the so called "attached" fraction and a different smaller particle size and much higher diffusion coefficient for the "unattached" fraction (the major mode of deposition for radon progeny is by diffusion). The importance of the unattached fraction of "free ion" component of the exposure atmosphere is that the presence or absence of free ions can profoundly affect site and magnitude of deposition in the respiratory tract. The free ions will deposit with virtually 100% efficiency due to their large diffusion coefficient. Raabe has described a method for calculating the unattached fractions of Po-218, Po-214, and Bi-214 if the aerosol size distribution and particle number concentration are known. When particle number concentrations are less than 10^4 per cc, the fraction of the total potential alpha energy unattached (fraction of WL unattached) can make a significant contribution to the respiratory tract dose. The influence of these factors especially with regard to the differences betwen mining and nonmining populations need to be investigated further. As a general rule, the particle concentration will be greater than 10^4 per cc for reasonable levels of human activity, and the increase in dose per WLM due to greater unattached fractions for nonmining groups will be less than 50%.

For children (12 years), deposition in the respiratory tract will also be different due to respiratory tract physiology and morphometry. Although direct data are not available for children on airway dimensions and clearance, scaling down from adult lung dimensions would indicate that the dose per WLM to children may be higher than for miners. However, it is not clear whether deposition patterns of bronchial epithelium thicknesses are substantially different in children as compared to adults. Large differences are not expected. This is another area for further research.

RANGE OF RISK FOR THE GENERAL POPULATION

From the previous discussion, the percent increase in excess relative risk for uranium miners analyzed over several higher exposure categories is about 0.4 - 1%WLM. The largest and at present unquantifiable source of uncertainty is associated with the risk/WLM value and subsequently with the rem/WLM value. The magnitude of the contribution of nonradiogenic carcinogens is not known. Uranium ore dust, diesel engine exhaust, arsenic, nickel and cigarette smoking are all likely contributors to the total risk of lung cancer. These estimates for uranium miners are likely to be overestimates for the general population. Unfortunately, the degree of conservatism is impossible to estimate. The judgment by Evans et al. of an upper bound lifetime risk for the general population of 10^{-4}/WLM is reasonable but cannot be completely confirmed. A start towards resolution of the problem may be made by application of more rigorous statistical techniques that would test reasonable hypotheses about the relative contribution of the various contributors to risk. A major uncertainty will be exposure estimates for the various possible contributors, including radon progeny. Some better estimates of these exposures might be made on the basis of measurements in experimental mines designed to mimic past exposures to the extent possible.

The 10^{-4}/WLM level of risk would correspond to about 2×10^{-5}/rem which is in accord with ICRP estimates of risk to the lung from external ionizing radiation and is not inconsistent with our analysis of the risk to uranium miners of 0.4 - 1%/WLM as the percent increase in excess relative risk. The 0.4 - 1%/WLM range would correspond to a lifetime risk for the miners of about $(0.8 - 2) \times 10^{-4}$/WLM.

RISK ASSESSMENT FOR INDOOR RADON PROGENY

The indoor radon progeny exposure estimates and the risk estimates summarized above may be combined to provide a risk assessment for general population exposures to radon progeny. Working level concentrations on the main floor of buildings averaged about 0.007 WL with a geometric standard deviation of 3.45. The value used by Evans et al. was 0.004 WL but is based on fewer measurements. Under conditions of continuous exposure, the cumulative exposure for a 0.007 WL concentration would be about 0.35 WLM per year or about 25 WLM in 70 years. If, as is commonly reported, about 80-90% of the day is spent indoors, then lifetime exposures would amount to about 20-22 WLM. Outdoor exposure levels would be a factor of 20 or more lower and do not make a significant contribution to total exposure. However, spending more time outdoors or increasing indoor ventilation could significantly lower exposures.

Risk estimates based upon the uranium miner experience are about 0.4 - 1%WLM as the percent increase in excess relative risk. thus, lifetime exposure at mean indoor radon progeny levels may represent an 8 - 20% increase in risk of lung cancer. This would probably represent a maximum increase for the general population. The numbers take no account of latency period or exposure to nonradiogenic carcinogens as discussed previously.

Exposure estimates for uranium miners did not include background exposures. Background exposures become important for the groups exposed to the lowest levels above background. Thus, the risk per WLM becomes more complicated for the lowest exposure categories. For exposure categories at or below 20 WLM, the risk/WLM could be overestimated by at least a factor of 2. For example, the risk/WLM would have been calculated as risk per 20 WLM plus background (up to 20 WLM or more in older miners). This problem with the lowest exposure categories, as well as large uncertainties in exposure estimates for individual cases, the small number of cases involved, and the role of cofactors, requires further study. In the interim, an upper limit of 10% increase in risk due to lifetime exposure to mean indoor radon progeny concentrations may be appropriate when radon progeny exposures are used as a surrogate for the total exposure complex.

073810046Walsh:25

REFERENCES

1. Pizzarella, D.J. and Witcofski, Basic Radiation Biology, Lea and Febiger, Philadelphia, 19701

2. Morgan, K. Z., and Turner, J. E. (Eds.), Principles of Radiation Protection, John Wiley and Sons, Inc., New York, 1967.

3. The discussion is taken from: Hamrick, P. E. and Walsh, P. J., Environmental Radiation and the Lung, Environmental Health Perspectives 9, pp. 33-52, 1974. This paper contains the necessary references to the open literature. They are not given here.

4. The discussion is taken from: Walsh, P. J. and Lowder, W. M. assessing the Risk from Radon in Dwellings, ORNL/TM-8824, July 1983. This report contains the necessary references to the open literature. They are not given here.

Health Physics Vol. 36 (May), pp. 601–609
Pergamon Press Ltd., 1979. Printed in Great Britain

0017-9078/79/0501-0601/$02.00/0

DOSE CONVERSION FACTORS FOR RADON DAUGHTERS*

P. J. WALSH
Health and Safety Research Division, Oak Ridge National Laboratory, Oak Ridge, TN 37830

(*Received* 26 *June* 1978; *accepted* 15 *November* 1978)

Abstract—Dose conversion factors that are consistent with present epidemiological, toxicological and theoretical evidence about radiogenic lung cancer are suggested for short-lived radon daughters. These dose conversion factors are based upon risk estimates derived from epidemiological studies that have demonstrated an association between exposure of the lung to ionizing radiation and lung cancer. Various risk estimators are compared including absolute risk, relative risk, percent increase in excess cases, and excess cases as a fraction of observed cases. The nature of risk per unit exposure as a function of exposure is shown to be dependent on the risk estimator used. The hypothesis that the excess of observed cases over expected cases is directly proportional to exposure is supported in the range of available data. The nature of exposure response relationships at low exposures is uncertain because of uncertainties in individual exposure estimates. Risks could be overestimated or underestimated depending on the risk estimator used when exposures approach background exposures, especially if background exposures are not included in exposure estimates.

INTRODUCTION

DOSE CONVERSION factors for radon daughters are of interest for several reasons. Exposure to radon daughters is associated with lung cancer in several underground mining groups, particularly uranium miners (Lu71; Wa65; Se76). Persons living near uranium tailings piles (EPA76), phosphogypsum piles (Gu77), in homes near or on uranium tailings (EPA75), or in homes built on reclaimed mining land (EPA75) may be subjected to increased risk of lung cancer. Even background levels of radon daughters and widespread diffusion of radon from waste piles, buildings, or areas contaminated with elevated levels of radium can be associated with increased numbers of lung cancers, especially if large populations are exposed. The particular radioactive isotopes usually of importance are ^{226}Ra and ^{222}R and their short-lived daughters.

Dose conversion factors for radon daughters have been at variance because of differences in assumptions and uncertainties related to aerosol properties, lung models and critical tissue (Pa69; Ne70; Wa170; Wa177; FRC68; BEIR72). Such variance has led in some instances to abandonment of dose calculations and reliance on relative exposure estimates and associated epidemiological data in order to suggest guidance for radon daughter exposures. Thus guidance for general population groups has been based upon risk per WLM (working level month) derived from data for underground miners, with recognition of the fact that dose per WLM to the general population could differ

*Research sponsored by the Division of Biomedical and Environmental Research, U.S. Department of Energy under contract W-7405-Eng-26 with the Union Carbide Corporation.

from that to miners. The WLM exposure unit was developed during a study in underground mines (Ho57) and is defined as exposure at a one-working-level (WL) concentration for 170 hr. One WL is defined as exposure to an atmosphere that contains any combination (of concentrations) of radon daughters so that the total alpha particle emission in 1 l. of air is 1.3×10^5 MeV in the complete decay through RaC′ (^{214}Po). Such a definition of WL was developed because it was recognized that most of the respiratory tract dose was due to alpha particles from the short-lived radon daughters, and thus measurement of the total alpha emission should provide a sufficiently accurate exposure estimate and provide a basis for dose calculations. However, the WL exposure estimates do not replace dose calculations in deriving general guidance. They do not provide needed information on particle size distribution. They do not provide a basis for comparison with exposures to other types of ionizing radiation. They do not provide a basis for extrapolation between population groups. It is therefore important to estimate the rem per WLM conversion factor for radon daughters so that comparison with maximum permissible lung doses (ICRP59) can be made. Also, comparisons could be made with other groups exhibiting excess radiogenic lung cancer, regardless of the type of radiation which may have been the inducer.

Many of the complexities of earlier dose calculations must be disregarded in the context of general guidance for radon daughters as related to a larger body of information on radiogenic lung cancer. Complexities such as critical cell dose, hot spot vs uniform doses, etc. are of great importance in understanding the mechanisms of radiation induced cancer and in constructing theoretical or mechanistic dose-response relationships. Research effort to unravel the complexities should certainly be increased to understand the theoretical basis of dose-response relationships in order that we may predict and extrapolate dose-response curves. However, in the interim, guidance is required using the admittedly sketchy empirical data available. The conceptual framework and methodology for such guidance and specific guidance for radon daughters are given herein.

GENERAL CONSIDERATIONS

The determination of absorbed dose (rad) to the respiratory tract due to inhalation of radon daughters has been discussed recently (Wa177; Har72; Ja73). Most discussions have related to the rad per WLM conversion factor and have emphasized lack of sufficient information to estimate the rem per WLM conversion factor. Specifically, quality factor (QF) and other modifying factors (OMFs) are not quantitative estimators of lung cancer induction in humans by alpha emitters. If these factors were known, then rad per WLM conversion factors could simply be multiplied by them to obtain rem per WLM conversion factors. Having obtained rem per WLM conversion factors, it would make no difference how rad per WLM conversion factors are determined since they would be multiplied by different conversion factors for each case in order to obtain the rem per WLM conversion. This conclusion follows from the definition of dose equivalent (DE) in rems, as will be discussed below. Dose calculations (in rad per WLM) have been directed by most workers to a determination of dose to the critical cells (the cells which become neoplastic). If such calculations could be accomplished accurately, then there would be fewer conversion factors (e.g. distribution factor, DF) involved in determining rem doses. Such calculations are important and necessary for development of mechanistic dose reponse models. However, given the appropriate conversion factors (QF, DF, OMFs), the resulting rem dose should be the same, regardless of the method of physical rad dose calculation.

The above discussion follows from the definition of dose equivalent developed by the International Commission on Radiological Protection (ICRP63). The absorbed dose (rad) is simply a physical energy absorption (100 erg/g) and does not necessarily relate to any biological response. According to the ICRP, the absorbed dose is to be multiplied by appropriate conversion factors to obtain the dose equivalent. Thus, the dose equivalent (DE) is

$$(DE) = D(QF)(DF)(OMFs) \quad (1)$$

where D is the dose in rads. The unit of DE is the rem. The DE relates to a given degree of biological response and was developed to enable comparisons of biological effect to be made on a common scale, regardless of the type of ionizing radiation involved. In other words, the DE in rem implies a degree of a particular biological response. Thus, the dose in rems will be the same for any type of ionizing radiation producing that degree of a particular biological response. The physical rad doses and conversion factors can and will differ for different types of radiation but in the sense that when multiplied together all will converge to the same rem dose. The practical significance of the definition of dose equivalent is that if the risk per rem is known for one type of radiation (e.g. where QF, DF, etc. are unity), then it should be the same for any other type of radiation. Still, having estimated the risk per rem for a given biological response, one must of course determine the rem dose in order to estimate risk for population groups where only exposure estimates are available. When comparing population groups exhibiting an excess of radiogenic lung cancer, one will, of course, see variations in the calculated risk per rem among the groups. Such variation is expected for many reasons, including uncertainties in exposure or dose estimates, conjoint exposure to cofactors and population characteristics.

HUMAN DATA AND RISK ESTIMATES

Epidemiological data on the induction of lung cancer have been used by Walsh (Wal76) to derive dose conversion factors for radon daughters based upon absolute and relative risk estimates. Here that analysis is extended to a consideration of other risk estimators and additional data. First, risk estimators are discussed in order to select an appropriate value for use in estimating dose conversion factors.

Epidemiological studies usually report the number of cases of a given biological end-point (e.g. cancer) in a population exposed to a potentially toxic material (observed cases, O) and the number of cases expected in a comparable population (expected cases, E) not exposed to the toxic material or exposed at a background level. Many considerations go into the selection of population groups to ensure their comparability, but we shall assume for purposes of this discussion that the groups have been properly selected. Given proper selection, statistical analysis of the data determines whether the excess cases ($O-E$), if any, are related to the exposure or dose of the toxic material in a statistically significant manner. If the excess is statistically significant, then the biological effect is said to be associated with exposure to the toxic material. The association is stronger if the excess increases with increasing exposure; however, such studies can only show associations, not cause-effect. Other supporting scientific evidence or repetition of the association in other groups strengthens the association, but the ideal of establishing a cause-effect relationship is not possible through epidemiological studies alone. In practice, however, results of epidemiological studies must be applied in a cause-effect sense to provide guidance on exposure to toxic materials. In fact, direct epidemiological evidence is presently preferred over laboratory toxicological studies or theoretical studies because of uncertainties associated with extrapolation. Unfortunately, such evidence does not exist in many cases, and where it does exist, levels of exposure are usually greatly in excess of those which would be acceptable for exposure of the general population. Thus extrapolations from existing evidence are necessary; sometimes over several orders of magnitude of exposure or dose and dose rate. Ideally, such extrapolation would be based upon knowledge of the mechanisms for induction of the biological response. Such knowledge would allow the calculation of the appropriate risk estimator from available data to provide a basis for exposure guidance. At present, there appears to be no scientific basis for selection among several risk estimators that have been used (BEIR72).

If there is a statistically significant association between observed cases (O) or excess cases ($O-E$) and exposure or dose to the population in population groups of a given size (say 10^5 persons), then several ways of expressing the risk are possible. Some of these are

$O/10^5$ persons = absolute risk
$(O-E)/10^5$ persons = excess risk or attributable risk
O/E = relative risk
$(O-E)/E$ = excess relative risk
$(O-E)/O$ = fraction of observed cases due to exposure (fractional relative risk).

The estimates of risk used most often are absolute or excess risk, and relative risk and excess relative risk are used to a lesser extent. The ratio $(O-E)/O$ has apparently not been used even though its use would appear to be as acceptable as use of the others. However, if one wishes to set a maximum permissible exposure, such as $(O-E)/E \leq K$, then one would arrive at the same maximum permissible exposure whatever risk estimate was used. In order to set a maximum permissible exposure, one must assume some relationship between exposure (or dose) and some combination of the variables O and E, and/or one can simply plot the data as exposure or dose vs all the risk estimators to see whether a relationship is suggested. Such a relationship will be valid only over the region covered by the data. Risk estimates are often given in terms of risk per year per unit dose, and calculations using available data have indicated that some of the risk estimates increase with decreasing dose when high LET (alpha particles) are involved. Such results suggest that high LET (alpha particles) are more effective at low dose and/or low dose rates than at higher doses and/or dose rates. But such results would be expected, depending on the underlying dose-response relationship. For example, suppose that the excess cases are directly related to excess dose, D_e, ($O-E = kD_e$), then the following relationships for risk per unit dose would be expected:

absolute risk per unit dose $\propto k + E/D_e$;

excess risk per unit dose $\propto k$

relative risk per unit dose $\propto \frac{k}{E} + \frac{1}{D_e}$

excess relative risk per unit dose $\propto \frac{k}{E}$

fractional relative risk per unit dose $\propto \frac{kD}{kD_e + E}$.

Thus, increases in some of the above risk estimates (absolute, relative, and fractional relative risks per unit dose) with decreasing dose would, in fact, confirm over the region covered by the data the underlying relationship $O - E = kD_e$.

Risk estimates for the Czechoslovakian uranium miners are given in Table 1. This particular group was selected because exposure estimates (WLM) are apparently more accurate and lower than those for United States uranium miners or other mining groups, and the group has been followed for a longer period of time. In addition, Group A data were used since these miners started mining earlier, were older (over 30), and thus should have shorter cancer induction-latent periods. This subgroup of miners should exhibit risks closer to lifetime risks. The data in Table 1 demonstrate that excess risk per WLM and excess relative risk per WLM are relatively constant, while absolute risk per WLM, relative risk per WLM, and fractional relative risk per WLM are inversely proportional to exposure in WLM. Thus, the Czechoslovakian data support a direct relaship between excess cases and excess

Table 1. Risk estimates based upon lung cancer incidence in Czechoslovakian (group A) uranium miners†

Exposure (WLM)	Risk per unit exposure (WLM)				
	Absolute‡	Excess§	Relative¶	Excess relative*	Fractional relative††
50	44	15	3.0	1.0	1.6
125	24	16	2.3	1.5	0.5
175	27	20	2.4	1.8	0.4
250	22	17	1.8	1.4	0.3
350	16	13	1.3	1.0	0.2
500	14	12	1.1	0.9	0.2
700	11	8	0.8	0.6	0.1

†Based upon data given in Ševc *et al.* (Še76).
‡Observed cases per million persons per year per WLM, $O/10^6$ py/WLM.
§Observed minus expected per million per year per WLM, $(O-E)/10^6$ py/WLM.
¶Observed expected/WLM in percent, 100 O/E/WLM.
*Observed minus expected/expected/WLM in percent, 100 $(O-E)/E$/WLM.
††Observed minus expected/observed/WLM in percent, 100 $(O-E)/O$/WLM.

exposure. Data from other groups, summarized in Table 2 and discussed later, also support such a relationship between risk and dose.

The estimators that appear to be more suitable (relatively constant) for expressing risks for uranium miners appear to be excess risk per unit dose and excess relative risk per unit dose if dose is excess dose (in excess of background). We have chosen to use excess relative risk per unit dose for comparing different population groups since the excess risk per unit dose varies directly with the number of expected cases and the expected cases vary from group to group. The excess relative risk is, on the other hand, not very sensitive to expected cases.

The expected cases must include cases that are due to background levels of radiation (particularly radon and radon daughters for uranium mining groups), but exposure estimates do not usually include background exposures. Background exposures could become important for the groups exposed to the lowest levels above background. Thus risk per WLM becomes more complicated for the lowest exposure categories. In any case since excess relative risk per WLM (where WLM is excess above background) is expected to be relatively constant, averaging over several exposure categories including those where background exposures should make a negligible contribution, should tend to negate the background exposure problem for low exposure categories. This problem with the lowest exposure categories, as well as large uncertainties in exposure estimates for individual cases and the small number of cases involved, requires further investigation. In the interim, averaging over several exposure categories using an estimator that is expected to be relatively constant appears to be a reasonable procedure.

Table 2. Excess relative risk (in per cent) of radiogenic lung cancer in groups exposed to alpha particles, X-rays, gamma-rays and neutrons†

Exposed group	Type of radiation	Per cent increase in excess relative risk		
		per WLM	per rad	per rem
Uranium miners				
U.S. (white)	α	0.9		
U.S. (Indian)‡ WLM > 300	α	0.4		
U.S. (15 years after start), WLM < 500§	α	0.9		
Canada§	α	0.9		
Czechoslovakian¶	α	1.2		
Fluorspar miners	α	3.0		
Metal miners	α	0.5		
Swedish metal miners	α	3.2		
Thorotrast (Portuguese)	α		1.0	
Bomb survivors	γ		0.3	0.3
	n		1.0	0.2
Spondylitics	X-rays		0.2	0.2

†Data from BEIR report (BEIR72) unless indicated otherwise.
‡Data from Archer *et al.* (Ar76).
§From data tabulated by Archer, personal communication.
¶From Ševc *et al.* (Še76).

Excess risks tend to decrease at the highest exposure categories. These decreases tend to occur at high doses (perhaps 2500 rem or greater) and may reflect competing risks. Thus, in calculating risk estimates given in Table 2, data where excess relative risk of lung cancer was reduced at higher exposure levels have been omitted.

DOSE CONVERSION FACTORS

Excess relative risks of radiogenic lung cancer in 10 different population groups are given in Table 2. The data for miners are average risks, with reduced risks at higher exposures deleted as discussed above. In order to calculate rads per WLM, data for alpha particles other than radon daughter alpha particles were needed. The only such data available are for thorotrast patients, and risk estimates for these patients were given in the BEIR report (BEIR72). The percent increase in excess relative risk per rad for thorotrast patients is given in Table 2 and is about 1% per rad. The overall average risk to all the mining groups from exposure to radon daughters is calculated from entries in Table 2 as being about 1.4%/WLM. Thus, the dose in rads per WLM is

$$\frac{1.4\%/\text{WLM}}{1\%/\text{rad}} = 1.4\ \text{rad/WLM}.$$

This dose conversion factor is, of course, based upon one data point for the thorotrast patients and may be subject to large unquantifiable uncertainty. Its value based upon dosimetric calculations will be discussed below. Our primary interest, however, as discussed previously, is risk per rem since this factor should be the same for all types of ionizing radiation.

To determine risk per rem, data are needed for which QF, DF and other modifying factors are unity. The reference radiations are usually X- or γ-rays. Data for bomb survivors and spondylitics, also discussed in the BEIR report, are given in Table 2. The risk for these two groups average 0.25%/rem. Thus, the dose in rem per WLM is

$$\frac{1.4\%/\text{WLM}}{0.25\%/\text{rem}} \sim 5.6\ \text{rem/WLM} \sim 6\ \text{rem/WLM}.$$

Similarly, an average value for rem per rad may be obtained as

$$\frac{5.6\ \text{rem/WLM}}{1.4\ \text{rad/WLM}} \sim 4.$$

The rem per rad value, however, again depends on the single thorotrast data point since rad per WLM depends on it.

The average of 1.4%/WLM includes all the underground mining groups. If only the uranium mining groups are considered, then the average percent increase in excess relative risk per WLM is about 1%/WLM. The value for U.S. Indian miners (0.4%/WLM) may be low since there were no observed cases at exposures below about 300 WLM. Values for mining groups other than uranium miners are around 3%/WLM. The higher values may be real or due to uncertain exposure estimates or other factors. The data are not adequate at present to identify what factors might account for the higher risks. An important factor may be that none of the uranium mining groups has been followed for its lifespan. Risks may increase as the groups are followed longer. However, data are included in Table 2 for the Group A, Czechoslovakian miners and for U.S. uranium miners with fifteen or more years of mining experience. These groups should perhaps exhibit the highest risks since they are older and have been mining longer. But the excess relative risks calculated for these groups are not substantially different from the other uranium mining groups. One can still not rule out the possibility that risks will become higher as the groups are followed longer. The same types of considerations also apply for the other groups given in Table 2 so that the dose conversion factors, depending as they do on the ratios of risks in the different groups, may not change substantially as the groups are followed longer.

CALCULATION OF THE RAD PER WLM CONVERSION FACTOR

Given a WLM exposure, calculation of a corresponding rad dose can be attempted if enough is known about the exposure conditions, deposition in the respiratory tract, translocation within and out of the respiratory tract, and the properties of the exposed tissues. Several discussions of the calculation of dose to the respiratory tract are available (Wa177; Wa170; Har72; Ja73), and a detailed discussion will not be given here. A review by Walsh (Wa170) concluded that a detailed site-by-site (e.g. an area as small as a bifurcation) dose calculation was not possible, and such calculations are still not feasible with any degree of certainty. Walsh calculated the average dose to each region (Weibel model, 17 regions, We63) of the tracheobronchial tree and showed that the highest doses to particular regions were not much higher than the average dose to the entire tracheobronchial epithelium. The average dose to the bronchial epithelium was, coincidentally, 1.4 rad/WLM. However, the dose to the basal cells of the bronchial epithelium (thought to be the critical cells) located at variable depths below the surface of the bronchial epithelium was estimated to be less than 1 rad/WLM. Later calculations by Harley (Har72) and by Jacobi (Ja73) have tended to confirm that dose to the basal cells is less than 1 rad/WLM.

A calculated dose of less than 1 rad/WLM (say 0.5 rad/WLM), along with the data in Table 2, would indicate that the factor for rem per rad is about 12. Since risk per rem must be invariant by definition, such results indicate that the basal cells are more sensitive than the entire bronchial epithelium on a rad dose basis, as would be expected. Higher rad/WLM (say 5 rad/WLM) would lead to rem per rad factors less than unity (1) and, thus, the basal cells would appear to be less sensitive than the entire bronchial epithelium.

Such a result would clearly not be in accord with rem per rad conversion factors for alpha particles. This point can be stated another way: a dose of 1.4 rad/WLM to the bronchial epithelium will correspond to a dose of < 1 rad/WLM to the basal cells and will yield the same degree of biological response; thus, the risk per rem will be the same in both cases, which implies different rem per rad factors in the two cases. It is interesting to ask whether the ICRP models provide an adequate basis for dosimetric calculations. If calculations could be based on these models, then determination of the dose to a population exposed to radon daughters would be more easily accomplished.

The Task Group on Lung Dynamics (ICRP66) calculated the expected deposition in humans of particles of various aerodynamic diameters and of log-normally distributed aerosol distributions. The Task Group treated the tracheobronchial tree as a separate functional compartment extending from the trachea down to and including all ciliated bronchioles. Diffusional deposition, the primary mode of deposition for radon daughters, was calculated using the Gormley–Kennedy equations (Go49) for diffusional deposition in cylindrical tubes. The same equations have been used to calculate deposition of radon daughters (Wa170; Ja73; Har72). The calculations specific for radon daughters used the anatomical lung model of Weibel (We63), while the ICRP Task Group used the anatomical model of Findeisen (Fi35). The fractional deposition (of the amount inhaled) calculated by the ICRP model is about 0.08. Using this fractional deposition, the average dose to the tracheobronchial tree is about 0.9 rad/WLM. Such a conversion factor, along with the value of about 6 rem/WLM calculated from the data in Table 2, would imply a rem per rad factor of about 6. If the rem per rad factor of 10 recommended for alpha particles (ICRP63) is used, the dose in rem per WLM would be about 9 rem/WLM, a conservative value.

Dose calculations as exemplified by the ICRP model or by the more detailed calculations of Walsh (Wa170), Harley (Har72), or Jacobi (Ja73) tend to support dose conversion factors such as those derived from Table 2 based upon epidemiological studies.

ANIMAL TOXICOLOGICAL STUDIES

Recently, an *ad hoc* committee of the National Academy of Sciences (NAS76) reviewed animal studies related to radiation-induced lung cancer. In discussing an analysis of experimental animal data for induction of lung cancer by external irradiation and by internally deposited alpha and beta-gamma-emitters, they listed a wide range of values based upon large variability of the data. In summarizing they state:

> "While alpha irradiation was generally more effective than uniform irradiation and beta irradiation, for all dose levels and all animal species the mean differences were less than 10, the value usually taken as the quality factor for alpha irradiation."

Other groups have reached similar conclusions, as noted by Walsh (Wa176). Thus the rem per rad of about 4 derived from the data in Table 2 is not contradicted by experimental animal studies.

Another area of interest here is that the *ad hoc* committee adopted relative risk estimates as the appropriate ones to use for their purposes of assessing lung cancer risk from alpha emitters. They also note that the BEIR committee suggested that if the relative risk method is used, a value of 0.29%/rem should be adopted for the incremental relative risk per rem, which is equivalent to the excess relative risk per rem given in Table 2. (Values are given as percent increase in excess relative risk.)

CONCLUDING REMARKS

In the above discussion of dose conversion factors for radon daughters, we have purposefully looked for concordance in the available data. The numerous uncertainties in the data base were not adequately discussed. The *ad hoc* committee on hot particles and the BEIR committee and others have discussed uncertainties associated with assessing radiation-induced lung cancer risk at length. We will not attempt to give such discussion here. The range of values of risk estimates reflected in Tables 1 and 2 does however, give a qualitative impression of the joint effects of the many uncertainties. Which uncertainties had what effect in what direction on which estimators cannot be determined from the present data. The concordance in the data appears to be best expressed by excess relative risk estimators, and conversion factors based on them are supported by separate dose calculations and animal toxicological studies.

The preceding discussion indicates the following general conclusions:

(1) Epidemiological studies exhibiting an association between radiation and lung cancer tend to support a direct proportionality between excess cases (observed minus expected) and excess exposure or dose over the range of available data.

(2) If the direct proportionality noted in item (1) holds, then excess risk per unit dose and excess relative risk per unit dose would be relatively constant. Absolute, relative, and fractional relative risk per unit dose (using definitions given herein) would be inversely proportional to dose. The analysis given in Table 1 indicates that such expectations are borne out by data.

(3) Analysis of the data for only one or a few exposure categories may be complicated at low exposures by uncertainties in exposure estimates, study group size, and multiple causes of the expected cases and at high exposures for the same reasons and because different biological effects (e.g. cytotoxicity vs cancer) may become dominant.

(4) Averaging risk per unit dose (exposure) over several exposure or dose categories, excluding higher categories where risks may decrease and using risk estimators that are expected to be relatively constant, such as excess relative risk per unit exposure or dose, would tend to minimize the effects of such uncertainties as listed in item (3) above.

(5) Given a constant risk per rem, the rem per rad conversion will vary with the method of dose calculation and with the critical tissue to which the dose is calculated. For radon daughters a dose conversion factor of about 6 rem/WLM, and a risk per rem of about 0.25%/rem (per cent increase in excess relative risk per rem), is compatible with epidemiological data on radiogenic lung cancer. The epidemiological data also indicate an average of about 1.4 rad/WLM and a rem per rad of about 4.

(6) Independent dose calculations (e.g. Wa170) indicate that the average dose to the bronchial epithelium may range up to 1.4 rad/WLM and that the dose to basal cells is probably less than 1 rad/WLM. For 6 rem/WLM these numbers would result in rem per rad factors of 4 and 6, respectively, and 12 if the dose to basal cells is about 0.5 rad/WLM. Dose calculations using ICRP models (ICRP66) appear to be sufficiently conservative. The average dose to the tracheobronchial tree is about 1 rad/WLM.

(7) Animal toxicological studies tend to suggest rem per rad factors less than 10, and thus do not contradict the calculations based upon epidemiological studies.

REFERENCES

Ar76 Archer V. E., Gillam J. D. and Wagoner J. K., 1976, "Respiratory Disease Mortality Among Uranium Miners", *Ann. N.Y. Acad. Sci.* 271, 280.

BEIR72 *Biological Effects of Ionizing Radiation*, 1972, A report of an advisory committee from the Division of Medical Sciences, National Academy of Sciences—National Research Council.

EPA75 U.S. Environmental Protection Agency, 1975, "Preliminary Findings—Radon Daughter Levels in Structures Constructed on Reclaimed Florida Phosphate Lands", Office of Radiation Programs, Tech. Note ORP/CSD-75-4.

EPA76 U.S. Environmental Protection Agency, 1976, "Potential Radiological Impact of Airborne Releases and Direct Gamma Radiation to Individuals Living Near Inactive Uranium Mill Tailings Piles", Office of Radiation Programs, EPA-520/1-76-001.

Fi35 Findeisen W., 1935, "Uber das Absetzen Kleiner, in der Luft Suspendierten Teilchen in der Menschlichen Lunge bei der Atmung", *Arch. Ges. Physiol.* 236, 367.

FRC68 Federal Radiation Council, 1968, "Radiation Exposure of Uranium Miners", A report of an advisory committee from the Division of Medical Sciences, National Academy of Sciences, National Research Council.

Go49 Gormley P. G. and Kennedy M., 1949, "Diffusion from a Stream Flowing through a Cylindrical Tube", *Proc. R. Irish Acad.* A52, 163.

Gu77 Guimond R. J., 1978, "Radiological Aspects of Fertilizer Utilization", in: *Radioac-*

tivity in Consumer Products (Edited by Moghissi A. A., Paras P., Carter M. W. and Barker R. F.) NURE6/CP-0001 (Washington, DC: U.S. Nuclear Regulatory Commission).
Symp. Public Health Aspects of Radioactivity in Consumer Products (Edited by Moghissi).

Har72 Harley N. H. and Pasternak B. S., 1972, "Alpha Absorption Measurements Applied to Lung Dose Calculations from Radon Daughters", *Health Phys.* 23, 771.

Ho57 Holaday, D. A., Rushing, D., Coleman, R., Woolrich, P., Kusnetz, H., 1957, "Control of Radon and Daughters in Uranium Mines and Calculations on Biologic Effects", *Public Health Service Publication* 494, Washington, D.C.

ICRP59 International Commission on Radiological Protection, 1959, "Recommendations of the International Commiseion on Report of Committee II on Permissible Dose for Internal Radiation", *ICRP Publication* 2 (Oxford: Pergamon Press).

ICRP63 International Commission on Radiological Protection, 1963, "Report of the RBE Committee to the ICRP", *Health Phys.* 9, 357.

ICRP66 International Commission on Radiological Protection, 1966, "Report of the Task Group on Lung Dynamics to the ICRP", *Health Phys.* 12, 173.

Ja73 Jacobi W., 1973, "Relation Between Cumulative Exposure to Radon Daughters, Lung Dose and Lung Cancer", in: *Proc. Las Vegas Noble Gases Symp.* (Edited by Stanley R. E. and Moghissi A. A.) Las Vegas, Nevada, ERDA CONF 730915.

Lu71 Lundin F. E., Wagoner J. K. and Archer V. E., 1971, "Radon daughter exposure and respiratory cancer—quantitative and temporal aspects", NIOSH-NIEHS Joint Monograph No. 1 (Springfield, VA: NTIS).

Ne74 Nelson I. C. and Parker H. M., "A Further Appraisal of Dosimetry Related to Uranium Mining Health Hazards", HEW Publ. No. (NIOSH) 74–106 (Cincinnati, OH: Office of Technical Publications).

Pa69 Parker H. M., 1969, "The Dilemma of Lung Dosimetry", *Health Phys.* 16, 553.

Še76 Ševc J., Kunz E. and Placek V., 1976, "Lung Cancer in Uranium Miners and Long-Term Exposure to Radon Daughter Products", *Health Phys.* 30, 433.

Wa65 Wagoner J. K., Archer V. E., Lundin F. E., Holaday D. A. and Lloyd J. W., 1965, "Radiation as the Cause of Lung Cancer among Uranium Miners", *New England J. Med.* 273, 181.

Wa170 Walsh P. J., 1970, "Radiation Dose to the Respiratory Tract of Uranium Miners—A Review of the Literature", *Envr. Res.* 3, 14.

Wa176 Walsh P. J., 1976, "Dose to the Tracheobronchial Tree due to Inhalation of Radon Daughters", in: *Proc. 10th Midyear Topical Symp. of the Health Physics Society*, Saratoga Springs, New York, 11–13 October, pp. 192–203 (Troy, NY: Rensselaer Polytechnic Institute).

Wa177 Walsh P. J. and Hamrich, P. E., 1977, "Radioactive materials—Determinants of Dose to the Respiratory Tract", in: *Handbook of Physiology*, Section 9: Reactions to Environmental Agents, pp. 233–242 (Bethesda, ND: American Physiological Society).

We63 Weibel E. R., 1963, *Morphometry of the Human Lung* (New York: Academic Press).