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RADIATION STANDARDS INCLUDING FALLOUT, Part 1, 1962

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# RADIATION STANDARDS, INCLUDING FALLOUT

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## HEARINGS

BEFORE THE

SUBCOMMITTEE ON

RESEARCH, DEVELOPMENT, AND RADIATION

OF THE

JOINT COMMITTEE ON ATOMIC ENERGY

CONGRESS OF THE UNITED STATES

EIGHTY-SEVENTH CONGRESS

SECOND SESSION

ON

RADIATION STANDARDS, INCLUDING FALLOUT

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JUNE 4, 5, 6, AND 7, 1962

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**Part 1**

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Printed for the use of the Joint Committee on Atomic Energy



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WASHINGTON : 1962

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(Appendixes to these hearings will be found in part 2)

#### ABBREVIATIONS

AEC	Atomic Energy Commission.
ASA	American Standards Association.
DASA	Defense Atomic Support Agency.
FDA	Food and Drug Administration.
FRC	Federal Radiation Council.
HEW	Department of Health, Education, and Welfare.
ICRP	International Commission on Radiological Protection.
ICRU	International Commission on Radiological Units and Measurements.
JCAE	Joint Committee on Atomic Energy.
LASL	Los Alamos Scientific Laboratory.
NACOR	National Advisory Commission on Radiation.
NCRP	National Committee on Radiation Protection and Measurements.
PHS	U.S. Public Health Service.
RPG	Radiation Protection Guide.

## RADIATION STANDARDS, INCLUDING FALLOUT

MONDAY, JUNE 4, 1962

U.S. CONGRESS,  
SUBCOMMITTEE ON RESEARCH,  
DEVELOPMENT AND RADIATION,  
JOINT COMMITTEE ON ATOMIC ENERGY,  
*Washington, D.C.*

The subcommittee met pursuant to notice at 2 p.m. in room AE-1, the Capitol, Hon. Melvin Price (chairman of the subcommittee) presiding.

Present: Senators Anderson, Dworshak, and Aiken; Representatives Price (chairman), Holifield, Hosmer, and Bates.

Also present: James T. Ramey, executive director; John T. Conway, assistant director; David Toll, committee counsel; Kenneth S. McAlpine, Jack R. Newman and George F. Murphy, Jr., professional staff members; and Edward J. Bauser, technical adviser, Joint Committee on Atomic Energy.

Representative PRICE. The subcommittee will be in order.

The Subcommittee on Research, Development and Radiation begins hearings today on radiation standards, including fallout.

Our subject matter has, of course, great topical interest in light of the resumption of atmospheric nuclear tests, first by the Soviet Union and then by the United States. The purpose of these hearings is a serious consideration of radiation standards, including fallout, in order to obtain a better perspective on all aspects of radiation hazards. Only in this manner can this committee fulfill its obligation to the Congress and to the American people.

The Joint Committee, historically, has approached these problems from the standpoint of obtaining better scientific and public understanding of these complicated issues. In 1957 and 1959, the committee held exhaustive hearings on the subject of fallout. In 1959 we also considered the effects of nuclear war.

In 1960, our hearings centered on the problem of radiation standards. In each instance, records were compiled which are regarded as among the most authoritative collections of views and materials on this vital subject. I intend that our contribution this year will be in the same high tradition.

Our objective this year is threefold: First, we will update the information which was previously developed on fallout and radiation standards. Second, we will attempt to identify and clarify the policy problems and organizational responsibilities associated with the es-

establishment and administration of radiation standards. Finally, we will try to consider, in the most clear and simple terms, the risks involved in manmade radiation.

Among the specific items we will look into is the role and function of the Federal Radiation Council, a subject left open by our 1960 hearings. In addition, we will try to derive a better understanding of the responsibilities of other Federal and State organizations in this field. We will also examine the relationship between governmental agencies and private organizations such as the ICRP and the NCRP.

Fallout from nuclear testing will be discussed later today and more extensively tomorrow, June 5. We hope to determine the changes which have occurred since our 1959 hearings in regard to worldwide fallout, including current monitoring and surveillance activities in the United States and organizational responsibilities in this area.

We will also have the opportunity to review new findings in the field of genetics, revealed by a recent report of the Federal Radiation Council.

The general format of our hearings has been described in an outline distributed in advance of the hearings. I believe we have called upon some of the best scientists in this country to discuss this vital subject. It is my hope that through their statements, a better understanding will be brought about on a subject which has been plagued by confusion and misapprehension.

Our task is a considerable one and I ask that all witnesses keep their oral presentations within the allotted time. More detailed statements will, of course, be accepted for the record of the hearings.

I should also like to observe that the occasion of these hearings has brought a considerable "fallout" of reports from the executive branch. Thus, there is the report by the Federal Radiation Council, entitled "Health Implications of Fallout From Nuclear Weapons Testing Through 1961," which was released last Saturday, June 2. In fairness I should point out that the Chairman of the Federal Radiation Council, Secretary Ribicoff, offered to release this report at the beginning of these hearings, but Chairman Holifield and I believed it would be desirable to get the report to our witnesses and the public before our hearings started so that it could be discussed more intelligently.

We also have the printed version of the AEC seminars last fall, and we understand that the National Academy of Sciences also has a report coming out sometime this summer. As usual, we also understand that one report is being withheld—the report by the National Advisory Committee on Radiation, called the NACOR report, to the Surgeon General on surveillance and detection.

I am pleased to have as our first witness Dr. G. Hoyt Whipple of the University of Michigan. He will be followed by Dr. Lauriston Taylor of the National Bureau of Standards and Dr. Charles Dunham of the U.S. Atomic Energy Commission.

Dr. Whipple, will you commence your presentation.

**STATEMENT OF G. HOYT WHIPPLE,<sup>1</sup> PROFESSOR OF RADIOLOGICAL HEALTH, SCHOOL OF PUBLIC HEALTH, UNIVERSITY OF MICHIGAN**

Dr. WHIPPLE. Mr. Price, it is a pleasure for me to appear before you again in the role of a college professor. Of the many topics you will consider, the one assigned to me is perhaps the only one where opinion and subjective judgment play no part. In saying this I do not wish to give the impression that college people have no opinions, or do not indulge in subjective judgment; we are as competent in these regards as most, but my assignment precludes these liberties today.

In the belief that greater clarity will result, I have inverted the order of the subjects in the schedule for the proposed hearings. I shall speak first of the types of radiation, then of the units of measurement, and finally of the sources of human exposure.

Types of radiation and their definition: For the present purposes of this subcommittee only four types of ionizing radiation need be discussed: alpha particles, beta particles, gamma rays, and X-rays. The table included with this statement summarizes some of the characteristics of these radiations.

(The table referred to follows:)

*Characteristics of the principal types of radiations*

Characteristic	$\alpha$ particles	$\beta$ particles	$\gamma$ rays	X-rays
Sources.....	$\alpha$ -emitting radioactive isotopes, e.g. Pu <sup>239</sup> .	$\beta$ -emitting radioactive isotopes, e.g. Sr <sup>90</sup> .	Many $\beta$ -emitting radioactive isotopes, e.g. Co <sup>60</sup> .	X-ray machines.
Mass.....	4 a.m.u. <sup>1</sup>	1/1800 a.m.u. <sup>1</sup>	0	0.
Electrical charge.....	+2e <sup>2</sup>	-1e <sup>2</sup>	0	0.
Velocity (in miles per second).	4,300 (1 mev <sup>3</sup> )	175,000 (1 mev <sup>3</sup> )	186,000 (all energies).	186,000 (all energies).
Typical energies (in mev <sup>3</sup> ).	4 to 8	0.1 to 2	0.1 to 5	0.01 to 1.
Typical ranges:	5 mev:	1 mev:		
In air.....	1.4 inches	10.5 feet		
In tissue.....	0.0014 inch	0.16 inch		
Half-value layer: <sup>4</sup>			1 mev:	0.1 mev:
In tissue.....			4 inches	1.6 inches.
In lead.....			0.3 inch	0.004 inch.

<sup>1</sup> A.m.u. is atomic mass unit and equals  $1.7 \times 10^{-24}$  gram.

<sup>2</sup> e is the charge on the electron.

<sup>3</sup> Mev is million electron volts and equals  $1.6 \times 10^{-8}$  ergs.

<sup>4</sup> The half-value layer is that thickness which reduces the intensity of the radiation to half its initial value.

Dr. WHIPPLE. (a) Alpha particles: Alpha particles, as a result of their relatively large mass and of their double electric charge, lose energy rapidly in passing through matter and as a consequence go only very short distances. To illustrate: a 5-million electron volt alpha particle has a velocity of about 10,000 miles per second and is stopped completely by an inch or two of air, or by 1 or 2 mills of living

<sup>1</sup> Biographical data: Name: Whipple, G. Hoyt. Born: San Francisco, Calif., May 4, 1917.

Education: Public schools: Rochester, New York. College: 1. Wesleyan University, 1935-39, B.S. in chemistry; 2. Massachusetts Institute of Technology Graduate School, 1939-42, no degree; 3. University of Rochester Graduate School, 1950-53, Ph. D. in biophysics.

Experience: MIT Division of Industrial Cooperation: 1942-47. Loran, radar, food dehydration, aerial bomb fuses, etc., Government-sponsor research. General Electric Co., Hanford works, Richland, Wash.: 1947-50. Research and development on health physics problems and instruments. University of Rochester atomic energy project: 1950-57. Teaching in health physics and research in biophysics. The University of Michigan School of Public Health, Ann Arbor, Mich.: September 1957 to present. Teaching and research; professor of radiological health.

tissue before losing all its energy and coming to rest as an ordinary atom of helium.

These characteristics lead to the conclusion that any radioactive materials such as plutonium 239 and uranium 238 which emit only alpha particles are of no biological consequence as long as they remain outside the body. The inert outer surface of the skin, which protects us from many environmental agents, is thick enough to stop completely the most energetic alpha particles you will encounter in your present deliberations. Alpha particles emitted inside the body are another matter and appear to produce more biological injury per unit energy absorbed than do the other radiations. This is a matter we shall consider when the rem unit is discussed.

(b) Beta particles: Beta particles are simply high-speed electrons. They are familiar as the agent which traces the picture on the television tube. As a result of their relatively small mass and of their single charge, beta particles lose energy much less rapidly in passing through matter than do alpha particles and as a consequence have much greater ranges, as the table shows.

To illustrate: a 1-million electron volt beta particle has a velocity nearly that of light and is stopped completely by about 10 feet of air, or by about three-sixteenth inch of tissue before coming to rest as an ordinary electron.

These characteristics mean that beta particles with energies greater than about 0.1 million electron volts can penetrate the inert layer of the skin and can therefore reach living tissue even when the beta source is outside the body. Beta particles emitted by radioactive materials inside the body will, like alpha particles, deliver all their energy to living tissue.

(c) Gamma rays and X-rays: Except for the fact that  $\gamma$ -rays (gamma) are produced inside the atomic nucleus, with one or a few discrete energies, while X-rays are produced outside the nucleus usually with a broad spectrum of energies, these two radiations are much the same. Like visible light, they have no mass or charge and travel with the speed of light. Unlike alpha and beta particles, X- and  $\gamma$ -rays do not have definite ranges in matter. A thickness of material, known as the half-value layer, will reduce the intensity of  $\gamma$ -rays to half their initial value; two half-value layers will reduce the intensity to one-fourth of the initial intensity; three such thicknesses to one-eighth, and so forth. One can reduce the intensity to any value he wishes with sufficient shielding, but in principle can never reduce it to zero, reminiscent of Zeno's paradoxical arrow which never quite reaches the target.

Because of their high penetrating power, X- and  $\gamma$ -radiation of all but the lowest energies can reach living tissue even when the source is a considerable distance away.

### 3. UNITS OF MEASUREMENT

The units of measurement pertinent to your present deliberations are the curie, the roentgen, the rad, and the rem. I shall discuss each of these briefly.

(a) Curie: The curie is defined as that amount of any radioactive material in which nuclear disintegrations occur at the rate of 37 bil-

lion per second ( $3.7 \times 10^{10}$  disintegrations per second). Note that the curie tells nothing about the mass of material involved. To illustrate: 1 curie of uranium 238 weighs about 3 tons while 1 curie of strontium 90 weighs less than one-thousandth of an ounce.

A homely analogy may help to understand what the strength of a radioactive source in curies tells about the source. When a pan of popcorn has been heated and begins to pop fairly steadily, one could count the number of pops per second and thus determine the rate at which the kernels of corn are disintegrating. The rate of popping corresponds to the amount of radioactivity in curies, and does not alone tell anything about how many ounces of unpopped corn there may be in the pan at the moment.

Multiples of the curie are used for convenience, such as the millicurie, the microcurie, and so forth. Concentrations of radioactive materials in air, water, and other materials are expressed in such units as microcuries per milliliter and microcuries per gram.

Representative PRICE. Dr. Whipple, Mr. Ramey has a question he wants to ask.

Mr. RAMEY. Could you define a little further what a millicurie is and a microcurie?

Dr. WHIPPLE. A curie is 37 billion disintegrations per second, and a millicurie is one-thousandth of this.

Mr. RAMEY. That is what always got me mixed up because you would think that millicurie is a million and it is a thousand.

Dr. WHIPPLE. I think this is faithful to the original Greek that 1 milli means 1,000; micro means 1 million.

Mr. RAMEY. I didn't take Greek.

Dr. WHIPPLE. I didn't take Greek either.

Mr. RAMEY. Then what is a micro-micro curie?

Dr. WHIPPLE. A micro-microcurie would be a millionth of a millionth of a curie.

Mr. RAMEY. And we use that term quite a bit in our measurement units. So it is a very small amount of radiation we are talking about.

Dr. WHIPPLE. Exceedingly small.

Senator ANDERSON. You have me off on another subject. I wonder if the rate of the disintegrations of popcorn had anything to do with how much butter is in it.

Dr. WHIPPLE. I am afraid I have to stop my analogy on the popping.

(b) The roentgen: The oldest unit of radiation dose is the roentgen. It is defined in terms of the amount of ionization produced in a given volume of air by X or  $\gamma$  radiation. Strictly speaking the roentgen cannot be used to express the dose of  $\alpha$  or  $\beta$  particles. The full practical and theoretical implications of the roentgen are not easily grasped, at least by our graduate students, so I shall give only a simple description of what the roentgen tells us, knowing that if I misrepresent it in any serious way, Dr. Taylor will set you, me, and the record straight.

Here again a simple analogy will prove helpful. When a physician prescribes a dose of some drug, say 10 grains of aspirin, he specifies the dose to be taken by his patient. A fraction of the dose will be absorbed by the body and the remainder will be excreted. Only that fraction absorbed has any effect on the patient. The physician, know-

ing the fraction of the drug that will be absorbed, can specify the dose to be taken which will result in the amount in the body of the patient to produce the desired effect. You see that two kinds of doses are involved here: the dose received by the patient, and the dose actually absorbed by the patient. For convenience, the physician prescribes the dose to be received, although it is the dose absorbed that is important.

The situation with radiation is similar to that with drugs. One can and frequently does measure the radiation dose to which a person is exposed. The roentgen is such a unit of exposure dose. Here, as in my analogy, the interest is in the amount of the dose absorbed in the person's body. With sufficient knowledge of the radiation, one can calculate or estimate the absorbed dose of radiation in various tissues from the exposure dose.

(c) The rad: The rad is the unit in which absorbed doses of any kind of radiation are expressed. In most situations the exposure of a person to 1 roentgen of X or  $\gamma$  radiation produces an absorbed dose of about 1 rad.

(d) The rem: For reasons not clearly understood, smaller absorbed doses of some radiations, e.g.,  $\alpha$  particles are required to produce the same biological effect as a given absorbed dose of X-rays. In radiation protection as in pharmacology, the important thing is not the exposure dose, or even the absorbed dose, but the effect produced. This and the fact that different types of radiations appear to have quite different biological effectiveness have given rise to the unit of radiation dose, the rem, defined as that dose of any radiation which produces the same biological effect as 1 rad of X-rays.

Senator ANDERSON. When you mention the X-ray, could you express some of these in terms of an ordinary X-ray that a person would have when he had a lung picture made by an X-ray or something of that nature?

Could you tell us how many rems that would be?

Dr. WHIPPLE. I believe a representative figure for good practice in radiology is that a 14 by 17 chest X-ray involves an exposure to the patient of about five-tenths<sup>1</sup> of a rem. Since the roentgen is about equal to one rad, and the biological effectiveness of X-rays is the reference—in other words, relative to X-rays—then the exposure to the patient's chest will be about five-tenths of a rem.

Senator ANDERSON. Does that continue with each X-ray? Supposing the patient is having a chest X-ray once a month; is this repetitive?

Dr. WHIPPLE. Yes, certainly to a first approximation of our understanding. I am not sure whether you are going to get recovery from this. In other words, if you go the other direction and say instead of giving him one a month for 20 years I give him the same exposure all on the same day, then the biological effectiveness of a large dose in a short time is much greater than that from the same dose spread over months or years. Is that the point?

Senator ANDERSON. No. I went out to the Southwest for tuberculosis treatment and had an X-ray picture of my chest once a month for 5 years. People worry about what is going to happen when these tests are made in the Pacific area. Am I going to get more radiation from the high altitude test that is going to be made or that was made

<sup>1</sup> A better estimate for modern practice is five-hundredths (0.05) of a rem.

today or tomorrow or sometime than I got by my 5 years of X-rays? That is what I wanted to deduce. I guess each person figures the same way. They have various types of X-rays made. I am wondering relatively whether it is a whole lot worse to be exposed to the fallout radiation from a series of tests than it is to go in and have a chest X-ray made every month for 5 years. Is there any way we can measure the relative hazard?

Dr. WHIPPLE. Yes.

Senator ANDERSON. I won't ask you to do it now. Will you give it to us sometime?

Dr. WHIPPLE. I can answer in the case you have given.

One chest X-ray a month for 5 years, it would seem to me by all estimates that I have heard of, would involve a great deal more exposure than we anticipate from fallout. There is one slight difference that you must recognize, and that is the chest X-rays you speak of involve exposure only to the chest, if it is properly done, and very little to the rest of the body. Whereas, with fallout, some of that material concentrates in one organ or another but it involves more nearly the whole body than does a chest X-ray.

Senator ANDERSON. I appreciate that answer. I think it is helpful. All I am trying to find out for my own satisfaction is, since I got, say, 30 roentgens by this 5-year period, do I get enough in this next series of tests or in this series of tests so that I should go around with my head bowed down and worry about it, or can I continue to live as I have lived 45 years since my time in the hospital.

Dr. WHIPPLE. I am not, sir, a prophet and prophecies are involved. My confident prediction is that the dose you will receive in the next few years from the fallout will be a very small fraction of what you received in that 5 years of medical examination.

Senator ANDERSON. Since I left the University of Michigan to go out in that part of the world, I appreciate that answer.

Chairman HOLIFIELD. I would like to carry that down a little bit further. We talked about 5 years once a month. That is 60 exposures of, I believe, you said five-tenths of a roentgen each. That would be 30 roentgens exposure. What is the estimated increase in the background radiation due to testing annually?

Dr. WHIPPLE. I am sure you are going to have witnesses before you that are better qualified to estimate the future conditions of fallout.

Chairman HOLIFIELD. I am talking about the increase annually in background radiation caused by testing over normal radiation—the average increase—from tests held to date.

Dr. WHIPPLE. From tests held to date?

Chairman HOLIFIELD. Yes.

Dr. WHIPPLE. According to every estimate that I have seen and our own work the increase is a few percent of the present natural background. In other words, if you take as a national average, as I have in my statement, one-tenth of a rem per year from natural sources of radiation, most of the data taken on a nationwide basis that I know of indicate that there may be a few hundredths of a rem per year as result from fallout.

Chairman HOLIFIELD. In other words, it is generally conceded that normal background radiation to which most people are exposed would amount to about 7 roentgens in a 70-year lifetime, is that right?

Dr. WHIPPLE. That is right; yes, sir.

Chairman HOLIFIELD. Therefore, when we are talking about 30 roentgens from X-ray tests that Senator Anderson had, we are talking about an exposure in 5 years from chest X-rays which would be about four times or a little over four times as much as you would be exposed to normal background radiation over a period of 70 years.

Dr. WHIPPLE. With the difference that the chest X-rays do not involve the total body.

Chairman HOLIFIELD. That is true. But also with the additional difference that the chest X-rays are stronger and are more concentrated than the natural background radiation in point of power and in point of time.

Dr. WHIPPLE. That is correct.

Chairman HOLIFIELD. For absorption.

Dr. WHIPPLE. That is correct.

Chairman HOLIFIELD. And in point of regeneration of the normal regeneration of body tissue which may or may not be harmed.

Dr. WHIPPLE. I think we are—

Chairman HOLIFIELD. This goes to the point that you made, that a dose of radiation received in one jolt, you might say, is more damaging to the body than if it is received in portions over a number of years.

Dr. WHIPPLE. As a general statement this was true. Whether taking this half of a roentgen exposure that Mr. Anderson spoke of in 1 minute in a month or spread it uniformly over the month, I don't believe we have biological data to show that that rate change makes much difference. If it has a difference it is in the direction that I spoke of.

Representative PRICE. Proceed, Doctor.

Dr. WHIPPLE. I was speaking of the rem. It is not a precise unit like the kilogram or the rad because the biological response to a given absorbed dose or radiation, like the response to a given dose of some drug, varies with a number of factors, physical, chemical, and biological. Even though it is not precise, the rem is a practical necessity if one is to evaluate the significance of the total radiation exposure received by an individual when this exposure will in general consist of the several types of radiation described at the beginning of this statement.

#### 4. PRINCIPAL SOURCES OF EXPOSURE TO HUMAN POPULATIONS

Human populations are exposed to four principal radiation sources: naturally occurring sources, manmade environmental sources, occupational sources, and medical and dental sources. Each of these has quite different scientific, moral, and legal characteristics, as I shall attempt to show.

(a) Naturally occurring sources: The naturally occurring radiation sources to which humans are exposed consist of cosmic radiation from outer space and the radiations from natural radioactive materials, such as uranium, radium, and potassium 40, in soil, water, air, building materials, and in the human body itself. On the average, natural radiation exposure amounts to about 0.1 rem per year, although levels five times as great are not unknown.

One can reduce his exposure from natural sources somewhat by living in a tent along the seacoast rather than in a granite house in

the mountains, but he cannot eliminate it entirely. It is an interesting, but unanswered question whether man has evolved to his present state because of or in spite of natural radiation exposure. In any event, man has lived with this level of radiation exposure from the beginning of time and it is hard for me to see how standards or regulations can be applied to it.

(b) Manmade environmental sources: Among the manmade environmental sources are the various radioactive wastes released into the atmosphere, surface waters, and the ground by the nuclear industries and users of radioactive isotopes, the stray radiations from such installations, and fallout from nuclear detonations. All of these have been thoroughly discussed before this committee and the printed hearings which resulted probably constitute the most complete body of information available on these subjects. There are only a few points about these sources of radiation exposure which I should like to emphasize.

The first point is that, like the natural sources of radiation exposure, there is not much the individual can do about exposure from manmade environmental sources. He can move away from nuclear facilities and hospitals and he can move to the Southern Hemisphere to escape some fallout.

The second point is that the release of radioactive wastes and of stray radiation into the environment is in most instances strictly regulated by law, while fallout from nuclear detonations is, of course, unregulated in any legal sense. One wonders what the regulatory agencies would do if a nuclear plant were to produce levels of environmental radioactivity similar to those produced by nuclear detonations in the last 4 years.

The final point I wish to make is that the human exposure from manmade environmental sources is, by all estimates I know of, only a few percent of the exposure from natural sources. There are a few exceptions to this general statement, as in the case of the unfortunate fallout in the Marshall Islands, but the overall record is surprisingly good.

(c) Occupational sources: There are today many occupations which involve radiation exposure. The nuclear industries come first to mind, but radiography (medical, dental, and industrial) probably exposes more workers to more radiation than do the nuclear industries. When an individual accepts employment in one of the radiation industries, he knowingly accepts, as one of the conditions of this employment, radiation exposure in addition to that he receives from other sources. Unlike the exposure to natural and manmade environmental radiation, occupational radiation exposure is accepted knowingly and voluntarily.

Standards for occupational radiation exposure have been evolved and agreed upon by several national and international committees, including the International Commission on Radiological Protection and our own National Committee on Radiation Protection and Measurements. The present basic standard for occupational exposure is 5 rem per year. This recommended standard has been given the force of law in the regulations of the Atomic Energy Commission and in many State regulations. It is proper to note that only rarely does a radiation worker receive a dose of 5 rem in a year and that the average

annual exposure, at least in the nuclear industry, is considerably less than 5 rem.

From the standpoint of population genetics it is not the dose to the individual, but the total dose to the entire population before the end of the reproductive years that is important. On this basis, occupational radiation exposure contributes only a vanishingly small fraction to the total genetically significant exposure. The doses received by radiation workers may be as much as 10 times those received from environmental sources, but radiation workers constitute such a small fraction of the whole population that the effect on population genetics is very small indeed.

(d) Medical and dental sources: The radiation exposure received by patients undergoing medical and dental diagnosis and therapy is to be distinguished from that received by the physicians, nurses, and technicians who administer to the patients. The latter type of exposure is properly classed as occupational and has already been discussed. The exposure received by the patient is quite different, as I shall now show.

Medical and dental exposures seldom involve the whole body. They are almost always restricted to a small portion of the body, and in particular the reproductive organs are spared whenever possible. Like occupational exposure, medical and dental exposure is accepted knowingly and willingly by the person exposed to obtain information or effects necessary for good health. Considerable progress has been made in recent years in achieving these ends with smaller exposures to the patient. The standards recommended by the National Committee on Radiation Protection have played a large part in this progress.

Most estimates of the population exposure to medical and dental sources of radiation indicate that the average from these sources is about equal to that from natural sources. Thus medical and dental exposure is one of the two major contributors to the total population exposure.

Although I feel that good standards for the medical and dental application of radiation and radioactive isotopes should be established and encouraged as widely as possible, I cannot see how these applications can be made the subject of legal regulations in the way that occupational exposures are regulated.

This concludes my statement. I hope that it may prove of some value to you in the decisions you are called upon to make.

Representative PRICE. Thank you, Dr. Whipple.

Doctor, on page 8 you state that man can reduce his exposure from natural sources by living in a tent on a seacoast. How much would this reduce his normal exposure?

Dr. WHIPPLE. I suppose it might reduce it 10, 20 percent, perhaps to as low as three-quarters of what I have given as the national average. The fellow living in the granite house on the mountains may have five times the national average.

Representative PRICE. You also state on that page that there is not much the individual can do about exposure from manmade environmental sources. What should the individual do, instead of moving way, as a practical view?

Dr. WHIPPLE. In the practical view, in my view of the practical matter, I can see no reason for trying to influence it.

Representative PRICE. Doctor, there is not much you can do about it?

Dr. WHIPPLE. I don't think it is important enough to do anything about it.

Representative PRICE. On page 9, in your comparison between fallout and nuclear plants, are you implying that fallout exceeds the limits set by regulations on nuclear plants?

Dr. WHIPPLE. No; I am not implying that. To my knowledge, in the strict legal sense of the term, I can think of no case where this has been true. My point in mentioning this is that the nuclear plant levels have actually been so very low that I think that we would be quite excited if we found that levels from such a plant were approaching levels we have seen from fallout.

Representative PRICE. What industries were you specifically referring to when you stated that the individual accepts knowingly and willingly radiation hazards when he goes to work?

Dr. WHIPPLE. Work in atomic energy plants, work in radiation clinics, isotope clinics; is this what you mean?

Representative PRICE. Yes. Is there anything outside of your Atomic Energy Commission facilities or other private industries where he is exposed to these radiation hazards?

Dr. WHIPPLE. Yes; there are many.

Representative PRICE. What were you thinking about. Were you thinking of private industry, also?

Dr. WHIPPLE. Yes; I was thinking first of the medical and dental practice of radiology, the physicians and nurses and so forth. These are radiation occupations. The industrial radiographers, the people who take pictures of welds and castings. The industries that work with radioactive isotopes, for example, in the preparation of self-luminous sources such as radium dials, wristwatches, industrial gages, beta gages, thickness, and level gages. There is quite a list of radiation industries outside of the Atomic Energy Commission.

Representative PRICE. In your colloquy, I think with both Senator Anderson and Mr. Holifield, at least partially, you have answered my next question, but I would like to reask it.

On page 11 you state that medical and dental exposure is one of the two major contributors to the total population exposure. How does this amount compare to what we receive from fallout on the average?

Dr. WHIPPLE. The round numbers, and I am sorry I cannot quote an exact source—perhaps Dr. Taylor can remember where I am getting these numbers—is a tenth of a rem from natural sources. The estimate, and you can realize it is only an estimate, to the total population from medical and dental practice, another tenth of a rem per year; and something like three-thousandths of a rem per year from fallout during the last few years per year.

Representative PRICE. Mr. Holifield.

Chairman HOLIFIELD. No questions.

Representative PRICE. Mr. Hosmer?

Representative HOSMER. No questions.

Senator ANDERSON. I like the statement very much.

Representative PRICE. Mr. Bates?

Representative BATES. No questions.

Representative PRICE. Senator Aiken?

Senator AIKEN. I have one question.

A few years ago our attention was called to certain Indian groups that had been living on certain coastal areas, I think on the monazite sands, for centuries, constantly exposed to something like 20 times what was considered to be the normal safe exposure to radiation. At that time we were told that there would be a study made of this situation. Has there been any study made and what was found as a reason for these people living for generations under what would normally—or what was then called unsafe conditions? Somebody must have made a study of that.

Representative PRICE. I think Dr. Dunham is in the audience. I think they had something to do with this matter at one time.

Could you reply to that question?

Dr. DUNHAM. I will attempt to. Two things have happened. One, the Indian Government has made a study of the actual exposures to the population living there. There was a meeting held by WHO to discuss this particular problem, particularly from the standpoint of possible genetic effects, pointing out the problems involved in making the study. You have a finite population. It is in an area which is not highly developed though it is near a first-rate medical school.

I do not think, to answer the question specifically, that the study has been made at the present time.

Senator AIKEN. But the situation still remains?

Dr. DUNHAM. Still remains.

Senator AIKEN. The results of the study would be interesting, it seems to me.

Dr. DUNHAM. Yes; I would like very much to see this study done.

Chairman HOLIFIELD. Mr. Chairman, I would like to clear up one point with Dr. Dunham. The people that live on the monazite sands, their exposure was a certain number of times greater or a certain number of degrees greater than the normal exposure of people throughout the world. But it had nothing to do with safe or unsafe. Senator Aiken used the words "20 times the safe amount." I think that the words "the normal amount of background radiation" should have been used.

Dr. DUNHAM. That is correct.

Chairman HOLIFIELD. I am not saying that the exposure from the monazite sands was safe or unsafe, but the comparison was as against normal exposure from an average normal background radiation throughout the world.

Dr. DUNHAM. That is right.

Senator ANDERSON. Could you tell us why nobody followed up the study. It was said that it was going to be done 3 years ago.

Dr. DUNHAM. I hear rumors from time to time that it may get accomplished. There are problems.

Chairman HOLIFIELD. Who is going to do it?

Dr. DUNHAM. It is a little of both involved. I think many people would like to see it done. It is not an easy situation in that particular province.

Senator AIKEN. I think a better question than "Who is going to do it?" is "Who is keeping it from being done?"

Dr. DUNHAM. I think Dr. Hasterlick, who will testify tomorrow or the next day, has visited there and he can give you a better feel of some of the problems.

Senator ANDERSON. Would this not be an important point to clear up?

Dr. DUNHAM. I think so.

Senator ANDERSON. If it is 20 times what might be regarded as normal exposures, would not that tell us something about the dangers from fallout?

Dr. DUNHAM. I think it would be very helpful.

Senator ANDERSON. Then why cannot we do it?

Representative PRICE. I think maybe that is a question we can put to the Commission in some official form.

Senator ANDERSON. Dr. Dunham is here. Is there somebody in the Commission that does not want it done?

Dr. DUNHAM. No; there is no one in the Atomic Energy Commission that doesn't want it done.

Senator ANDERSON. It seems to me if we can spend \$5 million every other day on one of the explosions that comes to nothing, you might spend a few thousand dollars in finding out something that people are interested in.

Dr. DUNHAM. I agree.

Representative PRICE. We will take this up with the Commission.

Thank you very much, Mr. Whipple. The committee appreciates having your testimony.

(Letter from AEC concerning monazite sands region follows:)

U.S. ATOMIC ENERGY COMMISSION,  
Washington, D.C., June 28, 1962.

HON. MELVIN PRICE,  
*Chairman, Subcommittee on Research, Development, and Radiation, Joint Committee on Atomic Energy, Congress of the United States.*

DEAR MR. PRICE: During discussion before your subcommittee on June 4, questions were raised concerning the role of the Commission in investigating the populations living on the thorium-bearing monazite sands of Kerala in southwest India.

As stated in the testimony, the United States has frequently called attention to the potential value of studying these populations. The sands have been used as a source of thorium for many years, and their significance radiobiologically was noted at the 1955 Atoms for Peace Conference. Dr. Shields Warren of the U.S. delegation to the U.N. Scientific Committee on the Effects of Atomic Radiation, offered the Indian delegation every assistance on behalf of the U.S. Atomic Energy Commission as early as 1957. There was additional recognition of the importance of studying these populations during the 1958 Atoms for Peace Conference, and at the twice-yearly meetings of the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR); also, the World Health Organization convened a special conference on "Investigation of Areas of High Natural Radiation" (1959), but the impetus from it was small. The latest report of UNSCEAR, which will be published in September, will have only a few additional data on the Karala area. There are always many difficult practical problems involved in the scientific study of such populations. The Indian Government is, of course, in the best position to evaluate these factors as they relate to the Karala region.

If we can provide additional information, please let me know.

Sincerely yours,

A. R. LUEDECKE, *General Manager.*

Representative PRICE. The next witness will be Dr. Lauriston Taylor, Chief of the Radiation Division, National Bureau of Standards.

Dr. Taylor, the committee is happy to have you back again. You may proceed with your presentation.

**STATEMENT OF LAURISTON S. TAYLOR,<sup>1</sup> RADIATION PHYSICS DIVISION, NATIONAL BUREAU OF STANDARDS**

Dr. TAYLOR. Mr. Price, I appreciate the privilege of meeting again with your committee. I am going to deal in my discussion with two of the three items listed in the outline, namely, the purpose of standards and some of their biological effects and their meaning to laymen. I would like to delay until further in the hearing discussion of the groups that are dealing with these questions, if this is agreeable with you.

Representative PRICE. That will be all right.

Dr. TAYLOR. Standards in the area of radiation protection, as in many other areas of hygiene, have as a principal purpose the formulations, first, of a philosophy—and then rules—designed to eliminate or minimize the chance of injury by radiation. Prevention of injury to man himself—or to his descendants—appears to be the most pressing problem, and indeed it is the problem that is of most immediate concern to the public. But while I do not wish to dwell on the subject, injury to lower forms of animal life and damage to our ecology are two elements that must not be overlooked. While probably occurring only under conditions of heavy and widespread radioactive contamination of our environment, the indirect long-range effects on man could be serious and the possibility of such occurrence should not be completely overlooked.

The fact that radiation protection standards could not be neat, clean-cut niceties was brought out in the 1959 fallout hearings but only received detailed attention in the 1960 hearings. At least your committee—if not the general public—now has an appreciation of this aspect of radiation protection. The part played by social and economic factors is recognized though little understood in any quantitative sense even by the various groups of specialists who have spent many years or even lifetimes studying radiation hazard problems.

Since 1960 the matter of the social impact of radioactive exposure has been one of the principal preoccupations of most protection groups and I add, one with which we have not really been able to come to grips. I will expand on this later.

Let me turn to the question of new advances in the field of radiation protection. When one realizes that radiation protection groups have struggled with their problems for some 35 years without finding any clear-cut answers, it should not be surprising that they cannot report now any startling new basic information that will materially

<sup>1</sup> Biographical material: Lauriston S. Taylor, National Bureau of Standards: Has been a member of the National Bureau of Standards since 1927, with the exception of a 3-year period during World War II, when he was in charge of Operations Research for the 9th Air Force in Europe and for a 1-year period in 1958 when he was Chief of the Biophysics Branch of the Atomic Energy Commission. Presently Chief, Radiation Physics Division, at NBS; Chairman, International Commission on Radiological Units and Measurements; member, International Commission on Radiological Protection; Chairman, National Committee on Radiation Protection and Measurements; Chairman, National Academy of Sciences Advisory Committee on Civil Defense; member, U.S. Public Health Service National Advisory Committee on Radiation.

alter the situation of the past few years. This is true in spite of the fact that the level of research effort in this area has been steadily increasing over the past decade.

Some operational improvements have been introduced, some few numbers have been changed and some improvements have been made that recognize the past apparent confusion in the relationships between occupational and nonoccupational exposure to radiation.

I say apparent confusion, because I do not believe that the major protection bodies have ever really failed to recognize the differences between these two major groups of exposed persons. However, it has been evident that they failed to give proper emphasis to these distinctions in their public writings. This omission is being rectified, we hope.

Part of the reason for the slowness of distinguishing between population and radiation worker groups lies in the fact that it has only been in the past few years that the entire population has had to face the possibility of widespread radiation exposure, as for example from fallout. While not devastating, or even serious, in its potential harm at present levels, it cannot be regarded as unimportant, since it does not carry with it the direct benefits of say, medical X-rays.

I will mention briefly a few of the factors that have been developed in the past 2 or 3 years—the list is not intended to be complete as I am sure that others will bring out additional points. The Federal Radiation Council has introduced a new term to lend emphasis to the long-recognized fact that radiation protection standards cannot be specified rigidly as “go, no go” limits above which there is risk and below which there is no risk. They use the term “radiation protection guide” in place of “maximum permissible dose.” They also emphasize the fluidity of our knowledge by expressing their guides in ranges of values. The upper value of the middle range corresponds to the MPD as recommended for some years by the NCRP. This is an innovation mainly in directing attention to the nonrigidity of our standards, but for practical purposes control agencies will still have to adhere to the general MPD concept.

The terms such as MPD, guides, etc., were discussed at length in the ICRP meetings held in Stockholm last month. They have agreed to continue the use of the term “MPD” for occupational exposure but will avoid its use in reference to nonoccupational exposure. No agreement was reached on a suitable term for use in reference to population exposure. They also preferred not to use the “exposure range” concept, feeling that it was too easily open to misinterpretation. The terminology in this area has been under discussion for 30 years. If you have a will to misinterpret, you can do so with virtually any term that you can invent.

The problem of additivity of radiation dose and effects has been a matter of concern for many years. How do you add the effect of risk of an X-ray and neutron exposure to a given organ if the absorbed dose for each is known? How, even, do you define and add the doses? This has been accomplished by modifying the physical dose measurement by a biological factor known as the “relative biological effectiveness” or RBE. At best, this has been a shaky procedure.

Attention was focused on the problem 5 or 6 years ago at which time the NCRP established a new committee to study it. More recently the ICRP has set up a similar committee and in fact the two

have cooperated closely. The overall problem is extraordinarily complex and neither group has reached any definite conclusions. I will be surprised if they do within the next few years, but I think it is safe to predict that some new and important concept will result from their studies.

The ICRU which met in Switzerland last spring was asked to define the RBE dose concept in consonance with the other physical definitions of radiation quantities and units. Its tentative recommendation embodying absorbed dose, a risk concept and judgment factors was not accepted by the ICRP as such, although the general principles were. In the meantime we will continue to use the present "RBE dose" concept.

The problem of dose additivity becomes even more complicated when you attempt to combine as a single risk factors a dose to, say, the thyroid from I-131 and a dose to the hands from an external source, say, X-rays. The NCRP is considering a radically new approach to the problems but it is too soon to say whether the end product will be useful.

Additivity of doses is of principal importance to radiation workers in the atomic energy field. Under present conditions it is mainly of academic interest with regard to population exposure, since these doses are so very low in the first place.

In spite of the generally low exposure of the general population, efforts continue to either hold the line or reduce it further. Exposure of children has long been recognized as a limiting benchmark in dealing with population groups and the FRC has recently specified this clearly in its Report No. 2.

The possibility of undesirable radiation exposure of students and staff in schools in the course of either experiments or demonstrations, has been recognized. Early this year the NCRP established a subcommittee jointly with the American Association of Physics Teachers and the PHS to study the problem. At its May meeting the ICRP also decided to study the question. An initial survey has indicated that while the problem does not appear to be critical in the United States at present, it might in the future. We will try to forestall the possibility without introducing unnecessary restrictions in the instructional uses of radiation sources.

The matter of relatively large accidental exposures of radiation workers is still a matter of concern, more from the administrative than the biomedical point of view unless the overexposures are very large. At present any exposures beyond the prescribed MPD tend to be viewed with administrative alarm in spite of the fact that the effects of say 25 rems are essentially undetectable in the individual. Nevertheless, accidents will occur with the worker possibly penalized as to his future work potential. Both the NCRP and ICRP are actively studying this problem.

Exposure of the population to very large doses of radiation, such as may be expected in the event of a nuclear attack or a major nuclear disaster, presents an entirely different order of problem. This has been under study by the NCRP for some 7 years and a report on the subject was issued a few months ago. Some of the recommendations regarding disaster decisions sound very harsh, as indeed they are. On the other hand, they are based on the philosophy that

you must save lives first and worry about long-range consequences afterward. For if you do not save lives, the question of long-range consequences becomes merely academic.

There are many other detailed facets under study by the NCRP and ICRP, but I want to emphasize that they are mainly detail. During the past 2 years no new information of a nature such as to importantly influence our present protection philosophies or practice has been developed. The initial work of the Russels, and now others, indicates the existence of a dose-rate influence on certain genetic effects but the magnitude of the effect, while of great academic importance, is not such as to warrant any relaxation of present standards. The somatic effects of low-dose and low-dose-rate exposure is still the major uncertainty in the establishment of radiations protection standards for the population.

Let me emphasize two of the most important bases upon which our whole radiation protection philosophy is founded: First, all radiation exposure of persons should be as low as possible commensurate with our medical, social, and economic need; and, second, any risk incurred as a result of radiation exposure is proportional to the dose and there is no threshold below which risk vanishes. This latter is an unproven assumption but is thought to operate in the conservative direction.

In attempting to place radiation protection standards in proper perspective it is important to break down the source of radiation exposure into several categories. The choice will depend upon the end purpose.

Dr. Whipple has discussed this and if you will bear with me I would like to go back over some of his ground from a slightly different angle.

The following is one possible breakdown:

(1) Natural radiation: Man has lived with it and must continue to live with it—there is nothing we can do about it. It amounts to roughly 125 millirems per year.

(2) Medical irradiation: This represents probably the most clear-cut example of a radiation use where the benefit far outweighs the risk. Improvements in technique and procedure can and are being made so that unnecessary exposure is being curtailed. In spite of the reasonable expectancy that medical uses of radiation will expand, it is probable that the average per capita dose will be further reduced. The 1956 estimates of the average level of medical exposure in the United States were such that it was thought to contribute some 150 millirems per year or 120 percent of natural background average per capita dose. Better evaluations made possible since 1956 indicate that a more likely figure would be in the range of 10 to 50 percent of background or possibly less.

Chairman HOLIFIELD. You are speaking about medical exposure there; are you?

Dr. TAYLOR. Yes, sir; this is exposure to the patients.

Chairman HOLIFIELD. In other words, what you are stating is that the average medical exposure is from 10 to 50 percent of the normal background exposure?

Dr. TAYLOR. That is correct, sir. The calculation of the percentages are mine.

Senator ANDERSON. And the previous concept was that it was one and a fifth times the background?

Dr. TAYLOR. That is right.

Mr. RAMEY. Do you have some newer studies that you can cite?

Dr. TAYLOR. These figures, which probably should not be regarded as official at this point, come from studies made for the U.N. Scientific Committee on the Effects of Atomic Radiation and are considered to be quite reliable.

Representative PRICE. Have we made any evaluation of our own since 1956?

Dr. TAYLOR. This has been done in a few isolated cases and those results, I believe, have been fed into the U.N. studies.

Representative HOSMER. Can you differentiate between the medical exposures of populations in advanced countries such as the United States as contrasted to such countries as Communist China where the radiation equipment is few and far between.

Dr. TAYLOR. I don't know a thing about Communist China or of many other countries.

Representative HOSMER. What is the 10- to 50-percent figure then? The whole population of the world or that of an advanced country or what?

Dr. TAYLOR. Those are estimates made by a number of different countries including some estimates made in this country.

Senator ANDERSON. It just brings out what Mr. Hosmer was saying. Are these based on the figures of the United States or are they United Nations figures which take into consideration the fact that there is very little X-ray equipment in many countries of the world? I saw some United Nations figures on the extension of life that do not check with the figures of this country, England, Norway, or Denmark. Is this based on how much there is in certain south African or middle African countries all lumped together? Is that why you changed the figures?

Dr. TAYLOR. No, indeed. This is on the basis of a better analysis of the information that is available. These studies have come from countries like Sweden, Denmark, Germany, England, France. I am not sure of all the countries. There may be some others; including the United States and some information from the Soviet Union, I believe.

Representative PRICE. Doctor, the other background figures we were talking about previously before your evaluation since 1956, what were they? Were they world figures or U.S. figures?

Dr. TAYLOR. Those were U.S. figures. At that time the figures for the United Kingdom were considerably less than the estimate made for the United States. In fact, they were down somewhere near the bottom of this range I mentioned.

Representative PRICE. Do you have pre-1956 figures for other nations that you could supply for the record?

Dr. TAYLOR. I don't believe that I know of any. There may be some, but I don't know about them.

Mr. RAMEY. We probably have some in our previous hearing record. As I recall, we had some.

Dr. TAYLOR. The only study that I know of in the 1956 period was Laughlin-Pullman study in this country and the British Medical Research Council study in the United Kingdom.

Representative HOSMER. Doctor, some time ago a witness from the AMA appeared before us and after some very severe cross-examina-

tion admitted that approximately 90 percent of the medical and dental X-ray equipment was in disrepair; as a consequence, spreading more radiation than was calculated. Is this figure based on the theoretical performance of machinery in good condition or the actual performance in bad condition?

Dr. TAYLOR. I can't answer that. I know that at least in a few cases the information that were supplied was what you might call across-the-board equipment. I am sure that you will find isolated cases where the equipment is not as good as it should be. On the other hand, with the great bulk of the equipment in the United States which has rather rapid obsolescence, we have quite good built-in inherent protection.

The use of radiation equipment by the medical profession is something else again. This is something that is very hard to get at. I am sure that you will find cases where radiation exposure is delivered unnecessarily. I don't think that you can put a high degree of reliance on these figures but I doubt you will find they are out by a factor of more than two, and that is not very important.

Representative HOSMER. The figures range from 10 to 50 percent of background; you have a lot of leeway.

Dr. TAYLOR. That varies between countries. This is about the degree of uncertainty, as a matter of fact, in making the estimates. On the other hand, there is a fair certainty that it is somewhere in the neighborhood of 50 percent of background or less now as compared with the estimates a few years ago of 120 percent of background.

Representative HOSMER. Is this an improvement in the estimates or an improvement in the techniques and equipment?

Dr. TAYLOR. I would say mainly an improvement in the estimates because I don't think there have been enormous changes in equipment in that length of time.

Representative HOSMER. You just testified that there has been magnificent improvement.

Representative PRICE. We will have testimony later on in the hearing on the equipment from Dr. Richard Chamberlain. I think he will cover the equipment.

Representative HOSMER. I am trying to substantiate this figure, Mr. Chairman, which appears to be pretty much of a "guesstimate" rather than a real estimate.

Senator ANDERSON. Could I ask one question there?

I want to follow exactly what Mr. Hosmer has been asking, whether it is an estimate or a "guesstimate." You are with the National Bureau of Standards. You said these were U.N. figures.

How much did you check into the U.N. figures? Did you take them just as they came?

Dr. TAYLOR. The Bureau of Standards is not involved in this.

Senator ANDERSON. Who is involved in it?

Dr. TAYLOR. The International Commission on Radiological Protection has studied this and we have done some verification in the ICRU.

Senator ANDERSON. They met at Stockholm?

Dr. TAYLOR. Yes.

Senator ANDERSON. Did they accept these figures?

Dr. TAYLOR. These figures were not discussed then.

Senator ANDERSON. This is not an ICRP figure, either?

Dr. TAYLOR. At the request of the United Nations Committee the ICRP and the ICRU have carried out two special studies dealing with the question of medical exposure of patients.

Senator ANDERSON. What is the ICRU?

Dr. TAYLOR. That is the International Commission on Radiological Units. They have put out two published reports on the subject of medical exposures.

Senator ANDERSON. Do these figures come from those two published reports?

Dr. TAYLOR. Not the final figures but the methodology and some of the tentative figures.

Senator ANDERSON. Where do the figures come from?

Dr. TAYLOR. I was not able to attend the U.N. meetings.

Senator ANDERSON. This is your paper, Doctor?

Dr. TAYLOR. Yes. I have their written material. I was not able to attend their meetings.

Senator ANDERSON. Where did you get the figures?

Dr. TAYLOR. From their written material.

Representative PRICE. Specifically what organization?

Dr. TAYLOR. From the ICRP and the ICRU reports prepared for the United Nations Scientific Committee on the Effects of Atomic Radiation.

Representative HOSMER. But you did not independently evaluate the data and assumptions upon which the conclusions were made?

Dr. TAYLOR. That is correct.

Representative HOSMER. So that you cannot certify to this 10 to 50 percent figure?

Dr. TAYLOR. No, sir; I cannot. I am quoting figures prepared for UNSCEAR by the ICRP and the ICRU.

Senator ANDERSON. Can you tell us whether the U.N. figure of 120 is based on the United States only?

Dr. TAYLOR. Yes, it was. It was based on the 1956 Laughlin-Pullman figure for the United States.

Senator ANDERSON. Can you tell us whether the figure of 10 to 50 is based on the United States only?

Dr. TAYLOR. No, sir. That included other countries.

Senator ANDERSON. Therefore, the two things are not comparable at all, are they? Are they oranges and apples?

Dr. TAYLOR. The U.S. figure is included in that 10 to 50 figure.

Senator ANDERSON. I understand. But if I ask you the population of the United States, you say it is 180 million and I say no, it is 4 billion because that is the population of the world and the U.S. population is included in it, it would be a little misleading.

Dr. TAYLOR. No, sir. The figures give the average per capita dose. This is the total dose delivered to all the people, divided by the number of people so that the size of population does not enter.

Senator ANDERSON. Is it safe to assume that you don't know which countries are involved in this 10 to 50 percent figure?

Dr. TAYLOR. I can find out. I gave you the names of some.

Senator ANDERSON. But there might be others. The United Nations covers a great many countries. The last vote was 2,375 to 1,280 or something like that. I forgot how it came out. It was more countries than I knew existed. Are all these countries in here?

Dr. TAYLOR. I believe I am correct, Senator, in saying that this comes primarily from about 12 of the more advanced countries.

Senator ANDERSON. You say a factor of 2. Am I right that in a factor of 2 if a 100 is a base it could go from 200 percent down to 50 percent? Is that not a factor of 2?

Dr. TAYLOR. That is a factor of 2 up or down.

Senator ANDERSON. This is a factor somewhat in that neighborhood. But they are widely different. I am trying to find out where they actually come from so we know how much reliance to place upon them.

Dr. TAYLOR. The studies that have been made in England, for example, are rather highly sophisticated because their radiation use is under fairly tight governmental control. This is covered in a report published by their Medical Research Council.

Senator ANDERSON. I do not wish to get on an unpleasant subject but they have so-called socialized medicine so there is no financial incentive to use the X-ray. Is that right?

I am just trying to find out. That is the point of these figures. They jump all over the landscape.

Dr. TAYLOR. I had better not try to answer that question.

Senator ANDERSON. Let me get back to the first question you gave out. The material you said came from the U.N. Scientific what?

Dr. TAYLOR. The material was prepared for the Scientific Committee on the Effects of Atomic Radiation.

Senator ANDERSON. Has that been published?

Dr. TAYLOR. The ICRP and ICRU reports have been published. The U.N. report is being prepared for publication now.

Senator ANDERSON. You got an advanced copy of it?

Dr. TAYLOR. No, sir. I have received some working papers from them in another capacity.

Senator ANDERSON. When was that finished, do you know?

Dr. TAYLOR. No, sir—Dr. Tompkins indicates July.

Senator ANDERSON. Of last year?

Dr. TAYLOR. Of this year.

Senator ANDERSON. It has been finished last July of this year?

Dr. TAYLOR. No; it is expected to be finished in this July.

Senator ANDERSON. It is not finished yet?

Dr. TAYLOR. No, sir.

Senator ANDERSON. So we may have to revise these some more. All the precincts are not in yet as they found out in Texas the other day.

Dr. TAYLOR. I think this is primarily a matter of editorial work, Senator.

I believe that the numbers have not been materially changed since they were first presented a year or two ago.

Senator ANDERSON. You recognize that this is a subject in which a great many people are tremendously interested?

Dr. TAYLOR. Yes.

Senator ANDERSON. I personally felt that the danger of radiation from medical practice is very slight. It is generally well controlled and kept in reasonably good shape. But there is a lot that is not. I am curious where they get these figures because I would think if the 120 percent figure comes from experience within the United States alone, you have a quite different story when you start broadening it to other

fields and we have to know exactly which countries you covered and how much weight is given to medical experience in those countries.

Dr. TAYLOR. The figures from different countries are not averaged in here.

Senator ANDERSON. If they did not, how do they get a figure of 10 to 50 percent? You would have to admit this is indefinite.

Dr. TAYLOR. This might mean in one country 10 percent as the result of their studies and another country 15½ percent, another country 30 percent, another country 50 and another 40.

Senator ANDERSON. They say it runs from 10 to 50 percent because one is 10 and one is 50?

Dr. TAYLOR. This represents spreads between five countries. You can not average the countries. There is no meaning to that. As you pointed out, you cannot add oranges and apples. The real point of this, as compared to our estimates in 1956, is that the evidence is now such that the medical exposure appears to be much less than it was considered to be 6 years ago.

Senator ANDERSON. We would say that these figures are not what we like to call scientifically correct.

Dr. TAYLOR. They are probably scientifically as good as you can make them at the present time. I don't think you can regard them as correct or incorrect.

Representative HOSMER. Would you say that the change downward is largely due to the abandonment of the widescale use of chest X-rays?

Dr. TAYLOR. I am not in position to answer that, Mr. Hosmer. I think part of the reason for these figures is that we have had time to develop better techniques of study. I think that if we had studied the 1956 situation by present techniques, the value reported then probably would not have been as high as indicated.

Representative HOSMER. I do not see how you can consistently support these figures having admitted that you made no investigation as to how they came about.

Dr. TAYLOR. These figures I am quoting are figures which I believe are reliable. It has been a very reliable committee. Groups that I have worked with have contributed to the methodology that has been used. Therefore I have confidence in the figures even though I had no personal part in obtaining them.

Representative PRICE. Senator Aiken.

Senator AIKEN. I was wondering, Dr. Taylor, to what extent is the dose of natural radiation influence by weather conditions: hot sun, rains.

Dr. TAYLOR. Only to a very minor degree, I believe.

Senator AIKEN. There is no great range of difference, then, between eastern Oregon and western Oregon or New Mexico where they always pray for rain and other parts of the country where they pray that it will stop raining?

Dr. TAYLOR. You will find there are differences between different States and different parts of a State that are just natural. But I don't believe these are importantly influenced by local weather.

Senator AIKEN. What is the reason that there should be the difference in the different States?

Dr. TAYLOR. There may be a question of altitude. This influences the amount of cosmic radiation you receive. The amount of radio-

activity in the soil is one of the important contributors to the material that gets into your body through the food chain. The kind of house you live in may influence your radiation dose.

Senator AIKEN. Atmospheric conditions would not ordinarily influence any wide range?

Dr. TAYLOR. That is correct; yes.

Senator AIKEN. Thank you.

Representative BATES. Dr. Taylor, let us assume that these figures are correct. What do they mean? Would you not have to really know all of the elements that go into the computation before they take on any significance? For instance, a new machine widely used with a very low dose will throw these figures into a cocked hat. We are more interested in the range so we know what the dangers are at the upper level rather than an average figure without any background as how it was arrived at, which could be rather meaningless. As a matter of fact, the real danger in certain cases could have skyrocketed and still have averages because of a new machine on a very low dose level that would bring the average way down.

Dr. TAYLOR. It is quite possible that some new equipment and new technique could substantially decrease the dose. On the other hand, you don't get any results, diagnostic or therapeutic, without exposing the patient to the direct beam of radiation. All you can do by way of improving the situation is to avoid unnecessary exposure; to cut down some leakage from the tube housings; to better shield parts of the body you don't need to expose and so on.

Representative BATES. In the event that these patients were not exposed to radiation they would not then be involved in these particular figures, would they?

Dr. TAYLOR. I am not quite sure I follow you. This is an average per capita figure. You estimate—

Representative BATES. But only for those who have been exposed?

Dr. TAYLOR. No, this includes the entire population in this country, for example. You make an estimate as best you can of all the radiation that was delivered to all of the people in the United States. This may be only 10 percent of the people. Then you divide this dose by the number of people in the United States. This gives you your average per capita dose. For genetic purposes, this is the figure that is significant.

Representative BATES. The original statement I made about a new machine with a low dose would have an impact. Also your second statement to the effect that perhaps now they are not treating people with radiation that maybe previously they did. But you would really have to know what goes into these figures to understand the significance.

Dr. TAYLOR. Yes, if you want a highly accurate quantitative answer to this question. This means virtually the measurement of every single individual exposure that is made of people. This is physically impossible. The Public Health Service may in a few years time—possibly a decade—through its survey activities provide us with a better cross-section of the radiation exposure problem than we now have. At the present time this is the best that can be done, and I would be the last one to say it is very accurate. Certainly the trend is clear enough to be, I think, quite acceptable. It certainly is, in my mind.

Representative BATES. The number of machines that we have now per capita has increased considerably since 1956.

Dr. TAYLOR. Yes.

Representative BATES. That would really put a little significance on this figure.

Dr. TAYLOR. If the number of machines per capita increases you might expect more radiation per capita. Actually it is less.

Representative BATES. So that gives some significance to your figure?

Dr. TAYLOR. Yes.

Chairman HOLIFIELD. This would also be effected, if the gentleman will yield, with the improvements on the new machines as against some of the older machines which were a little bit generous with their radiation. The results are obtained quicker under some of the new machines and with less radiation because we have more sensitive film than under the older machines.

We are not using the fluoroscopes because the alarm has been sent out on these shoe fitting devices and to some extent on fluoroscopes, so that your fluoroscope examinations are probably not as prevalent as they were when their danger was not so well understood.

Dr. TAYLOR. Yes.

Chairman HOLIFIELD. As I listened to this colloquy and these answers and questions, it seems to me that your saving word, Doctor, is that it indicates that is a more likely figure. Certainly these are not figures that we can rely upon, Dr. Taylor.

Dr. TAYLOR. They certainly are not.

Chairman HOLIFIELD. I think the record should show that they are evaluations which indicate but which certainly do not prove this lesser danger of medical or dental X-rays in proportion to background radiation.

Representative PRICE. Would you proceed with your statement.

Chairman HOLIFIELD. That is in the nature of a question.

Representative PRICE. I think he agreed to that.

Chairman HOLIFIELD. I do not think he has.

Dr. TAYLOR. I do not think I would extend this quite to the depth you have, Mr. Holifield. Certainly in my mind, this figure of 50 percent represents an upper figure now for the dose to the U.S. population from medical sources as compared with 120 percent figure before.

Chairman HOLIFIELD. That is quite a sharp reduction. That is more than half.

Dr. TAYLOR. Sir, if you will recall from the Laughlin-Pullman report, they gave a genetic dose figure of 4.6 rems distributed over 30 years as the average per capita dose.

Chairman HOLIFIELD. From medical and dental X-rays?

Dr. TAYLOR. Yes, sir.

They specified an uncertainty in that figure of plus or minus 3, if I remember correctly.

Chairman HOLIFIELD. A factor of 3?

Dr. TAYLOR. The figure might have been as low, I believe, as 1.6 rems or then it might have been as high as 7.6 rems in 30 years. I am not quite sure if my memory serves me correctly but it was in that range. This was the range of uncertainty of the 1956 estimates.

Now, the current estimates are believed to be much better. The earlier figure includes an enormous uncertainty.

Representative HOSMER. I have just one other question:

Do you think that any of these figures are meaningful unless a factor is included for average leakage, miscalibration, and other defects in medical and dental radiation equipment?

Dr. TAYLOR. Those factors are worked into these numbers.

Representative HOSMER. Have you any idea what they amount to?

Dr. TAYLOR. No, I am sorry, I don't offhand. Exposure due to leakage, inadequate shielding, and so on, with modern equipment is a small percentage of the direct beam dose to the patient; this I am sure of.

Representative HOSMER. I am not so certain of it from what testimony we have had and also from the proportion of modern equipment in use as against older equipment that is still in use.

Dr. TAYLOR. Modern equipment, as I think of it, became prevalent in this country on a wide scale in roughly 1940. Equipment prior to that was the open-tube type. It was relatively hazardous, and is now hardly to be found. Shielded tube equipment came in the late 1930's, and it is almost universal at the present time. Even that equipment has been improved upon gradually over the past two decades.

Representative HOSMER. Here is a survey of the New York City Office of Radiation Control, as of January 31, 1962. (See app. 2, p. 612.) A fluoroscope survey showed that 71 percent of the shutters do not adequately limit the X-ray beam. Radiographic units, 69 percent did not have the X-ray beam limited to the area of clinical interest. This was particularly true in connection with chest X-rays. X-ray machines reinspected, they reinspected 740 and they found 64 percent of those had been brought up to standard. So I think unless your figure for these leakages and so forth, is fairly high, the total figure you have given us is hard to evaluate as being very meaningful.

Dr. TAYLOR. Those leakage figures would normally come into the results. I might say that the standards against which they are making these comparisons are extremely high. If you allow the field to overlap the fluorescent screen or if you use too large a field you are not multiplying your problem by factors of 5 or 10; you are multiplying them by 10 or 15 percent. These are not the principal sources of radiation exposure. The principal sources are the direct beam.

Representative PRICE. Would you proceed with your statement?

Dr. TAYLOR. The third category is industrial and atomic energy sources.

Here, except for waste products, the principal recipients of exposure are radiation workers which represent only a fraction of a percent of the population. In spite of their being allowed technically, to receive exposures higher than the general public, their average is extremely low. In comparison with many other industrial hazards the atomic energy and radiation industry generally must be regarded as relatively safe.

The balancing of risk and benefit in the industrial use of radiation is almost impossible to evaluate, but because the risk seems to be so small the balance is probably favorable. At present the contribution of industrial radiation to the average per capita dose is probably less than 0.4 percent of the total (0.5 millirems per year).

Representative BATES. Do you have any figures on waste products?

Dr. TAYLOR. I don't think the figures are very reliable on that. But certainly the figure is very small at the present time.

The fourth category is fallout from weapons testing. Fallout is an unfortunate byproduct of some weapons testing programs. It can be eliminated or reduced only by the sacrifice of information needed for our national defense and security. Only in the wisdom of our national leaders can the gain and risk be compared and the general public is in no position to debate this point.

As long as we must learn to live in a world along with nuclear weapons we must chalk up one plus for fallout; its analysis gives us much valuable information about the weapons tested by other nations.

It is hardly worth testing just for that purpose, I might remark.

At its peak levels, fallout has contributed less than 1.5 percent of our average per capita dose<sup>1</sup> (an average of 2 millirems per year<sup>2</sup>).

The fifth category is fallout from nuclear warfare. This could well contribute many thousands of times the dose of radiation that man is now living with. There is no basis for comparison between its effects and those from present exposure levels.

Representative PRICE. Thank you very much, Dr. Taylor.

Dr. Taylor, were you implying on page 1 that nuclear testing and waste disposal are suspect in the harm to lower forms of animal life and damage to our ecology?

Dr. TAYLOR. The radiation from nuclear operations can be hazardous to lower forms of animal life and to our ecology.

Representative PRICE. Was this what you were thinking of?

Dr. TAYLOR. Yes, sir.

Representative PRICE. What are the factors that you state that the part played by social and economic factors and so forth, on page 1, imply?

Dr. TAYLOR. Sir, we set our radiation protection levels on the basis of some limited experience with man, some experience with animals, some biological experience, and so on. We are forced to make assumptions about the linearity of radiation effects or that radiation dosages can accumulate under certain conditions. These are unproven facts. We have not yet been able to establish any causative relationship between industrial exposures and injury to man. Therefore, we are of necessity working somewhat in the dark in this whole question of radiation protection standards. As long as this is the situation we have to use judgment factors as to what kind of radiation levels we are willing to work with. Our judgment factors are going to be influenced by public necessity, economic necessity, medical necessity, and so on.

Representative PRICE. Mr. Ramey has a question at this point.

Mr. RAMEY. When you are talking of social and economic factors, do you mean also this question of the statistical concept of risk? You mentioned these standards started out by way of necessity, such as radiation workers and the celebrated cases of licking the brushes by radium workers, and so on, where you actually found physical damage as a result of radiation. Now we are taking our standard to where they are applying to whole populations and where you can't observe or discover any damaging effects.

<sup>1</sup> See supplementary testimony at end of Dr. Taylor's testimony, p. 30.

<sup>2</sup> Editor's note: This is an annual genetic dose averaged over a period of 30 years.

Is this the case of going into social and economic factors that have not been really thought out entirely?

Dr. TAYLOR. Yes. It is not a case, Mr. Ramey, of their not having been thought out. There has been a tremendous amount of thought given to these questions, but there is nothing to grab hold of. You cannot describe risk in units in the same sense that you can describe dose, for example. We don't know precisely what these risks are. We speculate on the risks on the basis of animal experiments extrapolated to man. We use judgment and we use consensus principally in untangling different concepts of the professional people working in the field. But you don't have any sound numerical basis on which you can evaluate risk, or compare risk to risk. You can't compare the risk of automobile driving with the risk of working with radiation. They are entirely different things, but they are both risks. Until you can do that you have to use your best judgment.

Representative PRICE. Dr. Taylor, on page 8 where you are talking about fallout from weapons testing, you say that at its peak levels fallout has contributed less than 1.5 percent of our average per capita dose, of 2 millirems per year. (See footnotes 1 and 2, p. 26.) How about the recently reported levels of iodine 131 in the Midwest?

Dr. TAYLOR. I am sorry; I have not tried to put those figures into this context. Somebody else can undoubtedly answer that question.

Representative PRICE. I wonder if Dr. Dunham could comment on that question.

Dr. DUNHAM. I don't have all the figures.

Representative PRICE. Do you intend to cover that in your presentation?

Dr. DUNHAM. I think Dr. Chadwick from the Public Health Service was planning to provide those data.

Representative PRICE. You are familiar with the widespread story about the excessive fallout in the St. Louis milkshed and other areas of the Midwest in recent weeks. Later on in the hearings we will get some comment on that?

Dr. DUNHAM. That is right.

Representative PRICE. Are there any other questions of Dr. Taylor?

Senator ANDERSON. I would like to know where he gets the 1.5 figure.

Dr. TAYLOR. It is a figure supplied by Dunning.

Senator ANDERSON. What is that based on?

Dr. TAYLOR. Again it is based on the analysis of the kind of information that was fed into the U.N. Scientific Committee from various sources of which the U.S. delegation probably was one.

Senator ANDERSON. What was the figure that the U.S. scientists turned in as to what they thought the fallout amounted to?

Dr. TAYLOR. I don't know their figure. Perhaps Dr. Dunham does.

Senator ANDERSON. Is this 1.5 a published figure? This other one was not published. We cannot check it. Is this a published figure?

Dr. TAYLOR. It is a figure that will be published.<sup>3</sup>

Senator ANDERSON. Will be. How will we check it?

Dr. TAYLOR. It will be available in July of this year.

Senator ANDERSON. Along with the other figures?

<sup>3</sup> L. S. Taylor, "Radiation Exposure in Realistic Perspective," *Physics Today*, June 1962.

Dr. TAYLOR. Yes, sir. Excuse me, may I ask Dr. Tompkins a question about this?

Senator ANDERSON. Yes.

Dr. TAYLOR. You were at the meetings, were you not?

Dr. TOMPKINS. Yes.

Senator ANDERSON. Is this an approximate figure they will include in their final report? This is a scientific paper. You should have found out if somebody heard something and if that is the figure they used. Where did you get it?

Dr. TAYLOR. I derived it from their papers. They had meetings after I left the country. You were asking about the U.S. figure in here.

Senator ANDERSON. I am asking where the 1.5 came from. What scientific calculations were there that went into that? What is our average per capita dose?

Dr. TAYLOR. From fallout?

Senator ANDERSON. No, from the language of your paper. At its peak levels fallout has contributed less than 1.5 of our average per capita dose. What is our average per capita dose? I want to take 1.5 of that and find out what we get from fallout.

Dr. TAYLOR. Our average per capita dose is something over 125 millirems per year. It is 125 millirems per year plus the medical contribution.

Senator ANDERSON. And the medical contribution amounts to what?

Dr. TAYLOR. It is from 14 to 60 millirems per year, I believe. This is from memory.

Senator ANDERSON. That would make about 140 millirems per year.

Dr. TAYLOR. It could be. Background plus 14 to background plus 60. It could go as high as 185 and as low as 140 millirems per year, roughly, depending upon the medical value. I am just giving you these numbers from memory at the moment.

Senator ANDERSON. We had figures before that indicate that the fallout is as low as that.

Dr. TAYLOR. Yes, sir.

As a matter of fact, I believe this is in agreement with a report by Dr. Dunning of the AEC. He is here in the room and can perhaps either verify this or correct me.

Senator ANDERSON. When you use the term "fallout has contributed less," do you mean per year?

Dr. TAYLOR. In this year.<sup>4</sup>

Senator ANDERSON. Would it be in the last 3 years when they had what was known as a holiday on testing?

Dr. TAYLOR. This covered the whole period to now—1962.

Senator ANDERSON. 1958 was a year in which there was some testing?

Dr. TAYLOR. Yes.

Senator ANDERSON. This is based on 1958?

Dr. TAYLOR. Yes.

Senator ANDERSON. Did the U.N. say so?

Dr. TAYLOR. Sir?

Senator ANDERSON. Did the U.N. so advertise it as based on 1958? Does that show in their figures?

<sup>4</sup> Editor's note: See Dr. Taylor's supplementary statement indicating a misunderstanding to this question, p. 30.

Dr. TAYLOR. I am not sure what their actual statement will be with regard to this.

Senator ANDERSON. Do you happen to know whether the U.N. agreed on this? Whether the member countries agreed and whether there was a vast difference and argument between the members?

Dr. TAYLOR. I am sure there was a great deal of argument but there was basic agreement.

Senator ANDERSON. Basic agreement on an average figure or basic agreement that they could not agree?

Dr. TAYLOR. On an average figure.

Senator ANDERSON. Was there a majority viewpoint and little respect for the minority viewpoint?

Dr. TAYLOR. Sir, I was out of the country when these discussions were being held so I can't answer that question.

Senator ANDERSON. The story of iodine levels rising in Wichita, Kans., with peaks of 220 to 340 micro-microcuries per liter of milk; 660 on May 15, from 220, and so forth. Kansas City with peaks of 190 and 300 had 600 on May 18.

Are we trying to show that testing doesn't do any damage or doesn't raise any hazards? This is a statement which would surely leave the impression that there is no real danger in testing; would it not? If in 1958, the highest year, we had only 1.5 percent of our average per capita dose that we live with today, and don't worry about, then we don't have to worry about the 1.5 percent.

Dr. TAYLOR. I was not trying to create that impression. I was listing the various sources of radiation that we are now exposed to with their levels as we best understand them in order to put some perspective on the whole problem. Actually you cannot compare a medical exposure with a fallout exposure. They are both radiation exposure but you cannot say 2 millirems of X-rays is the same as 2 millirems from strontium 90.

Senator ANDERSON. If you cannot compare them, why did you do it?

Dr. TAYLOR. I have been comparing in this case the gonadal dose, the genetically important dose.<sup>5</sup>

Senator ANDERSON. You say you cannot do it and then you proceed to show that it is only 1½ percent.

Dr. TAYLOR. You cannot compare the overall exposures from fallout with the overall exposures from X-rays.

Senator ANDERSON. Then why did you?

Dr. TAYLOR. I have been comparing here the gonadal dose. This you can compare.

Representative HOSMER. That is what is best known as a dose to reproductive cells.

Dr. TAYLOR. Germ cells, yes.

Senator ANDERSON. You estimate the amounts to 125 millirems per year?

Dr. TAYLOR. Yes, sir.

Representative HOSMER. Then you said that fallout contributes about 1½ percent of the per capita dose.

Dr. TAYLOR. To the gonads.

<sup>5</sup> Editor's note: See supplemental statement of Dr. Taylor, p. 30.

Representative HOSMER. To the gonads. The Federal Radiation Council chart indicates 10 to 25 millirems per year which works out to about 6 percent as compared to your 1½ percent figure.

Dr. TAYLOR. That is from all tests through 1961. I was giving it for 1 year. (See statement below.)

Representative HOSMER. You mean that is cumulative or yearly? It says 1 year in the column on the left-hand side.

Dr. TAYLOR. I would have to study this report to know precisely what that figure means.

Representative HOSMER. Would you like to submit a short statement comparing your figures with theirs?

Dr. TAYLOR. I will try to do this.

(Subsequently, Dr. Taylor submitted the following supplementary statement:)

EXTENSION OF TESTIMONY PRESENTED BY LAURISTON S. TAYLOR

In my testimony on June 4 there were some questions regarding the sources of data used, as well as the end results presented. Some further information and the correction of one step is given below, relative to the statements comparing the medical to the total average per capita genetic dose of the population.

The paper as presented was not specific in stating that the figures related to gonadal dose for a 30-year period. Within the limits of accuracy, they also apply to whole body exposure.

With regard to natural radiation, I prefer to use a figure of 125 millirems annual average per capita dose rather than the rounded-off figure of 100 millirems per year. I believe that a similar value is used by the United Nations Scientific Committee on the Effects of Atomic Energy in its 1958 report. For later comparisons, the value of 125 gives a dose from natural background of 3,750 millirems over a 30-year period.

Medical procedures in the United States contribute to the average per capita dose at a rate now variously estimated at 33 to 50 millirems per year. (Norwood et al., 1959, 45 millirems; Lincoln and Copton, 1958, 50 millirems; FRC Rept. No. 3, 1962, 33 millirems.) I have chosen the highest figure as being the least conservative, as far as medical practice is concerned. On this basis, the 30-year contribution to the average per capita dose is 1,500 millirems; this is less than half the dose received from natural sources.

The contribution to the average per capita genetic dose by radiation workers is probably less than 0.5 millirems per year, or 15 millirems over 30 years.

The 30-year average per capita genetic dose to children born in 1962, resulting from all past tests, is approximately 60 millirems (derived from Dunning, TID-14377, 1962). This is the figure used by Dr. Langham in his testimony of June 5 and is the lower figure of the range specified in FRC No. 3, table I.

The sum of these average per capita genetic doses is as follows:

	<i>Millirems</i>
Natural.....	3,750
Medical.....	1,500
Occupational.....	15
Fallout.....	60
Total.....	5,325

On the basis of these figures, fallout contributes  $\frac{60}{5325}$  of the total or 1.1 percent of the total average per capita genetic dose. (My original statement said "less than 1.5 percent," which is in agreement with the more precise value stated above.) It is my own opinion that the estimates for the various doses above may be in error by as much as 25 percent each.

In my statement it was improper to give the fallout figure as 2 millirems per year, derived by dividing the 30-year dose by 30. However, the value was not used this way in my calculations.

Again, referring to the tabulation above, the average per capita contribution of medical exposures to the 30-year genetic dose is  $1500/3325$  or 28 percent of the total per capita dose. Compared with background, the medical contribution would be  $1500/3750$  or 40 percent.

With regard to the legitimacy of comparing doses such as I have done above, I quote from my own publication on this subject, "One must use great caution in using such data, because the various exposures indicated are comparable only for very limited conditions. There is no real basis for comparing the effects of TV radiation with that from  $K^{40}$  or  $Sr^{90}$  in the body."

Studies of the dose to the population resulting from medical procedures were carried out for the United Nations Scientific Committee on the Effects of Atomic Radiation by a joint study of the International Commission on Radiological Units and Measurements and International Commission on Radiological Protection. The ICRU and ICRP in their 1957 and 1961 reports dealt with the methodology and preliminary data to be employed in surveying and evaluating medical exposures on a national scale. I personally participated throughout the studies by the latter groups. The study for UNSCEAR covered the following countries: Argentina, Denmark, Federal Republic of Germany, France, Italy, Japan, Netherlands, Norway, Sweden, Switzerland, United Kingdom, United States of America, U.S.S.R., United Arab Republic. Since the conditions in countries vary and since national techniques for collecting and evaluating the data may differ, it is not proper to average the results across countries.

In any case, the U.S. figure appears to be near the upper end of the range for these countries. This may be due to our more extensive use of X-ray diagnostic procedures, less discrimination in the use of radiation, less well-protected equipment, the difficulty of analyzing the problem in a country as large as the United States (as compared, say, with Denmark) or other causes. Our equipment is as well (or better) protected as any in the world. Our radiologists are as well trained and qualified as any in the world.

In the United States, however, we probably have a larger fraction of our X-ray equipment in the hands of general practitioners than in many other countries (e.g. United Kingdom, Denmark, Sweden). This may account for some unnecessary exposure, but this has not been demonstrated. It is probable that the main reason for the higher per capita genetic dose in the United States is our higher per capita use of X-rays in the first place. This is not to imply that procedural improvements should not be sought after and introduced whenever compatible with securing the desired diagnostic results.

For your information and inclusion in the record if you so desire, I attach a copy of the second ICRU/ICRP report entitled "Exposure of Man to Ionizing Radiation Arising from Medical Procedures with Special Reference to Radiation Induced Diseases."

Representative PRICE. If you desire to present a comment on the Federal Radiation Council report, you may do so, Dr. Taylor.

Dr. TAYLOR. Thank you.

Representative PRICE. If there are no further questions, thank you very much, Dr. Taylor.

The concluding witness for this afternoon's session will be Dr. Charles Dunham, Director of the Division of Biology and Medicine, U.S. Atomic Energy Commission.

Dr. Dunham, please proceed.

**STATEMENT OF C. L. DUNHAM, M.D.,<sup>1</sup> DIRECTOR, DIVISION OF BIOLOGY AND MEDICINE, U.S. ATOMIC ENERGY COMMISSION**

Dr. DUNHAM. Mr. Chairman, it is a privilege to appear before this committee which has taken such a constructive interest in radiation protection standards and in fallout from the testing of nuclear weapons. You have recognized in the planning of these hearings that weapons testing is once again a fact.

You have asked that I summarize in advance of testimony by the experts our current knowledge about radioactive fallout from the testing of nuclear weapons with special emphasis on knowledge accrued since the 1959 hearings.

The Atomic Energy Commission, during this period, has done its utmost to take advantage of the absence of testing to gain as much knowledge as possible about fallout. Much of this new knowledge is summarized in the report of the fallout conference held at Germantown, November 15-17, 1961. This report has already been made available to you.

With the resumption of atmospheric testing by the U.S.S.R. last fall and more recently by the United States, we are intensifying our fallout studies. These new injections of radioactive debris into the atmosphere at different latitudes and a wide range of altitudes afford a unique opportunity to extend further our understanding of the mechanisms involved in the transport and distribution of fallout; information not only of significance in terms of weapons testing and

<sup>1</sup> Curriculum vitae, Charles L. Dunham, M.D.:

Born: Evanston, Ill., December 28, 1906.

Education: Evanston Township High School; B.A., Yale University, 1929; M.D., Rush Medical College, University of Chicago, 1933.

Experience: Interned at University of Chicago clinics, April 1933 to June 1934. Assistant resident in medicine at New Haven Hospital, New Haven, Conn., June 1934 to February 1935. Full-time assistant in medicine, Billings Memorial Hospital, University of Chicago, working in the gastrointestinal clinic, later in allergy clinic and laboratory, 1936-42; instructor, then assistant professor of medicine in charge of the arthritis clinic and hospital service, 1946-49. Served in U.S. Army September 1943 to May 1946, first as chief, outpatient service station hospital, Los Angeles Port of Embarkation, Torrance, Calif., later as assistant and finally as chief, preventive medicine and medical inspector for Headquarters, Armed Forces, Office of the Surgeon, Headquarters, Army Forces in Middle Pacific. Joined the U.S. Atomic Energy Commission as Assistant Chief, Medical Branch, Division of Biology and Medicine, 1949; Chief of the Branch, 1950 to June 1954; Deputy Director, July 1954 to September 1955; Director, October 1955 to date. Past member of National Cancer Chemotherapy Committee, AEC representative on the National Academy of Sciences National Research Council's Division of Medical Sciences; American Medical Association, Industrial Medicine Association, Radiation Research Society, Health Physics Society, Society of Nuclear Medicine, American Nuclear Society, New York Academy of Sciences, Radiological Society of North America, American Rheumatism Association, A.A.A.S., and Sigma Xi.

nuclear war, but also of significance in terms of the application of nuclear energy to our space program.

During your committee hearings in June 1959 on the biological and environmental effects of nuclear war, it became apparent that the 1957 edition of the *Effects of Nuclear Weapons* required updating. The Department of Defense, with the full cooperation of the AEC and its laboratories, has completed the revision, and the 1962 edition was issued May 8, 1962.

The detonation of nuclear devices produces fission products in greater or lesser amounts depending on the characteristics of the particular device employed. Fission devices, which are generally in the low yield range, derive their explosive force from nuclear fission which gives rise to amounts of radioactive fission products roughly proportional to explosive yield. Thermonuclear devices have a large fraction of their explosive force produced by a thermonuclear or fusion reaction. Such devices derive only a part of their explosive force from the fission reaction. Of the fission products produced in the fission reaction, those with the greatest potential health significance are Sr<sup>90</sup>, Cs<sup>137</sup>, I<sup>131</sup>, Sr<sup>89</sup>, Ba-La<sup>140</sup>, and Zr-Nb<sup>95</sup> (half lives 28 years, 30 years, 8 days, 54 days, 13 days, and 65 days respectively).

Thermonuclear reactions may give rise to tritium (radioactive hydrogen, half life 12.8 years). The very large number of neutrons released in the reactions transform nitrogen in the air into radio-carbon (carbon 14, half life 5,760 years).

In addition, the neutrons produced in either fission or fusion reactions induce radioactivity in certain chemical elements used in the construction of the devices themselves. If detonated from towers, radioactivity is induced in the materials of the towers, and if detonated relatively close to a land or ocean surface, in elements in these surface materials. Most of these induced activities are, aside from carbon 14, short lived and although they may be very important constituents of early or near-in fallout, they have little health significance in worldwide fallout. Fe<sup>59</sup>, Mn<sup>54</sup>, Si<sup>31</sup>, Cl<sup>38</sup>, Na<sup>24</sup> with half lives of 47 days, 310 days, 2.6 hours, 37 minutes, and 14.8 hours, respectively, are the most prominent ones.

Measurable amount of Zn<sup>65</sup>, half life 250 days, and Co<sup>60</sup>, half life 5.3 years, have also been detected in fallout. Plutonium and uranium isotopes, basic materials in the fissionable components of nuclear weapons, are also contained in fallout material.

There are three different classes of fallout from tests, local or near-in fallout, tropospheric fallout, and stratospheric fallout.

(See fig. 1, p. 34.)



FIGURE 1.

The local fallout is material that falls out close to the point of detonation, tropospheric fallout travels around the world and the stratospheric fallout which behaves quite differently from the local and tropospheric fallout.

The relative abundance of each is determined by the nature of the weapon, its yield, and the conditions of detonation, particularly the altitude.

Local or near-in fallout occurs when the fireball of the bomb touches or comes sufficiently close to the ground to draw up into the vaporized cloud matter from the surface of the earth. The radio-nuclides produced by the explosion may be deposited on or incorporated into this material depending upon whether or not the latter is more or less completely fused or totally vaporized. After the fireball cools, the larger particles deposit on the earth over a period of from a few minutes up to many hours after the detonation. This constitutes the local or near-in or early fallout which for small weapons may extend out from the point of burst a few miles and cover tens to a few hundreds of square miles while for megaton weapons it may extend out to several hundred or more miles and cover thousands of square miles.

Tropospheric or latitudinal fallout is a more delayed fallout of the debris which has not penetrated the tropopause to the stratosphere and the particle size of which is such that it does not fall rapidly. It occurs over a period of 2 weeks to a month or so after a detonation and consists of relatively fine material (a few micra to small fractions of a micron) suspended in the lower part of the atmosphere, the troposphere, where rain and other weather phenomena occur. It is carried around the world in the same general band of latitude as that of its origin although excursions of tropospheric debris as far as 20° to 30° from the test latitude are not uncommon. Tropospheric fallout from tests at temperate or polar latitudes does not in any significant amount cross the equator. It is deposited on the earth's surface by weather events, principally rain or snow and possibly to some extent by dew, dry deposition being important only in relatively arid areas. Thus, the distribution of tropospheric fallout is determined generally by the paths of air masses passing over the site of formation, with factors such as local weather conditions and distance traveled (in thousands of miles) determining regions of greater ("hot spots") or less concentration.

Tropospheric fallout has contributed significantly to the radioactive debris in the Northern Hemisphere as a result of weapons testing in the Pacific, in Nevada, and by the U.S.S.R.

The principles stated above for near-in and tropospheric fallout were apparent at the time of the 1959 hearings. Since then there has been some refinement in our knowledge of the tendency for local or near-in fallout to contain greater amounts of certain fission products as compared to others, and the tendency for the closer in fallout particles to have certain nuclides in a less soluble form than the smaller particles which predominate farther out. This affects the availability of these nuclides for early incorporation into the food chain via the soil. Additional information on these points has been developed from analysis of data collected prior to 1959. Local fallout consists in large part of larger particles which tend to fall out first. These particles are somewhat poorer in Sr <sup>90</sup> as compared to the finer particles which fall

out at greater distances. This fractionation is most pronounced in the case of low-yield, land-surface bursts and least in air bursts and very high yield bursts.

The particle size distribution in the debris cloud from a land-surface burst, and hence in the fallout, shifts with time toward the smaller sizes which contain a larger proportion of fission products relative to earth material. This is because the larger particles fall out first. The fraction of the nuclide, which is soluble and hence immediately available biologically, tends to increase with time and distance from the burst. Actual measurements at the Nevada test site show a low ratio of biologically available to total  $\text{Sr}^{90}$  within a few miles from the burst point as compared with the ratio at greater distances. The ratio of  $\text{Sr}^{90}$  to total fission products in the closer in area is also low.

Irregularities and "hot spots" in the distribution pathway of the fallout within the first few hundred miles have been observed unrelated to rainstorms which seem to be the principal immediate cause of "hot spots" farther away. Irregularities of terrain and small-scale irregularities of the wind field in time and space are probably responsible, however, present meteorological data are inadequate to account for and hence precisely predict them.

On the other hand, upper wind observations closely spaced in time have permitted substantial improvement in predicting the direction of the major axis or "hot line" of the fallout pattern.

Stratospheric fallout has somewhat different characteristics and distributions. It consists of particles which rise into the upper atmosphere and which are too small to fall out as local or tropospheric fallout during the first month following their formation. Because of their small size, 0.01 to 1 micron (one-millionth to one ten-thousandth of a centimeter in diameter), they are removed from the atmosphere slowly and their average time of suspension, depending on their initial placement in the stratosphere, is a matter of several months or years. The distribution of both artificial and natural radioactivity in the stratosphere, and the time scales and mechanisms involved in their transport and deposition on the surface of the earth, have received considerable study, and during the past 3 years a number of significant advances have been made in understanding these phenomena.

It has become clear now that the principal mechanism of transport of these particles from the lower stratosphere into the troposphere is downward movement of air masses. The hypothesis put forward in the 1959 hearings of a spring maximum and a fall minimum of stratospheric fallout in the Northern Hemisphere has been established by observations made in the absence of recent testing during 1960 and 1961. A similar though less pronounced seasonal variation was observed in the Southern Hemisphere.

Now if I may have the next chart (see fig. 2) it is now quite apparent that tropospheric concentrations and deposition rates of stratospheric debris are higher in the middle latitudes ( $20^\circ$  to  $60^\circ$ ) of both hemispheres than they are at the Equator, regardless of the latitude or altitude of the stratospheric injections. You can see in this chart I have indicated in the gray area the middle latitudes where most of the fallout tends to accumulate regardless of our original point of injection into the stratosphere. I also have indicated the general latitude of various places around the world where testing has been carried out.

# LATITUDES OF PRINCIPAL TEST SITES IN THE NORTHERN HEMISPHERE

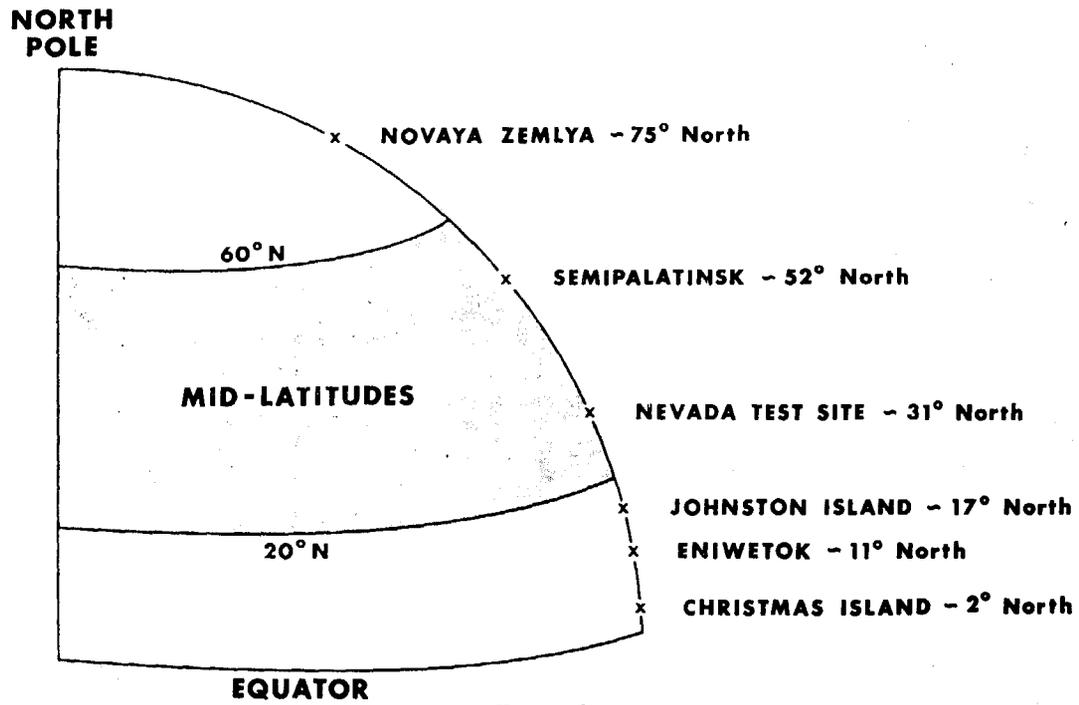


FIGURE 2.

Poleward from the middle latitudes the total deposition of stratospheric debris decreases with decreasing precipitation (rain and snow). It should be noted however that there does not appear to be a strongly decreasing trend in air concentration and concentration in precipitation from the middle latitudes poleward.

Making use of planned and incidental tracers in debris from the specific detonations, and taking advantage of changing  $\text{Sr}^{89}/\text{Sr}^{90}$  ratios with time from different series of tests, we can now with considerable certainty make estimates of residence time in the stratosphere for debris introduced at certain locations in the stratosphere.

1. More than 50 percent of the debris from the 1958 U.S.S.R. Arctic tests in the range of a few hundred kilotons to a few megatons injected into the lower stratosphere (30,000 to 90,000 feet) was deposited in the Temperate Zone of the Northern Hemisphere during the spring following injection.

2. Debris from equatorial tests in the low megaton range exhibited a half-residence time of the order of 1 year during the first year and increasing somewhat in half-residence time after 1 year.

3. Debris injected at a very high altitude (greater than 130,000 feet) near the Equator began to appear in the lower altitudes after 1 year and has been deposited at a rate corresponding to a half-residence time of at least 3 years.

There is still to be determined the relative roles of horizontal transport and vertical transport in the holdup of high altitude equatorial debris. Also, we have yet to learn whether the fallout pattern from a debris cloud, such as that from the U.S.S.R. 55 to 60 megaton detonation of October 1961 which reached an altitude of 130,000 to 170,000 feet in the Arctic, will behave more like very high altitude equatorial debris, like low stratospheric arctic debris, in some intermediate fashion or in some different fashion altogether.

So much for the transport and distribution of fallout. Let us turn now to techniques for estimating fallout rates in a given geographic location. Surface air sampling techniques have changed little in the past 3 years. These samples, when held for 4 to 5 days to permit decay of natural radioactivity and then analyzed by gamma ray spectroscopy, give an index of the concentration in the air at ground level of important gamma-emitting fission products ( $\text{Cs}^{137}$ ,  $\text{I}^{131}$  and zirconium-niobium isotopes) in the tropospheric or relatively fresh fallout and of  $\text{Cs}^{137}$  in stratospheric fallout. These readings do not relate directly to final deposition on the ground. I think it is important to keep this in mind.

The latter information must be derived from analysis of soil and vegetation or from material collected in pot or funnel systems as the greater part of the radioactive debris is brought to earth in rain or snow.

In the 1957 hearings it was suggested that  $\text{Cs}^{137}$  in milk and in humans might prove to reflect fallout rate more than accumulated fallout. Data presented in 1959 made this even more plausible. Today there can be no question but that this is the case. The milk levels which peaked in the spring of 1959 had fallen by later summer of 1961 to about one-eighth that value. Levels in humans tend to lag behind milk levels by about 6 months.

$\text{Sr}^{90}$  in milk and man has a large component related to uptake in plants of accumulated  $\text{Sr}^{90}$  in the soil. This is evident from the fact that milk values which peaked in the early summer of 1959 had fallen by no more than a factor of about three by the summer of 1961.

It now appears that the overall ratio of  $\text{Sr}^{90}$  to calcium in the infant bones in this country to the  $\text{Sr}^{90}$  to calcium ratio in their diet is about 0.5. Studies on 1- to 2-month-old infants suggest the ratio may be as high as 1.0, insofar as milk is concerned. By early childhood it has fallen to 0.25. Whether this change reflects change in diet habits or it is related to the changes in the physiology of absorption of  $\text{Sr}^{90}$  from the gastrointestinal tract, or merely reflects less demand for calcium-like elements, is not certain.

The most recently available data from human bones in the United States indicate an average of about 3 strontium units in infants in 1961 and 1 in adults. A strontium unit is one micro-microcurie of strontium 90 per gram of calcium.

Values ranged up to 5.1 in infants. These data are consistent with UK mean values of about 3 and 0.3 for 1960. Most of the data on bones and diets of Eskimos in Alaska run about 25 percent higher than for the United States as a whole. Further, a few samples of adult Eskimo bone are about four times these figures suggesting that certain individuals are eating food, presumably caribou meat, which is exceptionally high in  $\text{Sr}^{90}$ . No bone data are available from a known caribou-eating tribe, but  $\text{Sr}^{90}$  in urine from adult persons in such tribe suggests that bone deposition is four times that in persons on a caribou-free diet. Samples of caribou meat have shown as much as 190 strontium units. Meats are relatively low in calcium compared to milk. Swedish data on  $\text{Cs}^{137}$  in reindeer meat have shown exceptionally high  $\text{Cs}^{137}/\text{K}$  ratios. In fact, some individuals are at or slightly above the generally accepted permissible levels for the population.

It was expected that  $\text{Cs}^{137}$  and  $\text{Sr}^{90}$  in the diet would begin another rise this spring. In fact, the most recent data from the Argonne National Laboratory shows a rise in  $\text{Cs}^{137}$  air concentration though not at an alarming rate.

By 1957, data had accumulated indicating that tropospheric fallout resulted in sufficient  $\text{I}^{131}$  in food that it could be measured in human urine, and human and animal thyroid glands.

The 1959 hearings brought out the importance of  $\text{I}^{131}$  in cows' milk as a source of  $\text{I}^{131}$  in the thyroid gland of infants. Available data on  $\text{I}^{131}$  in milk supplies indicated that the average U.S. infant received 0.1 to 0.2 rad exposure to the thyroid gland in the period May-September 1958. No more radioiodine resulting from weapons tests was observed in milk supplies until October 1961 following the resumption of nuclear weapons testing by the U.S.S.R. Actual measurements of  $\text{I}^{131}$  in New York City infants, October-December 1961, indicate an average exposure of about 40 millirad. Infants in certain other cities such as Omaha, Nebr., presumably had higher exposures in view of the fact that  $\text{I}^{131}$  values in milk were 2 to 3 times those for New York City milk. Milk seems clearly to have been the principal source of the  $\text{I}^{131}$ .

As far as our knowledge of the biological effects of fallout is concerned, the newer observations all indicate that the hypothesis of straight proportionality of effect irrespective of dose and dose rate

provides upper limiting estimates of the possible number of cases of leukemia and bone cancer and curtailment of average lifespan that might result from chronic exposure to fallout radiation from weapons tests.

The true values will probably lie below these. As FRC Report No. 3 has said:

Dose rate is important: within certain limits a protracted dose is much less effective than the same total dose given in a short time.

New data on genetic effects have strengthened the view that continuous low-level radiation exposure of the gonads of a population is one-fourth and maybe one-sixth as effective as higher dose rates in producing gene mutations.

The production of thyroid cancers in persons who as infants received therapeutic radiation of 150 rad and more at relatively high dose rates to the thyroid gland or to the head and neck region is an established fact. Incidentally, these cancers have for the most part responded remarkably well to treatment. The significance of these observations with respect to possible thyroid cancer induction from much smaller radiation doses due to  $I^{131}$  accumulations in infant thyroids as a result of nuclear testing is uncertain.

A full and up-to-date discussion of the health implications of radiation including fallout radiation has been developed by the U.N. Scientific Committee on Effects of Atomic Radiation, and their report will be published in the late summer.

Chairman HOLIFIELD. Mr. Chairman, I would like to stop there and have you give us what information you have on the composition of this United Nations Scientific Committee. Do you happen to have the names of those people, the countries they come from, and their standing as scientists?

Dr. DUNHAM. I can give you an answer for it now, but I would like to provide a full statement for the record. It represents 15 nations. (The information requested follows:)

DELEGATES OF STATES MEMBERS OF THE SCIENTIFIC COMMITTEE ON THE EFFECTS OF ATOMIC RADIATION

Argentina:

Dr. Dan Benison, National Commission of Atomic Energy.  
Dr. Juan G. Flegenhelmer, National Commission of Atomic Energy.  
Mr. Alejandro Placer, National Commission of Atomic Energy.

Australia:

Mr. D. J. Stevens, director, Commonwealth X-ray and Radium Laboratory.  
Dr. A. M. Clark, professor of zoology, University of Tasmania.

Belgium:

Prof. J. A. Cohen, Medisch Biologisch Laboratorium RVO/TNO, Riiswijk, Netherlands.  
Dr. J. Block.

Brazil:

Dr. Carlos Chagas, professor at the Institute of Biophysics, University of Brazil, Rio de Janeiro.  
Dr. C. Pavan, director, Department of Biology, University of Sao Paulo.  
Father Francis X. Roser, S.J., director, Institute of Physics, Catholic University of Rio de Janeiro.  
Dr. Luiz Renato Caldas, Instituto de Bioffsica.

## Canada :

- Dr. E. A. Watkinson, head of Environmental Health Division, Department of National Health and Welfare.  
Dr. F. D. Sowby, senior medical officer, Radiation Protection Division, Department of National Health and Welfare.  
Dr. W. E. Grummitt, Biology and Health Physics Division, Atomic Energy of Canada Limited.  
Dr. H. B. Newcombe, Biology and Health Physics Division, Atomic Energy of Canada Limited.  
Dr. G. H. Josie, Department of National Health and Welfare.

## Czechoslovakia :

- Prof. Dr. Ferdinand Hercik, director, Institute of Biophysics, Brno.  
Prof. Dr. Frantisek Behounek, head, Dosimetry Section, Czech Institute of Nuclear Physics, Prague.  
Dr. Ludvik, Novak, expert for somatic effects.

## France :

- M. le Prof. Louis Bugnard, Directeur de l'Institut National d'Hygiene.  
M. le Dr. Henri Jammet, Chief du Service de Protection entre les Radiations au Commissariat de l'Energie Atomique.  
M. le Dr. Jerome Lejeune, Centre National de la Recherche Scientifique.  
M. Gerard Lambert, Commissariat de l'Energie Atomique.

## India :

- Dr. A. R. Gopal-Ayengar, chief scientific officer and head, Biology and Medical Divisions, Atomic Energy Establishment, Trombay, Bombay.  
Mr. P. N. Krishnamoorthy, research officer, Health Physics Division, Atomic Energy Establishment, Trombay, Bombay.  
Dr. K. G. Vohra, research officer, Government of India, Atomic Energy Establishment.

## Japan :

- Dr. Kempo Tsukamoto, director, National Institute of Radiological Sciences.  
Dr. Yoshio Hiyama, professor, faculty of agriculture, Tokyo University.  
Dr. Eizo Tajima, professor, faculty of science, Rikkyo University.  
Dr. Yataro Tajima, head of Department of Morphological Genetics, National Institute of Genetics.  
Dr. Yasuo Miyake, professor, Tokyo University of Education.  
Dr. Motowo Kimura, National Institute of Genetics.  
Dr. Ryushi Ichikawa, National Institute of Radiological Sciences.

## Mexico :

- Dr. Manuel Martinez Baez, Institute of Health and Tropical Diseases.  
Dr. Fernando Alba Andrade, Institute of Physics, National University of Mexico.  
Dr. Horacio Zalce, director, Oncologic Hospital, Mexico City.

## Sweden :

- Prof. R. M. Sievert, Institute of Radiophysics, Stockholm.  
Prof. Torbjorn O. Caspersson, Karolinska Institutet, Stockholm.  
Dr. A. G. A. Nelson, assistant professor in radiobiology, Chief, Division of Medicine, Research Institute of National Defence, Stockholm.  
Dr. Bo Lindell, Institute of Radiophysics, Stockholm.  
Prof. K. G. Luning, Institute of Genetics, University of Stockholm.  
Dr. Lars Fredriksson, Royal Agricultural College, Uppsala.

## Union of Soviet Socialist Republics :

- Prof. A. M. Kuzin, corresponding member of the U.S.S.R., Academy of Sciences.  
Dr. N. A. Kraevsky, U.S.S.R., Academy of Sciences.  
Prof. V. Klechkovsky, U.S.S.R., Academy of Agricultural Sciences.  
Prof. O. Leipunskii, U.S.S.R., Academy of Sciences.  
Dr. V. Shtukkenberg, Academy of Medical Sciences.  
Dr. M. A. Arsenieva, U.S.S.R., Academy of Sciences.  
Dr. V. T. Kozlov, U.S.S.R., Academy of Sciences.  
Dr. V. Terentiev, Academy of Sciences of the U.S.S.R.

## United Arab Republic :

- Dr. M. E. A. El-Kharadly, associate professor and cancer specialist, University of Alexandria.  
Dr. K. Mahmoud, Head, Radiation Protection Department, Atomic Energy Establishment, Cairo.  
Dr. M. M. Mahfouz, lecturer in radiotherapy and oncology, University of Cairo and Head of the Medical Unit, Atomic Energy Establishment.

## United Kingdom of Great Britain and Northern Ireland:

- Dr. E. E. Pochin, director, Medical Research Council's Clinical Research Department, University College Hospital Medical School, London.  
 Dr. W. G. Marley, Head, Radiology Protection Division, United Kingdom Atomic Energy Agency, Harwell, Didcot.  
 Dr. A. C. Stevenson, Medical Research Council, Population Genetics Research Unit, Oxford.  
 Prof. L. F. Lamerton, Physics Department, Institute of Cancer Research, Sutton.  
 Dr. Scott Russell, Agricultural Research Council, Radiobiological Laboratory, Grove, Wantage.

## United States of America:

- Dr. Shields Warren, professor of pathology, Harvard University, Cambridge, Mass.  
 Dr. Austin M. Brues, Director, Division of Biological and Medical Research, Argonne National Laboratory.  
 Dr. Charles L. Dunham, Director, Division of Biology and Medicine, Atomic Energy Commission.  
 Dr. John Harley, Health and Safety Laboratory, New York Operations Office, Atomic Energy Commission.  
 Dr. William L. Russell, Oak Ridge National Laboratory.  
 Dr. Arthur Upton, Oak Ridge National Laboratory.  
 Dr. Max R. Zelle, Argonne National Laboratory.  
 Dr. Paul Tompkins, Office of Radiation Standards, Atomic Energy Commission.  
 Dr. John R. Totter, Department of Biophysics, University of Georgia, Athens, Ga.  
 Dr. Lester Machta, Chief, Meteorological Projects Section, Weather Bureau, Washington, D.C.  
 Dr. C. L. Comar, Laboratory of Radiation Biology, Cornell University, Ithaca, N.Y.

Chairman HOLIFIELD. I would suppose these are the advanced nations that have physicists and geneticists?

Dr. DUNHAM. They are representative nations. They are Australia, Canada, United States, United Kingdom, Japan, Mexico, Argentina, Brazil, United Arab Republic, India, Czechoslovakia, U.S.S.R., Belgium, France, Sweden. I may have left something out.

Chairman HOLIFIELD. And the United States.

Dr. DUNHAM. Including the United States. Each country has sent very clearly its most competent and outstanding people in the field.

Chairman HOLIFIELD. It is your professional opinion, then, that conclusions reached by this group would be scientifically credible and of scientific respect throughout the world?

Dr. DUNHAM. I feel so. It is a group of considerable stature. They spent a tremendous amount of time developing information and going over the available data and I think when their report comes out one can have full confidence in it.

Chairman HOLIFIELD. Would it be fair to say that it is the consensus of opinion arrived at by compromise between possible ranges of viewpoints?

Dr. DUNHAM. Not this last session. There may have been some discussion, and Dr. Tompkins was there much more of the time than I was, about just how much fallout occurred and where. But in terms of biological effects there was perhaps more agreement between the scientists than there was at the first go-around, the report that came out in 1958.

Chairman HOLIFIELD. Then you would say that it was a reasonable consensus of opinion rather than a controversial opinion that was expressed in the conclusions?

Dr. DUNHAM. Very definitely.

Representative PRICE. And not a compromise situation?

Dr. DUNHAM. No.

Chairman HOLIFIELD. Would you say that the science of genetics was well represented there as well as somatics?

Dr. DUNHAM. Yes. It was represented from this country by people like Dr. Russell and Dr. Zelle. I don't remember offhand who else was there. Paul may remember. Dr. Stevenson from England who is probably the world's outstanding human population geneticist represented his country. No; it was a good representation.

Chairman HOLIFIELD. Their working papers have been furnished you and the other people in the Atomic Energy Commission?

Dr. DUNHAM. Yes; we have seen them.

Chairman HOLIFIELD. I understand that Dr. Taylor has a set of them. While these have not been published yet, they will shortly be published.

Dr. DUNHAM. That is right. They are practically in press now. I imagine many of the chapters are actually being printed now.

Chairman HOLIFIELD. Dr. Taylor indicated that the delay was one of editing.

Dr. DUNHAM. That is correct.

Chairman HOLIFIELD. Rather than a conspiracy.

Dr. DUNHAM. No. It is just a matter of having the staff of the Secretariat editing the papers.

Chairman HOLIFIELD. And these papers will be available to people that had a definite competence in this field to look at, I suppose?

Dr. DUNHAM. Yes.

Chairman HOLIFIELD. In other words, you have these papers, and if any person credible in the scientific disciplines wanted to see these papers they are available?

Dr. DUNHAM. They are.

Chairman HOLIFIELD. I wanted that to be clear on the record because there was some indication perhaps, or the impact of some of the questions that maybe this was not being made available as soon as possible.

Dr. DUNHAM. No; they are working on it as hard as they can.

Chairman HOLIFIELD. Thank you.

Representative PRICE. Will you proceed.

Dr. DUNHAM. I was asked by your committee to discuss briefly a nuclear war scalewise as compared with fallout from weapons tests and to comment on hazard criteria.

It is important to stress that in the testing of nuclear weapons over the past 10 years we have made extraordinary efforts to minimize not only blast and thermal effects but local fallout in populated areas. Population radiation exposure levels, with the exception of relatively small population groups such as the Rongelap Island people have been well below accepted levels for normal peacetime activities.

In nuclear war, it is fair to assume that the reverse would be the case. For instance, in the hypothetical nuclear war which formed the basis for the 1959 Joint Committee on Atomic Energy hearings

on the biological and environmental effects of nuclear war, it was assumed that over a relatively brief period of time, probably not more than a day or two, a total of 3,946 megatons were detonated. All of the 263 nuclear weapons which were delivered on the United States were detonated on the ground at 224 locations within the continental United States. The yield was 1,446 megaton TNT equivalent and 723 megatons of fission, roughly six times the total yield of weapons tests through 1961 (280 megaton explosive—117 megaton fission). The effects on our people, however, would have been dramatically different. Unprepared as we were on that date, it was estimated that there would have been 50 million fatalities, about 12 million of which would have resulted from fallout. There were estimated 20 million seriously injured; 50 percent of dwellings were estimated to have been destroyed or rendered unusable for a period of several months. It is altogether conceivable that an all-out nuclear war could involve several times the megaton yield of this example; in which case the effects would be even greater. For comparison, the present concern over the possible effects of fallout from weapons tests to date, has to do with a zero to one one-hundred-thousandth chance of development of leukemia, zero to one three-hundred-thousandth chance of developing bone cancer, and a one one-millionth chance an infant being born with a gross physical or mental defect among the first generation offspring.

This should make it clear that in a nuclear war situation in which survival of a whole people is at stake, a totally different set of standards of radiological protection must be invoked. Report No. 29 of the National Committee on Radiation Protection offers criteria that are applicable to this situation. It is significant to note that this report suggests that exposures to as much as 500 roentgens may be accumulated during the emergency and produce at the time no medically significant symptoms. This is twice as much as any radiation worker is permitted to accumulate during a lifespan of 70 years under the radiation protection guides established by the Federal Radiation Council in Staff Report No. 1. There would still need to be the basic approach of keeping overall radiation exposures as low as possible. This approach is compatible with achieving the best possible total survival and recovery.

Radiation exposures that would be incurred would range from fatal in a few hours, days, or weeks to exposures comparable to what the surviving Japanese within two to three thousand meters of the hypocenters received at Hiroshima and Nagasaki.

Even our annual 40,000 deaths from automobiles pale by comparison with the nuclear war. Persons in the open in some of the very heavy fallout areas would have been exposed to three to ten thousand roentgens per hour or more. A very few minutes of that would, of course, have resulted in fatal exposure. A large percentage of the survivors, perhaps 20 million people, would have received an average whole body external radiation exposure of 200 rad, at varying dose rates, far higher than the 0.15 rad average for the lifetime exposure which has been estimated would result from weapon tests through 1961.

As to  $\text{Sr}^{90}$  and  $\text{Cs}^{137}$ , the less heavily contaminated part of the country (75 to 80 percent of the land mass) would within a few years have had values of  $\text{Sr}^{90}$  and  $\text{Cs}^{137}$  in the soil in the range of 20 to 50 times the levels likely to result from tests prior to 1961. In the more heavily

contaminated areas, levels up to a few thousand times those predicted for weapons tests through 1961 would occur.

Let us look at one example of the possible delayed or long-term medical effects of this nuclear war. Using a straight proportionality of dose versus effect as an upper limiting case as was done by the United Nations Scientific Committee on Effects of Atomic Radiation in its 1958 report, I estimate that  $\text{Sr}^{90}$  induced leukemias in the 120 million survivors and their immediate progeny would not exceed 12,000 cases in the ensuing 30 to 40 years. It might be very much less than that figure. The 12,000 figure is based on the assumption that these persons would carry an average body burden of 200 strontium units throughout this period of time.

I have assumed that these same individuals would have received an additional 4 rad of whole body radiation over the same period of time and arrive at a limiting figure of 14,000 additional cases of leukemia from that cause. On the other hand, for leukemia induction among the 20 million survivors who were estimated to have received in addition an average exposure of 200 rad during the emergency, there is a high probability of there being 60,000 cases of leukemia as a result of this exposure.

For this calculation I have used the 1960 NAS-NRC report as a basis. The latter predicted 100 cases per 100 rads of high dose rate exposure per million population in the ensuing 10 to 15 years. This gives a total number of cases of leukemia of the order of 90,000 and an average incidence rate of 2,600 cases per year, but it is possible that in some 1 year a peak of 10,000 cases might occur. After this 30- to 40-year time period the rate would fall off as an increasing percentage of the population would have body burdens of  $\text{Sr}^{90}$  of less than 200 strontium units and have whole body radiation exposures of less than 4 roentgens. It is apparent that delayed effects of radiation would not begin to approach other causes of death in any year.

Countermeasures to reduce both external exposure and contamination in food in the period after the war might be worth consideration as a way to reduce the part of such effects which would result from the addition of the first two components to the radiation exposure burden with which the survivors and their progeny would face the future. In a war of greater magnitude, where residual radioactivity would be higher and high levels would be present over a much greater area of the country, the value of instituting appropriate countermeasures would be considerably greater.

Representative PRICE. Thank you very much, Dr. Dunham.

Dr. Dunham, on page 8 you state that there is still to be determined the relative roles of horizontal and vertical transport in the holdup of high-altitude equatorial debris. What studies on this are presently being made and what else should be done?

Dr. DUNHAM. We have laid on ever since the Russian tests began last fall an intensification of our studies both by sampling at high altitude and by taking advantage of a device developed at the Argonne National Laboratory by Dr. Gustafson, a gamma spectrometer which can be sent up in a small balloon and will telemeter its readings down to the ground. We have had several successful flights from Thule, and we have demonstrated that around 110,000 feet there is a very definite layer of radioactive material. Also there is a layer in the general vicinity of 70,000 feet. I think the people who will

discuss these things tomorrow will give you much more detail on that. That is one type of approach.

Another approach is looking for possible tracers in the very large scale detonations, the two large ones of the Russians. We may be able to trace them quite specifically.

In our own tests in the Pacific, tracers have been introduced into certain of the devices so that we can get very good followup data as to where the material from any particular device goes and how long it stays in the stratosphere and where it comes out.

Representative PRICE. Do you expect the 1962 spring fallout measurements to throw any further light on the situation involved in the Soviet 60-megaton test?

Dr. DUNHAM. I think we will learn a great deal about it, definitely.

Representative PRICE. Have you had problems in connection with this so far?

Dr. DUNHAM. The problem has been only to gear up fast enough. We have had a tremendous amount of cooperation from everybody whom we have asked to help on it.

Representative PRICE. You mention at certain levels of cesium 137, humans tend to lag behind the milk level by about 6 months. Would you explain the reason for this more fully?

Dr. DUNHAM. Dr. Langham can probably give you a better answer. It is my understanding there are two factors here. One, cesium is more in meat than it is in milk and consequently a large part of the cesium comes into the diet late because meat is held before it is eaten. The other factor is that the body turns over cesium relatively rapidly, about 100 days half-life in the human body, and it takes a while to reach the equilibrium level.

Representative PRICE. On the figures of the amount of strontium 90 in the milk supply, and so forth, as a result of previous fallout, are they far below the permissible level?

Dr. DUNHAM. Yes; I think they have been well below the permissible level.

Representative PRICE. How far below would you say?

Dr. DUNHAM. Some of them have gotten as high as 30 to 40 strontium units from time to time. I think the permissible average levels for a year for the population as a whole as recommended by FRC are 66.

Representative PRICE. The mere presence of any strontium in the bone structure of a child or adult is hazardous itself. It is the presence of any strontium.

Dr. DUNHAM. Certainly no more hazardous than the normal amount of radium in people's bones. The strontium is not natural but it is the same sort of thing. It doesn't necessarily mean certainly in any given child that it is going to cause serious trouble. It is a matter of degree.

Chairman HOLIFIELD. You spoke of radium being in the natural bones of a child.

Dr. DUNHAM. Yes.

Chairman HOLIFIELD. What is the measurement there in relation to the strontium 90 which has been absorbed?

Dr. DUNHAM. In general the radium content of bones on the average is relatively low. There are certain areas in the country, and I think Mr. Price knows where I am referring to, in which the local

water supplies come from deep wells, the children there have radium 226 and 228 levels that are producing radiation to the bone two to three times background. This is many times the dose from levels of strontium 90 expected from fallout from weapons tests to date.

Chairman HOLIFIELD. Are the amounts you speak of of strontium 90 absorbed in infants' and children's bones, is this enough to start cancerous action on the bone cells?

Dr. DUNHAM. We don't know. This is the area that we are trying to work on very hard. We had a 2-day session last week with people from the Argonne and Oak Ridge National Laboratories to get the final signals on these large-scale multimouse experiments aimed at trying to get the shape of the curve at these low levels.

As I pointed out in my testimony, most of the newer information coming in suggests that when you are talking about a low level chronic exposures situation you are dealing with much less effect than taking the original straight linearity proportional curves that were developed several years ago in relation to acute whole body radiation.

Chairman HOLIFIELD. Is this buildup to strontium 90 to, I believe you said, as much as 60 percent of the maximum permissible level which has been set—

Dr. DUNHAM. That is not in the bone, sir. That is the general ground rule for what is permissible in milk. The bones are running an average of around three strontium units as opposed to 66.

Chairman HOLIFIELD. I am glad to have that clarified. I could hardly accept the fact that the bones have absorbed up to 40 percent of the allowable.

Dr. DUNHAM. No.

Chairman HOLIFIELD. The evidence you have to date is that it is 5 percent.

Dr. DUNHAM. The average is about 4 to 5 percent.

Chairman HOLIFIELD. Of the allowable?

Dr. DUNHAM. Yes. There have been a few samples that have been as high as 5.1 strontium units which would be roughly 8 percent.

Chairman HOLIFIELD. When we are talking about micromicrocuries, as we are talking now, we are talking about the tremendously small particles or elements, are we not?

Dr. DUNHAM. We are talking about very small quantities.

Chairman HOLIFIELD. Is there any laboratory evidence to show that a 3-percent absorption of the allowable has produced somatic effects to the bones of mice?

Dr. DUNHAM. No; it would take several million mice to show that. We are having enough trouble showing that a hundred times that produces an effect.

Chairman HOLIFIELD. I am asking these questions not to minimize—

Dr. DUNHAM. No; this is a practical problem.

Chairman HOLIFIELD. But to put it in the proper perspective. I think this committee's work in producing the facts is probably the most valuable work that it has done in that we have tried to bring the facts out from the most credible witnesses possible. We leave up to people the interpretation of those facts. Some of them are interpreted in very sensational ways and they cause a great deal of concern and anxiety among people who are not qualified to recognize the rela-

tive values that we are talking about. A micromicrocurie means nothing to a layman. They don't understand that this means a millionth of a millionth of a curie. They further do not realize the somatic or genetic effect, that the detection of either the somatic or genetic effect when you are dealing in such small fractions of a curie has been impossible to determine in our laboratories. Because they do not realize that, the scare literature that is circulated has caused many people to quit feeding milk to their children or in some instances to quit feeding bread made from wheat in certain areas of the country. I think it is very important that this be understood without exaggeration either upward or downward and in its true relation to its facts.

Dr. DUNHAM. That is why I think this FRC report will be a very helpful supplement to your proceedings.

Representative PRICE. Dr. Dunham, in your statement you referred to uptake in plants of accumulated strontium 90 in the soil. Does this mean that strontium 90 continues to contaminate food long after the fallout has stopped coming down?

Dr. DUNHAM. That is right.

Representative PRICE. Is this true of cesium 137?

Dr. DUNHAM. Much less so because cesium tends to get bound in the soil. The strontium stays much more readily available.

Representative PRICE. I think you said someone else would be in a position to deal with these temporary heavy fallouts in different areas.

Dr. DUNHAM. That is right. You are talking about radioiodine?

Representative PRICE. Yes.

Dr. DUNHAM. I believe somebody from the Public Health Service is going to give the more recent data for the last few weeks on iodine 131 in the milk.

Representative PRICE. Does Argonne have a national monitoring effort to determine the amount of fallout throughout the country?

Dr. DUNHAM. Argonne itself has been monitoring fallout since 1952. They were the first group to actually measure and point up the importance of short-lived gamma emitting activities as far as the whole body exposure from fallout is concerned. They were able to identify and measure the zirconium-niobium component and barium-lanthanum. I think that material first appeared at the last hearings.

Representative PRICE. What do you mean by cesium 137 air concentration?

Dr. DUNHAM. Just how much passes by in the air but it doesn't necessarily get down in the ground or food unless the rain brings it down.

Representative PRICE. In a given area?

Dr. DUNHAM. That is right.

Representative PRICE. You speak of newer observations all indicating the hypothesis of the straight proportionality of biological effect. What are these newer observations?

Dr. DUNHAM. I might mention a few. I think first and perhaps one of the most interesting is the fall off in the number of new cases of leukemia in Japan among the surviving population. The straight proportionality figures and estimates based on that assume that these number of cases would continue. Similarly, the study in England of the arthritis cases that got radiation therapy, there have been no new

cases of leukemia in them in the last few years. This is why the academy report talks about so many cases in the first 10 or 15 years. So much for those.

Then there is the data that Dr. Upton and Firth and a number of people developed on 7,000-odd greenhouse mice which were subjected to acute whole-body radiation in which he found there seemed to be an optimal dose for each type of leukemia and cancer that was induced. The minute you varied from that dose you got into a much lower incidence of that particular effect. The group at Argonne have just finished and are reporting on an experiment involving about the same number of mice showing that in terms of lifespan the time you get down below 5 roentgens per day, which is still a fairly high dose rate, other factors seem to be more important in effecting the lifespan than the radiation itself, except in particularly rugged creatures.

Representative HOSMER. You mean by other factors, unrelated to radioactivity?

Dr. DUNHAM. General health of the animal and that sort of thing.

Then one other very interesting group of experiments was done by Dr. Mole at Harwell in England. He has by varying the dose and using fairly high dose rates and giving a total dose of 700 roentgens over a period of 6 or 7 weeks obtained the maximum cases of leukemia in his mice. If he uses a continuous low level exposure up to the same dose over the same period of time it is very much lower. All of these things point in that direction. They do not necessarily prove or indicate that there is a threshold but certainly the effects, as the FRC said, are very much lower from low dose rate continuous chronic rate of exposure.

Chairman HOLIFIELD. With a massive dose you have a destruction of the red corpuscles where in the gradual dose you have the regenerative effect in the blood of replacing the corpuscles that have been damaged or killed.

Dr. DUNHAM. This is certainly one of the factors.

Another thing I might mention. Davies, a British plant geneticist, has shown there is a big dose rate effect in somatic mutations in plants. It is hard to get at somatic mutations in humans. But in plants you can do this. He has found a factor of 10 between 85,000 roentgens per hour and 25 roentgens per hour in somatic effects. This I think is important because much of the proportionality hypothesis was based on the idea that maybe these effects were due to somatic mutations.

Representative PRICE. Mr. Ramey.

Mr. RAMEY. Dr. Dunham, I think each session we have on this subject we always inquire as to the status of research generally in the field of fallout. Are you getting enough financial support these days?

Dr. DUNHAM. I ought to ask Mr. Holland about that if you are talking about the sampling program. I think we will get enough support.

Mr. RAMEY. Not just sampling but research on low level effects.

Dr. DUNHAM. I think we are moving as fast as the available manpower will let us. Perhaps not completely optimal. We have the facilities now, thanks to your committee. I think we are moving ahead with this program all right now.

Mr. RAMEY. Would it be possible to give us a little supplementary statement on how much money is being expended in this general field comparable to the statement you gave us a few years ago?

Dr. DUNHAM. We will be happy to prepare one.

Chairman HOLIFIELD. Did you ever get into the large animal experiments that we talked about a year or two ago?

Dr. DUNHAM. That is the one about which we had this meeting with the group from Argonne and Oak Ridge. Oak Ridge will do the whole body external studies in 10 to 20 thousand mice per experiment. The Argonne will do it with strontium 90 and some of the other internal emitters. There is also developing a fairly large-scale dog program at Argonne.

Representative PRICE. You were talking about larger facilities for cattle and so on. You were talking about those at one time.

Dr. DUNHAM. We have not gotten into really large-scale studies in cattle. The expense goes up quite a little when you go into that. We have the swine project at Iowa which is a straight quantitative genetics project which involves six to eight thousand little piglets born every year.

Chairman HOLIFIELD. That is a considerable advance over what you had a few years ago.

Dr. DUNHAM. Definitely.

Chairman HOLIFIELD. We were not in this swine work at all hardly.

Dr. DUNHAM. No; we were not doing it before. I think we are definitely moving out of the horse-and-buggy stage and try to catch up with our other programs, with Dr. Russell's work, which sort of set the pattern of what can be done. You are familiar with his results in genetics studies.

Chairman HOLIFIELD. With mice you can do it much cheaper?

Dr. DUNHAM. Much cheaper.

Chairman HOLIFIELD. What about the comparative results in extrapolation from mice or swine?

Dr. DUNHAM. This is why we have chosen some other species to go into, like the swine, simply so we don't get caught with something very unusual about the mouse that is not the case in swine. We are doing it also in rats.

Chairman HOLIFIELD. The question is whether man resembles a mouse or a pig.

Dr. DUNHAM. In some respects the man's hide from what the dermatologists and people studying flash burns say is much more like that of a pig than it is of a mouse. On the other hand, as you know, alcohol protects a mouse against radiation but in terms of a man the dose would be a little lethal.

Chairman HOLIFIELD. I knew there was some good in alcohol.

Representative PRICE. Will the U.S. space programs such as Rover produce fallout?

Dr. DUNHAM. Not of the sort of thing we are talking about with megaton weapons. There is the problem as the program gets underway, particularly if they begin to use the Rover devices as the first stage of a certain amount of fissionable material being released. We are talking in terms of something comparable to very low kiloton detonations. It will be released along the way. If one of these devices after it has been used up were to reenter and burn up completely in the

stratosphere, or if it lands in the ocean, we will have a certain amount of contamination. Our program is oriented to try to define those problems well in advance.

Representative PRICE. Are there any other questions?

Chairman HOLIFIELD. I would just like to compliment Dr. Dunham on his testimony today. I think this is a very fine piece of testimony, Doctor.

Dr. DUNHAM. Thank you.

Representative PRICE. Thank you very much, Doctor. I am sure that other members of the committee also join in that compliment and appreciate having your testimony.

That will conclude the hearing for this afternoon. The committee will resume its hearings tomorrow morning at 10 o'clock.

(Whereupon, at 4:50 p.m., Monday, June 4, 1962, the committee recessed, to reconvene at 10 a.m., Tuesday, June 5, 1962.)

## RADIATION STANDARDS, INCLUDING FALLOUT

TUESDAY, JUNE 5, 1962

U.S. CONGRESS,  
SUBCOMMITTEE ON RESEARCH, DEVELOPMENT, AND  
RADIATION, JOINT COMMITTEE ON ATOMIC ENERGY,  
*Washington, D.C.*

The subcommittee met, pursuant to recess, at 10 a.m., in room AE-1, the Capitol, Hon. Melvin Price (chairman of the subcommittee) presiding.

Present: Representatives Price, Holifield, Aspinall, Hosmer, and Bates; and Senator Aiken.

Also present: James T. Ramey, executive director; John T. Conway, assistant director; Kenneth S. McAlpine, Jack R. Newman, and George F. Murphy, Jr., professional staff members, Joint Committee on Atomic Energy.

Representative PRICE. The committee will be in order.

Yesterday, the first day of our hearings, we received testimony of an introductory nature on both radiation standards and fallout.

Today we will spend the entire morning and afternoon sessions on worldwide fallout since 1959. Following the scientific witnesses this morning and early afternoon, we will have a prediction panel of experts on prediction statement on fallout from U.S. nuclear testing.

Dr. Lester Machta of the U.S. Weather Bureau is our first witness this morning. I would also like to add that I hope all our witnesses today will try to keep to their allotted time.

Dr. Machta, will you come forward.

The Chair would also like to make a further announcement. In order to maintain order and the proper decorum of the committee, it would be appreciated if only members and staff members would come behind the horseshoe. Any communication should be handed to staff at the end of the hearing table.

Dr. Machta, will you come forward, please.

**STATEMENT OF LESTER MACHTA,<sup>1</sup> CHIEF, METEOROLOGICAL  
RESEARCH PROJECTS BRANCH, U.S. WEATHER BUREAU**

Dr. MACHTA. Mr. Chairman, if I may, I should like to submit my written testimony for the record and devote my time to a discussion of a few of the placards in order that the less technical aspects be brought out in verbal testimony.

Representative PRICE. That will be all right. We may question you a little on the complete statement.

(The statement referred to follows:)

**WORLDWIDE FALLOUT SINCE 1959—METEOROLOGICAL ASPECTS**

Statement prepared by Dr. Lester Machta<sup>1</sup> and Mr. Kosta Telegadas,<sup>2</sup> U.S. Weather Bureau, for the hearings on radiation standards, including fallout, of the Joint Committee on Atomic Energy during the period June 4-7, 1962

The purpose of this presentation is threefold: First, to report observed inventories of strontium 90; second, to describe the latest findings of the seasonal and geographical distribution of fallout; and third, to review current ideas on the behavior of the stratosphere in transporting bomb debris.

**INVENTORY CALCULATIONS**

**1. Pre-Soviet 1961 inventory**

Figure 1 displays the strontium 90 content of the atmosphere (divided into the troposphere up to between 30,000 to 55,000 feet and the stratosphere overlying the troposphere) and the worldwide strontium 90 fallout as of May 1961. The table shows that over 80 percent of the strontium 90 had already been deposited just before the Soviet 1961 resumption of atmospheric testing. It also indicates that the stratosphere was still the prime reservoir of the airborne radioactive debris. Figure 1 further reveals an unexpected approximate equality of stratospheric content between hemispheres. One should remember that all (or almost all) of the stratospheric injections took place in the Northern Hemisphere. We shall later see that there are very meager data in the Southern Hemisphere, and it may be that equality is not entirely well founded.

Figure 2 compares the total observed inventory of strontium 90 at three times. These numerical values show good stability and a decrease, during a period of no additional injections, as expected from the slow radioactive decay of strontium 90. On the lower line, a similar series of numbers is given as derived from the official AEC announcements on fission yields and using a conversion of 1 megaton of fission product energy equaling 0.1 megacurie of strontium 90.

Both the observed inventories and AEC derived estimates contain uncertainties. The observed data are based on only a limited number of sampling

<sup>1</sup> Dr. Lester Machta: Dr. Lester Machta is Chief of the Meteorological Research Projects Branch, Office of Meteorological Research, U.S. Weather Bureau, Department of Commerce. Dr. Machta received his Sc. D. from Massachusetts Institute of Technology in 1948 at which time he joined the Weather Bureau to begin his studies on atmospheric radioactivity. He was a member of the U.S. International Geophysical Year Nuclear Radiation Committee, is currently a member of the World Meteorological Organization's Panel of Experts on Atomic Energy, and in 1958, went to Geneva with the U.S. delegation on atomic test moratorium conference. As an adviser to the Atomic Energy Commission, he has participated in several of the U.S. atomic series. He has been an adviser on the U.S. delegation of the United Nations Scientific Committee on the Effects of Atomic Radiation and on the Working Group of the Federal Radiation Council. He is a rapporteur for the Meteorology Committee of the National Academy's Committee on the Biological Effects of Atomic Radiation.

Dr. Machta was born in New York, N.Y., in 1919, graduated cum laude from Brooklyn College in 1939. His meteorological training also includes graduate work at New York University (master of arts, 1946). During the war he taught meteorology in both a civilian and military capacity for the Air Force. He is a member of Sigma XI, Pi Mu Epsilon, the American Meteorological Society, and the American Geophysical Society, and has been given a gold medal for exceptional service by the Department of Commerce. His publications in the meteorological literature are numerous, and in recent years, include many papers on atomic energy and meteorology.

<sup>2</sup> Kosta Telegadas: Meteorologist, U.S. Weather Bureau: Associated with atomic energy and meteorology since coming to Washington in 1955. Born in New York, N.Y., in 1924, graduated from New York University in 1950. His meteorological training includes graduate work at New York University (master of arts, 1951), and from 1951-55, as a research assistant at New York University. He has served with the Fallout Prediction Unit on Operations Redwing, Plumbbob, and Hardtack phases I and II.

points on the earth's surface and in the atmosphere. An especially serious source of error is due to possibly greater fallout over oceans. This will be discussed shortly. There is a large uncertainty in the fraction of the U.S. Pacific test strontium 90 which deposited as local fallout and was thus unavailable for worldwide fallout. The numbers in the lower row assume that about a third of all the strontium 90 was deposited as local fallout. This number, 3 megacuries, as evidenced by the question mark, is uncertain and there is some reason to believe that it may be too high. Assuming that the fission yield information, the 9.2 megacuries, is approximately correct, a smaller local fallout could create a larger and possibly significant discrepancy between the two approaches. If there really is more worldwide fallout available than has been estimated from the 3 megacuries of local fallout, this extra amount is most likely in the oceans where we have been unable to properly measure it.

## 2. The Soviet 1958 and 1961 inventories

The Soviet Union conducted a large nuclear test series in the autumn of 1958. The AEC estimated that between 1.25 and 1.50 megacuries of  $\text{Sr}^{90}$  were added to the atmosphere. By dating from short-lived isotopes, it was possible to distinguish with some confidence between the radioactivity from this and other sources. The numbers in the first column show that of the approximately 0.80 megacurie accounted for from actual observations (fig. 3), 80 percent had fallen out by the end of 1959. There is a discrepancy between the 0.80 megacurie and the AEC release, however. The most likely explanation is the greater oceanic fallout which would raise the 0.63 and, if true, would argue that even more than 80 percent had already fallen out.

The second column, the inventory for the 1961 Soviet tests, cannot yet be properly completed. As will be seen later, it appears that fallout in 1962 is roughly the same as that in 1959 and on this basis, one can estimate about 0.2 megacurie of Soviet strontium 90 deposition up to March 1962. The stratospheric inventory to 70,000 feet has been computed by the Defense Atomic Support Agency and their contractor, Isotopes, Inc., based on U-2 aircraft sampling. The sum of the two numbers, 0.2 and 1.3, is 1.5 megacuries. Again, there is a discrepancy but here, the explanation is more likely to be inadequate stratospheric sampling as seen in the next placard.

Figure 4 shows a north-south cross section of the atmosphere. The horizontal axis is so arranged that equal lengths cover equal areas of the earth's surface. The vertical axis is altitude in feet. The average position of the tropopause, with the troposphere below it and the stratosphere above it, is indicated at about 50,000 feet south of 30° N. and at about 30,000 feet north of 30° N. It has at least one break in each hemisphere and, particularly in the stormy temperate zone, undergoes large day-to-day changes in height. The placard shows that the construction below 70,000 feet reaches a maximum in the polar regions and near the latitude of the Novaya Zemlya Soviet proving grounds. The zone of greatest radioactivity concentration slopes upward toward the equator where the radioactivity becomes less concentrated. Some of the Russian debris has reached the equator and passed into the Southern Hemisphere by April 1962. This has been confirmed by the AEC balloon flights in southern Australia at 50,000 feet from February through April 1962. This picture, it must be remembered, preceded any U.S. atmospheric testing and subtraction of the pre-Russian 1961 radioactivity was accomplished with little difficulty.

At present only balloons are capable of sampling above about 70,000 feet. The AEC has a station which operates an air filtration unit with the cooperation of Air Force at San Angelo, Tex., and the profile of Russian debris for the month of February 1962 is given as the horizontal lines emanating from the vertical line located at about 30° N. latitude. The peak coincides with the peak concentration detected by the aircraft and at 70,000 feet, it appears as though the nuclear cloud has been topped. But at 90,000 and 100,000 feet, it is evident that here is a tendency for increasing concentrations once again. Dr. Gustafson, of Argonne National Laboratory, with AEC, Air Force, and Weather Bureau participation flew a different kind of monitoring instrument at Thule, Greenland, in April and the horizontal bars at about 80° N. show the results of his measurements. Although this peak does not exactly coincide with the peak in the aircraft profile there is again evidence of increasing radioactivity at higher altitudes. It must be concluded that the inventory calculation to 70,000 feet has neglected those Soviet clouds which rose to great heights, a condition fully recognized by the Defense Atomic Support Agency group constituting the inventory.

## THE GEOGRAPHICAL DISTRIBUTION OF FALLOUT

There are two prime means of monitoring deposited radioactivity; soil sampling and pot or funnel collectors. The preferable method is soil sampling because it is nature's measure of accumulated radioactivity. The results of the latest available analyses in 1960 are given in figure 5. The isolines delineate locations with equal amounts of strontium 90 deposition and the darkened areas show the areas of heavier fallout. The dots indicate the locations at which soil samples were collected by Dr. Alexander of the U.S. Department of Agriculture and analyzed by the Health and Safety Laboratory of the AEC. The interpolation between sampling places has been performed by the Weather Bureau assuming that there is a relationship between fallout and rainfall; the more rainfall in a given climatic region the more the fallout. It is evident that levels of fallout are greatest in the North Temperate Zone.

Fallout is greater over oceanic than over land areas because rainfall is greater. There is a suggestion from data collected in the oceans and seas both by Dr. Bowen of Woods Hole and from certain Soviet studies, that there may be additional mechanisms over large water bodies which further enhance the fallout. One such is the capture of the radioactive aerosols by heavy salt particles which then settle out into the ocean. The problem of oceanic deposition is among the main unresolved scientific questions on fallout. The magnitude of the removal by impaction on herbage and other vertical surfaces is another source of present-day ignorance on fallout. The research in the areas of the rainout mechanism under Federal sponsorship has, however, made notable gains since 1959.

The somewhat heavier fallout in the Midwest United States is probably attributable, in part, to the extra fallout from Nevada atomic tests. However, a comparison of the north-south profiles of the fallout during the interval mid-1959 to mid-1960 when there was no Nevada fallout, showed the same general peak at about 40° N. Thus, it is probably that not all of the Midwest fallout excess can be attributed to the Nevada tests.

For the most part, except immediately downwind of a proving ground, the strontium 90 fallout is derived from powerful tests which lift their nuclear clouds into the stratosphere.

Figure 6 displays a north-south cross section of the accumulated strontium 90 fallout. The vertical axis has the deposition increasing upward. The uppermost line shows the cross section of the total strontium 90 fallout from all tests before mid-1961. This is derived from the soil picture of the previous placard on which the accumulated fallout was presented up to mid-1960 plus the fallout for the ensuing year. The increment since mid-1960 is obtained from the second method of measuring fallout; collecting precipitation in pots and funnels each month. The Atomic Energy Commission, whose data have been here used, has a worldwide network of approximately 125 stations making such incremental collections.

This line brings out more clearly the peak in the 30° to 60° N. band and the presence of a secondary peak in the 30° to 60° S. band, with equatorial and polar minima. It should be mentioned that virtually no samples are taken south of 40° S. latitude. The amount of precipitation decreases toward the poles and this may well account for the decrease in fallout toward each end of the graph but this is not the case in the equatorial regions. The equatorial minimum results from lower air concentration, confirmed by the extensive ground level U.S. Naval Research Laboratory measurements and limited aircraft observations in the troposphere. It is concluded by virtually all scientists in the fallout field that the temperate or polar regions are the part of the earth's atmosphere where the stratospheric-tropospheric exchange takes place. This high latitude exit from the stratosphere accounts for the lower air concentrations in the troposphere near the Equator.

The middle line shows the fallout from the Soviet October 1958 tests during the year 1959. This 1-year period has been chosen because the fallout is likely to be of stratospheric origin (the tropospheric component having been largely washed out by 1959) and because the end of 1959 is about as late as one can reasonably distinguish between Soviet October 1958 fallout and other sources. It should be recalled that by the end of 1959, about 80 percent of the Soviet October 1958 strontium 90 had already been deposited.

This line is believed to lie entirely within the Northern Hemisphere and peaks in the temperate zone. It is for this reason that predictions of fallout from Soviet 1961 nuclear tests were forecast to affect the Northern Hemisphere

clusively. Finally, the lowest curve reflects the geographical distribution of S. debris added to the lower equatorial stratosphere in the summer of 1958 and also deposited in 1959. The year 1959 was chosen to compare it with the Soviet fallout curve as well as for other reasons. It is based on tungsten 185 which was a unique tracer for the U.S. Pacific 1958 tests. An arbitrary but reasonable relationship between tungsten 185 and strontium 90, derived from study by Hardy of the AEC, permits one to compute the strontium fallout. It is clear that fallout from the equatorial source is distributed more widely than the Soviet fallout and close scrutiny will again reveal peaks in the temperate zones of each hemisphere. The 1959 fallout in the Northern Hemisphere from the U.S. tests was about twice that in the Southern Hemisphere. For comparison with the 80 percent of the Soviet fallout, the fraction of strontium from the 1958 U.S. Pacific tests which was deposited during 1959 was about 10 percent thus reflecting the faster fallout from polar than from equatorial clear clouds.

#### SEASONAL VARIATIONS

Figure 7 shows the seasonal variation of Northern Hemisphere fallout for the year 1959. The horizontal axis is time in months, with the spring season shaded and the vertical axis shows strontium 90 fallout per month, increasing upward. The uppermost line shows the total amount of deposition in the Northern Hemisphere while the middle and lowest lines show the fallout contribution to the total from the U.S.S.R. 1958 and U.S. 1958 Pacific tests respectively. All three curves indicate that during 1959 the spring season was a period of heaviest fallout.

The table on the placard indicates that during the spring of heaviest fallout prior to 1962, that is in 1959, of the total fallout, 73 percent was of Soviet October 1958 origin, about 13 percent could be identified as U.S. Hardtack number 1958 origin marked by the tungsten and the remaining 14 percent from all other sources.

The seasonal variation of Northern and Southern Hemisphere fallout from 1958 to the most recent period of data availability is displayed on figure 8. The horizontal axis is time with the calendar year labeled below and the vertical axis shows the amount of strontium 90 fallout per month, increasing upward. The spring for each hemisphere is identified. The lower curve displays the Southern Hemisphere fallout picture. If the spring were always the time of maximum fallout, the lower curve should peak at each Southern Hemisphere spring and dip at each Southern Hemisphere fall through which it passes. In the latter half of 1960 and onward is this true however. The dashed portion of this curve (in late 1961), is based on incomplete data.

In the Northern Hemisphere, the upper curve, one finds a very clear-cut seasonal trend with each April-May showing a maximum and October-November as a minimum. This, it should be noted, is true even though in 1960 and 1961 there were no atmospheric nuclear tests during the previous fall. It had been speculated that a possible explanation for the spring maximums prior to 1960 was a delay in the fallout from Soviet tests the previous autumn. This seems now not to be the case, although it is clear that the presence of large amounts of Soviet stratospheric debris, as in 1959, greatly enhances the magnitude of the spring peak.

Since it appears likely that the spring peak is meteorologically induced (it occurs in other stratospheric tracers like cosmic ray created beryllium 7 analyzed by Gustafson at Argonne and by the British), why does it not occur regularly in the Southern Hemisphere? There are two likely explanations. First, it is noted that until 1960, the Northern Hemisphere troposphere contained much more radioactivity than the Southern Hemisphere, as evidenced by the upper versus the lower curves. There is other evidence of cross-equatorial mixing which can bring radioactivity from the more contaminated to the less contaminated hemisphere. Thus, the Southern Hemisphere may have had two sources of strontium 90, the first from the stratosphere which may be showing seasonal regularity and a second source, the Northern Hemisphere troposphere, with an entirely different season of injection into the Southern Hemisphere troposphere. Then, in 1960 and 1961, when the air content of both hemispheres leveled to equality in the troposphere (see fig. 8), as well as in the stratosphere (noted earlier), the controlling seasonal factor in the Southern Hemisphere became the stratosphere.

Hence, the appearance of seasonal regularity in the Southern Hemisphere, which many meteorologists expected, in 1960 and 1961. The other explanation

for the lack of a seasonal variation in the South Hemisphere depends on a different behavior of the Southern Hemisphere stratosphere. There is evidence gleaned from the International Geophysical Year weather data that differences do exist.

For example, both hemispheres in winter have a quasi-circumpolar vortex in the polar regions, close to, but not necessarily symmetrical about the pole, with strong winds observed to extend upward from 70,000 feet. In the Northern Hemisphere this vortex breaks down into waves and is accompanied by sudden temperature increases in a few days which have been observed to occur sometime between late January and April, either before or after the vernal equinox (the first appearance of sunlight at the north pole). In the Southern Hemisphere there can either be a sudden or a gradual temperature change neither of which has been observed to occur until after the vernal equinox.

To complicate matters this past winter and spring, the Northern Hemisphere vortex did not undergo a sudden breakdown but was similar to the gradual one found at times in the Southern Hemisphere. The importance of this phenomenon may be greater than one realizes. Many meteorologists attribute the sinking motions or mixing in the polar regions to the sudden breakdowns of the circumpolar vortex. This sinking or mixing is believed to be the method by which radioactivity and other tracers are dumped into the lower atmosphere. Time will tell how seriously this disparity of 1962 from previous years in the Northern Hemisphere stratosphere will affect the pattern of the spring 1962 fallout.

Before turning to the latest fallout data from Soviet 1961 tests, some comments on special injections marked with unique tracers may be of interest. The seasonal variations of the tungsten, which it will be recalled was injected in the lower equatorial stratosphere, indicated a peak in the Northern Hemisphere spring but no apparent peak during the Southern Hemisphere spring. It could be noted that the fallout of radiotungsten was considerably greater in the Northern than in the Southern Hemisphere so that the cross-equatorial tropospheric flow may possibly have accounted for the disruption of the Southern Hemisphere seasonal variation. Figure 9, however, shows data for an isotope, rhodium 102, which contains a seasonal trend of the expected type in both hemispheres. The rhodium was derived from the August 12, 1958, rocket nuclear event at Johnston Island at a latitude of 17° N.

Later we will note that the rhodium appeared in the stratosphere near the poles of both hemispheres in about equal concentrations. This isotope, then, is not higher in the Northern Hemisphere as were all of the other previously viewed tracers. There is clearly a spring maximum and an autumn minimum in the appropriate stations at Santiago, Chile, and at Argonne National Laboratory in Illinois, both slightly delayed. This result strongly supports the first explanation for the absence of a seasonal trend in the Southern Hemisphere—the one which blames the lower atmospheric cross-equatorial mixing for confusing a regular seasonal trend from the stratosphere.

Figure 10 now brings up to date the recent fallout. The lag in analyzing fallout has restricted the very recent results to one station, air concentration measurements of cesium 137 at Argonne National Laboratory from Soviet 1961 tests. Where data are available for earlier months at other locations there is substantive agreement with the Argonne results. One way view the cesium and strontium trends interchangeably since both have about the same half-lives; although the concentrations of cesium 137 are about twice those of strontium 90. The curve indicated as 1961 U.S.S.R. shows that there is an upward trend in the cesium 137 beginning in October 1961 and continuing through May 1962 as predicted from earlier findings.

For comparison, two other curves are given. The high-peaked curve shows the history of cesium 137 fraction attributable to the Soviet October 1958 series. It is evident that the fallout in 1962 is about the same or perhaps slightly lower than occurred after the Soviet October 1958 tests in the Chicago area. In 1960-61, the levels of cesium 137 had decreased very considerably as seen in the lowest curve. The new atmospheric tests in 1961 raised the levels by about a factor of 5 to 10. The full history of the spring 1962 must await more complete results. It should be noted that the fission yield of the 1958 Soviet series was about half that of the preliminary estimate for the 1961 Soviet tests and simple extrapolation would suggest a doubling of fallout in 1962 over 1959. This now seems to be unlikely, probably due to the greater altitude of the nuclear clouds.

## MODELS OF STRATOSPHERIC TRANSPORT

The earliest predictions of fallout from nuclear test clouds injected into the stratosphere were of two varieties. First, a mathematical model was, and is still being used, in which the stratosphere is assumed to be a thoroughly mixed reservoir. Material added anywhere in the stratosphere would be completely mixed within it in a matter of days, weeks, or a few months and leaks slowly into the troposphere below. Such a model permits a numerical treatment in which the holdup by the stratosphere may be characterized by a "residence" time. Specifically, the half-residence time is the time required for half of the material in the stratosphere to enter the troposphere. Early and preliminary estimates for equatorial injections suggested a 5- to 10-year residence time which was subsequently reduced to a few years. Then, with the advent of readily distinguishable Soviet polar fallout, the residence time for the Soviet debris was estimated to be much shorter than a few years. Finally, the half-residence time of the U.S. high altitude fallout was estimated to be much longer than a few years. Thus, it became evident that the half-residence time varies with the latitude, altitude, and season of the test and further, the half-residence time might change from year to year even for the same point of injection. The concept of half-residence time is still probably the simplest way of comparing fallout rates from different tests.

The meteorologist, on the other hand, has tried from the first to model the stratosphere with the best possible concepts of circulations and mixing processes. But unable to be quantitative, he has failed to provide real help to the fallout predictor. Nevertheless, there is qualitative and semiquantitative information which is derivable from truly meteorological models of the stratosphere and these will be discussed below.

The earliest model brought to the attention of the fallout field was that derived from ideas expressed by two distinguished British scientists, Brewer and Dobson. They speculated that the dry air observed in the lower stratosphere over England could best be accounted for by the air having previously passed through the tropopause region at the Equator. Here the air temperature is very cold and literally can wring the air dry. Stewart in England and then Machta suggested models which, as seen in figure 11, had fountains of rising air in the lower equatorial stratosphere and compensating subsiding air poleward. Some early bomb carbon 14 measurements led Machta to extend the upward motions to at least 80,000 feet, while Stewart was, wisely, less specific.

This modified Brewer-Dobson picture explained a number of the observed characteristics of fallout. Though the early stratospheric injections were made near the Equator the peak in fallout was in the temperate zone. This is understandable from the poleward motions. There was an unequal partitioning between hemispheres, presumably due to the Eniwetok clouds having been caught mainly in the Northern Hemisphere circulation arm. Brewer and Dobson on the basis of certain meteorological considerations, also predicted a maximum exit from the stratosphere in late winter or spring. This too is, as noted earlier, a feature of the fallout pattern.

The death knell for a theory of rising air to altitudes of over 80,000 feet over the Equator resulted from the tungsten experiment. The stratospheric measurements, illustrated by figure 12, disagreed with the model. In this placard, the horizontal axis is again latitude, the North Pole to the left, the South Pole to the right, and the Equator in the center. The vertical axis is height increasing upwards in thousands of feet. The solid-dashed lines are the tropopause. The observation points are indicated by the black squares. The isolines delineate lines of equal concentration of tungsten 181, an isotope injected in the lower equatorial stratosphere over Eniwetok in the summer of 1958. This figure shows the distribution of the material about  $2\frac{1}{2}$  years later, in November 1960. If there were an upward current as envisaged in the previous placard, the maximum concentration would have moved away from the source. But this is not the case; the highest concentration of radiotungsten is still in the vicinity of the source region at  $11^\circ$  N. Thus, the radiotungsten tracer experiment has proven invaluable to the meteorologist in eliminating one kind of circulation model.

But Brewer and Dobson never claimed that the fountain reached to 80,000 or even 70,000 feet. Two other British scientists, Brown and Goldsmith, have tried to rescue the rising current model as shown by their picture in figure

13. The rising current through the equatorial tropopause is still present, but the height to which the fountain rises is very much lower over the Equator. Elsewhere the transport process is purely mixing, a mechanism which can leave the highest concentration at the source position while diffusing it away at the edges. There is still evidence from water vapor and ozone observations that some kind of rising motion occurs near the equatorial tropopause. This upward movement is now restricted to just 5,000 or 10,000 feet above the tropopause, the maximum extent allowed by the tungsten data.

An alternative solution was proposed by the HASP analysts and is illustrated in figure 14. In 1958 and 1959, the HASP sampling program had already detected the downward slope of the zone of maximum concentration of the tungsten and the persistence of the maximum concentration at the latitude of injection. This fitted their original view that virtually all of the movements of bomb debris could be described by a model in which only mixing processes were present. The mixing is indicated by arrows in both directions along surfaces which slope downward toward the poles.

Not all of the details of the HASP model are shown in the figure. Thus, it is argued that the horizontal mixing close to the Equator is slower than away from the Equator. Hence, the U.S. injections at 11° N., at the Eniwetok Proving Grounds, have an easier time mixing into the Northern than into the Southern Hemispheres; and more fallout is observed in the Northern Hemisphere from this source. Second, the thermal stability just above the equatorial tropopause will inhibit an exit into the equatorial troposphere. In fact, the HASP analysts favor an exit through the breaks in the tropopause as the main mode of entry into the troposphere. The maximum "storminess" occurs in the winter and early spring period which accounts for the seasonal variation in fallout. The HASP model is appealing in its simplicity of having only one mode of transport mixing, and does explain the observed fallout features without undue difficulties.

Before leaving the subject of movements of air in the stratosphere, one further figure, 15, may be of interest. This shows the stratospheric distribution of rhodium 102, the tracer that was added to the very high atmosphere, over 300,000 feet according to reports, in August 1958 over Johnston Island. The squares are the observation points and the solid-dashed lines are the tropopause. It is apparent that the highest rhodium concentrations up to about 70,000 feet lie in the polar regions at the highest observable altitudes. Further the concentration in the Southern Hemisphere is at least as high as in the Northern Hemisphere despite Johnston Island being 17° in the Northern Hemisphere.

It is apparent that the Johnston Island rocket injection debris was, more or less equally partitioned between hemispheres. Since there is a possibility of large-scale, high-altitude radioactivity injections during a nuclear war by antimissile missiles, it is of some consequence to know whether an injection at say, 45° N. would behave like that of the Johnston Island tests. At present we think it will.

There is also a lack of agreement on an equally important subject, the region of exit from the stratosphere. It has been suggested that the transfer of radioactivity and tracer material from the stratosphere into the troposphere can occur by at least three mechanisms. Three important exchange processes are:

1. Through the gap which is normally situated between the tropical and polar tropopause.
2. By a continuous and gradual mixing across the tropopause.
3. By the day-to-day or seasonal variability in tropopause height which may leave behind pools of stratospheric air in the troposphere.

Which of these three mechanisms, or others, dominate the transfer of stratospheric radioactivity into the troposphere is still open to debate. Meteorolo-

gists are therefore not in unanimous agreement on the stratospheric circulation and mixing processes—neither on the qualitative nor the quantitative aspects of transport within or removal from the stratosphere.

#### PREDICTIONS

The payoff in the meteorology of fallout is an accurate prediction of the fate of an arbitrary injection of debris anywhere in the stratosphere. The previous discussion indicates that this is not possible on purely meteorological grounds. Hence, the fallout forecasters almost all extrapolate from past experience and their own intuition. It should be noted, however, that some of the models will predict the same fallout pattern even though their details may differ significantly.

By way of illustration and because of current interest, the last few moments of this talk will be devoted to a set of predictions for events of current interest.

Figure 16 shows zones of the stratosphere in which nuclear clouds may have essentially the same history. For example, the lower polar and temperate zone stratosphere up to about 80,000 feet will be characterized by fast fallout deposited in the same hemisphere as the injection. These features are derived from past polar injections. It is the present view that stratospheric clouds injected as far equatorward as 30° may behave like the polar clouds. Injections at the Equator, like the current U.S. tests at Christmas Island—those whose nuclear clouds reach only to 80,000 feet—are in the zone identified on the placard as lower equatorial B. It is characterized by somewhat slower removal and roughly equal partitioning between hemispheres. There have, of course, been injections into this zone by United Kingdom tests prior to 1959 but the lack of unique tracers and confusion of the United Kingdom debris with other fission products prevents one from actually using the history of the United Kingdom fallout in future predictions. The forecasts are, therefore, based on experience from the U.S. Eniwetok tests and meteorological intuition.

Figure 17 shows a cross section of the geographical spread of fallout for equal inputs into the two zones—for simplicity to be called the polar (Soviet) and the equatorial (United States). The Soviet fallout is shown to be limited primarily to the Northern Hemisphere with a temperate zone peak while the U.S. fallout is distributed about equally into both hemispheres with lesser peaks in each temperate zone.

Figure 18 displays the time history of the fallout. The horizontal axis is time, in years, increasing toward the right and monthly deposition increasing upward on the vertical axis. The lower polar fallout, indicated by the dotted line, comes down virtually entirely in the first year, while the U.S. fallout, indicated by the dashed line, takes many years for the same amount to be deposited. In both cases a spring maximum is expected.

Figure 19 repeats the lower equatorial curve dashed line in figure 18 but adds a dotted line for a case of fallout from a different zone. This is from the very high atmosphere zone in figure 16 such as the clouds from high altitude nuclear rocket detonations. Experience from the 1958 Johnston Island events marked with rhodium 102 forms the basis for these predictions. The fallout from these high-altitude injections will partition about equally between hemispheres and likewise peak in the temperate zones. But the time history given by the dotted line shows the much slower rate of fallout; in fact it may take a whole year before even the first fallout is received at ground level.

#### CONCLUSION

Experience derived from fallout since 1959 permits more confident predictions of fallout from many kinds of stratospheric injections. But the meteorology explaining the observed fallout still lags behind the empirical findings.

<b>SR-90 INVENTORY</b>		
<b>May 1961</b>		
		<b>MEGACURIES</b>
<b>N. Hemisphere</b>	<b>Stratosphere</b>	<b>0.45</b>
<b>S. Hemisphere</b>	<b>Stratosphere</b>	<b>0.52</b>
<b>World</b>	<b>Troposphere</b>	<b>0.03</b>
<b>Total</b>	<b>Atmosphere</b>	<b>1.00</b>
<b>Deposited on Ground</b>		<b>4.2</b>
<b>Total</b>		<b>5.2</b>

FIGURE 1.

<b>SR-90 INVENTORY</b>			
<b>Megacuries</b>			
	<b>May 1960</b>	<b>Nov. 1960</b>	<b>May 1961</b>
<b>Observed world wide distribution</b>	<b>5.3</b>	<b>5.3</b>	<b>5.2</b>
<b>Available for world wide deposition*</b>	<b>5.5</b>	<b>5.4</b>	<b>5.3</b>

\*Based on 9.2 less 3.0 (?) megacuries of local fallout and radioactive decay

FIGURE 2.

Estimates of Sr-90 inventory from USSR Fall 1958, 1961 tests [Megacuries]		
	Fall 1958	Fall 1961
Deposited on ground	0.63 [TO DEC. 1959]	0.2 ? [TO MAR. 1962]
Measured in stratosphere	0.17 [DEC. 1959]	OVER 1.3* [JAN.-MAR. 1962]
Total measured	0.80	OVER 1.5
Injected into atmosphere (AEC estimate)	1.25-1.50	APPROX. 2.5

\*TO 70,000 FT.

FIGURE 3.

**Sr-90 from 1961 USSR tests, January-March 1962**  
[DEFENSE ATOMIC SUPPORT AGENCY]

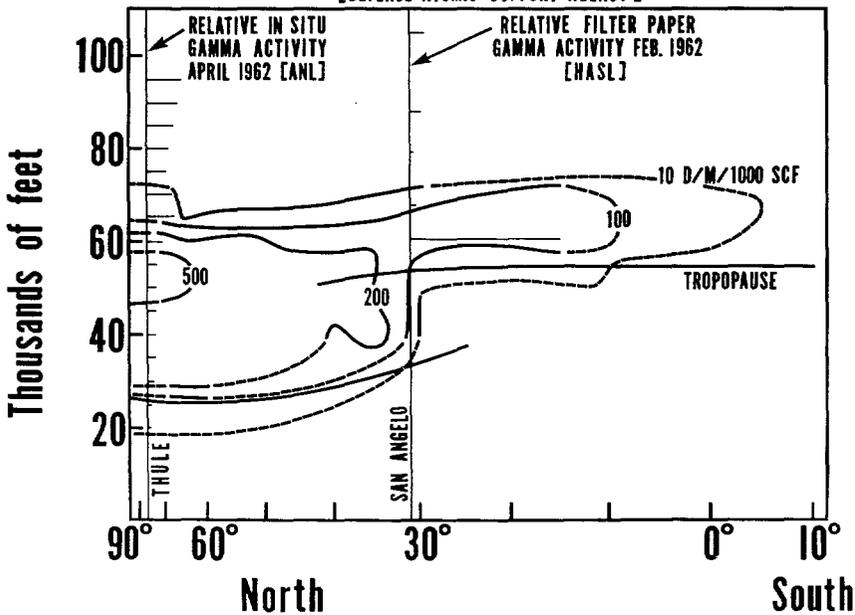


FIGURE 4.



FIGURE 5.

**LATITUDINAL DISTRIBUTION OF SR-90 FALLOUT**

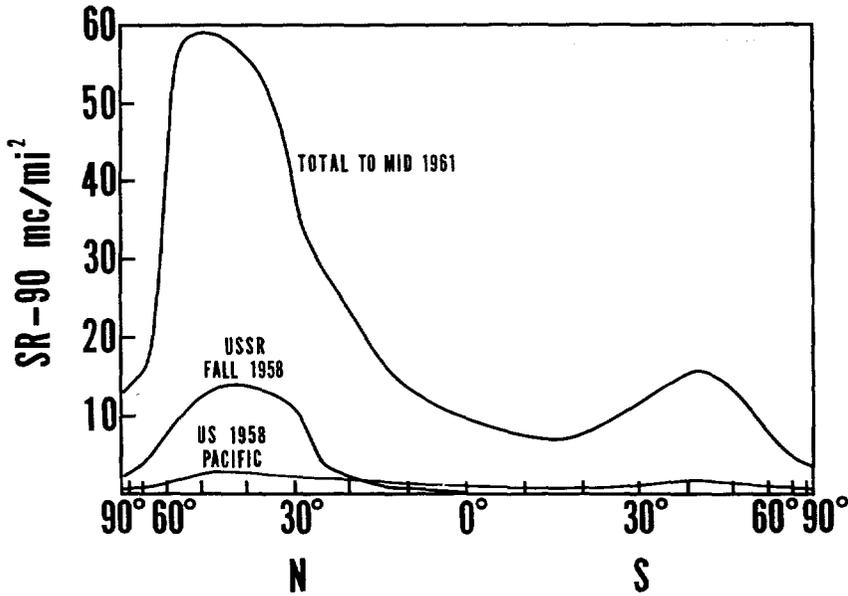


FIGURE 6.

**Sr-90 Fallout  
Northern Hemisphere 1959**

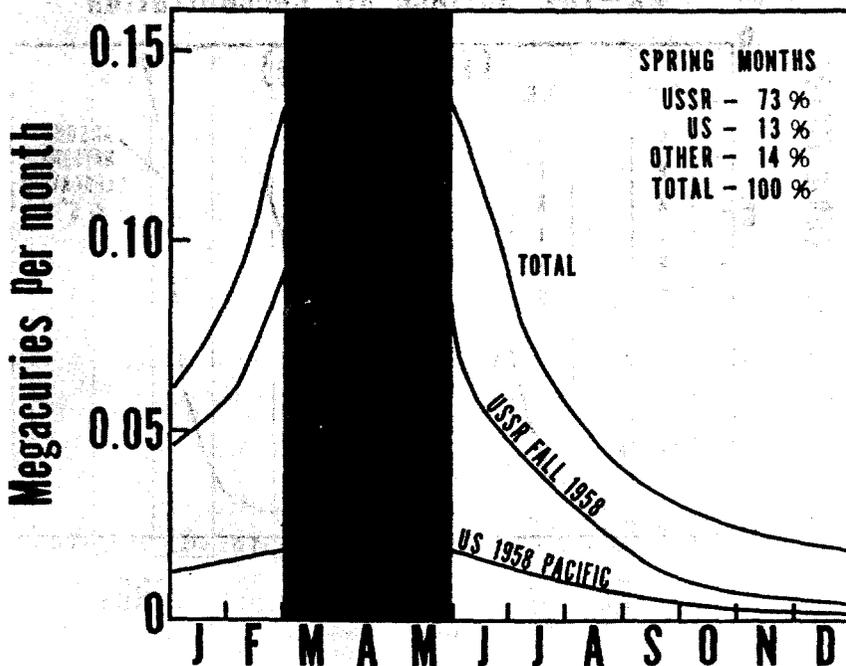


FIGURE 7.

### Average monthly distribution of Sr-90 fallout

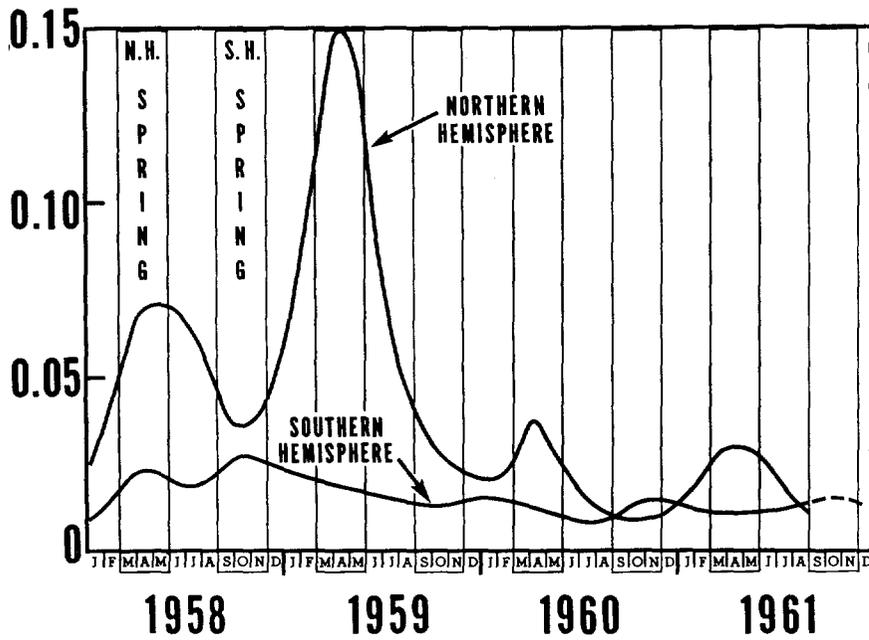


FIGURE 8.

### Rh-102 surface air concentration

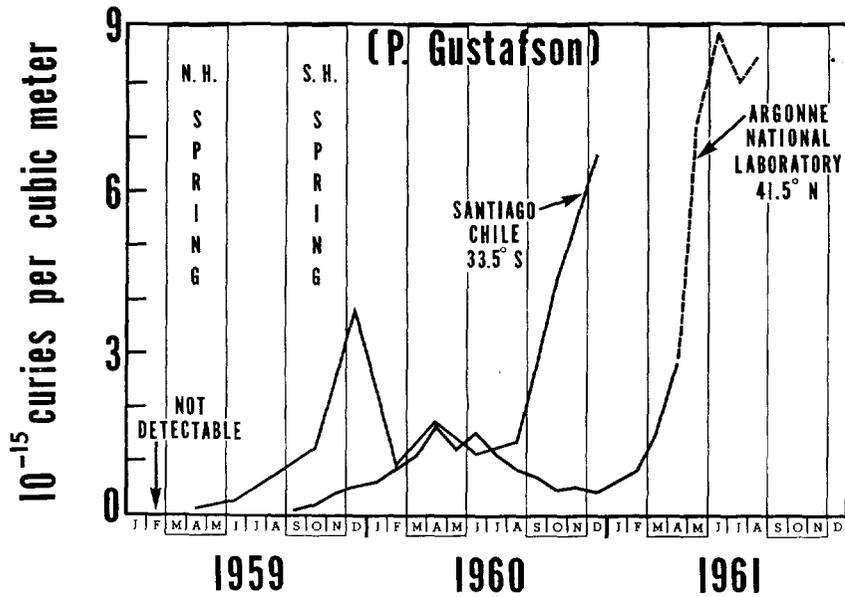


FIGURE 9.

**Cs-137 surface air concentration Argonne Natl. Lab.**

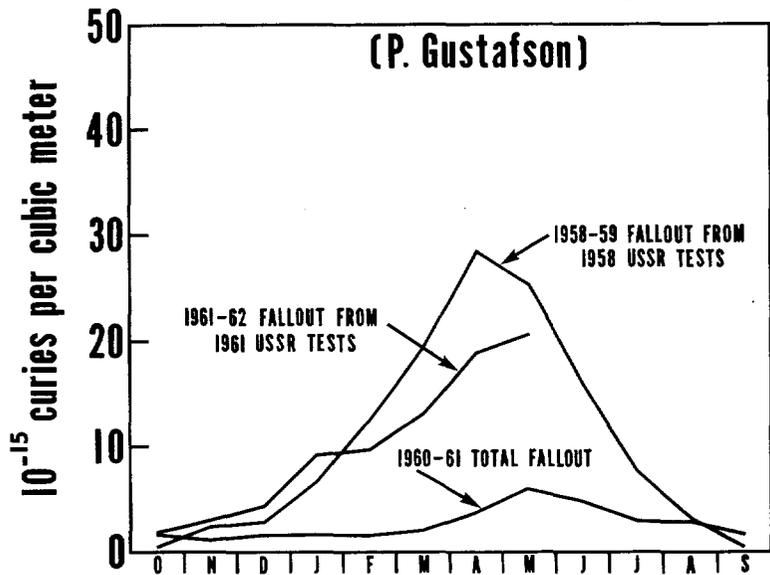


FIGURE 10.

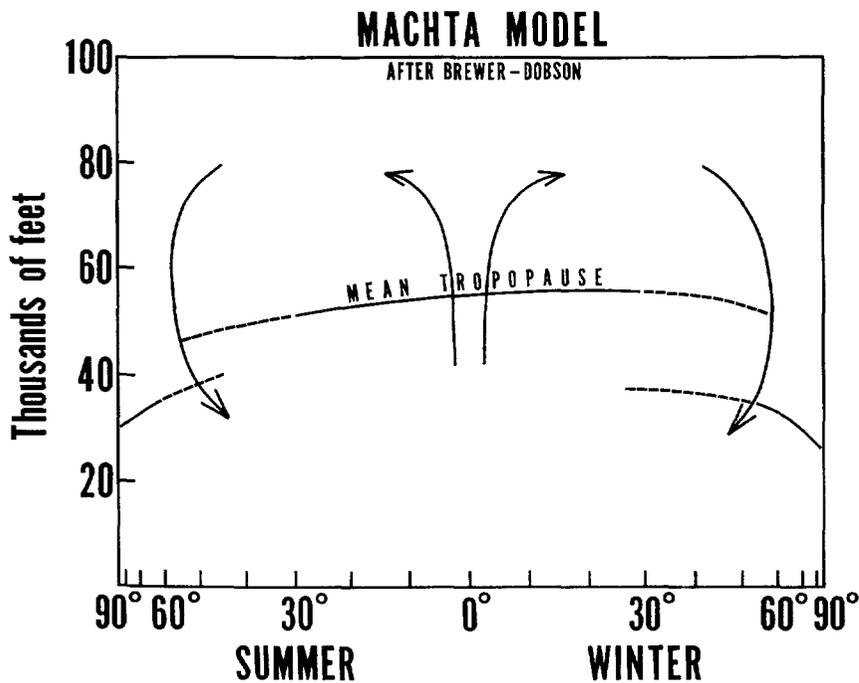


FIGURE 11.

**TUNGSTEN -181 d/m/1000 scf  
NOV. 1960**

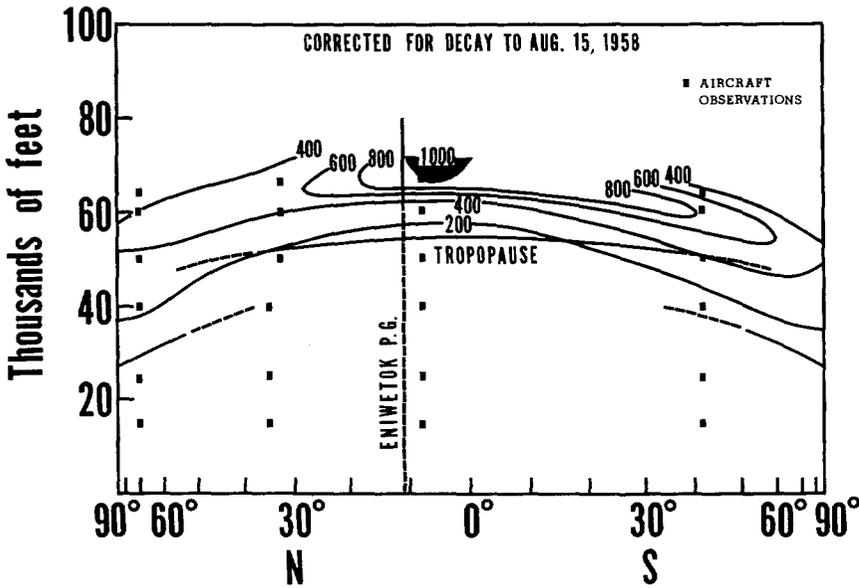


FIGURE 12.

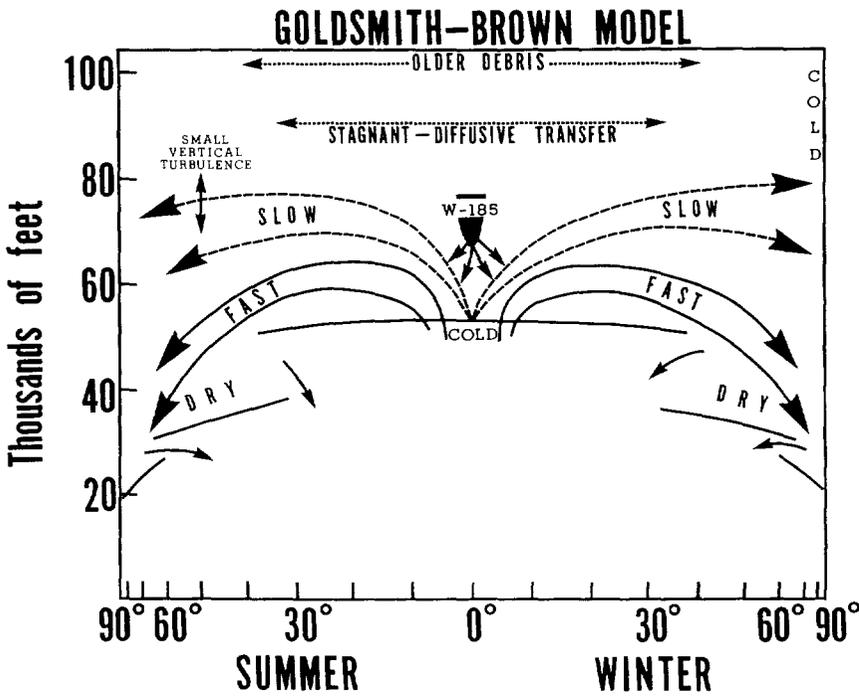


FIGURE 13.

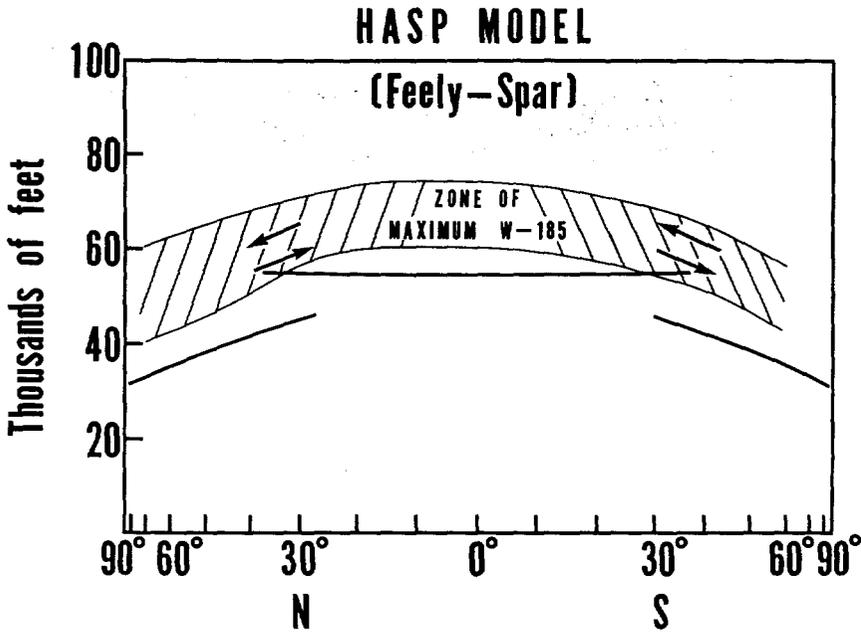


FIGURE 14.

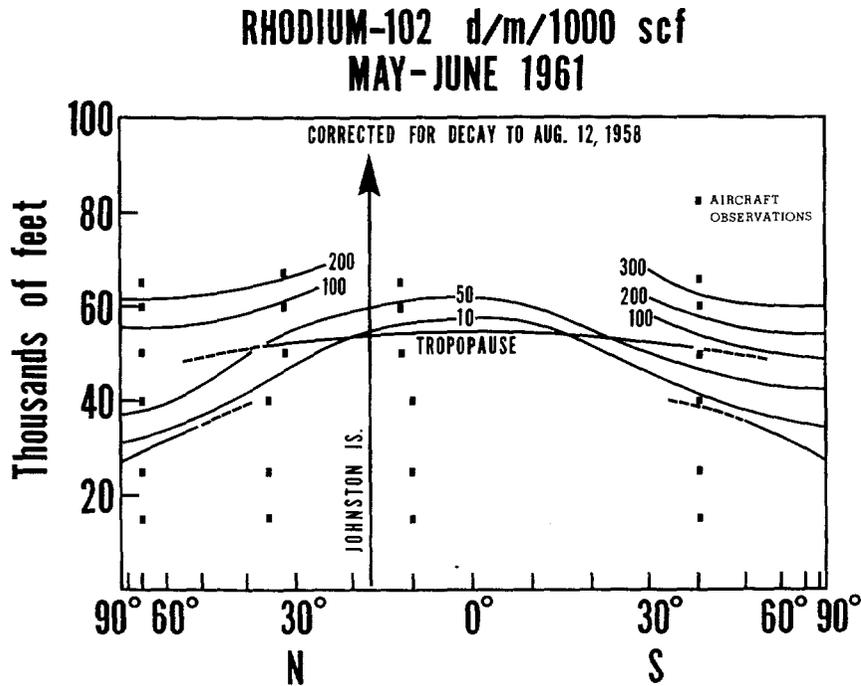


FIGURE 15.

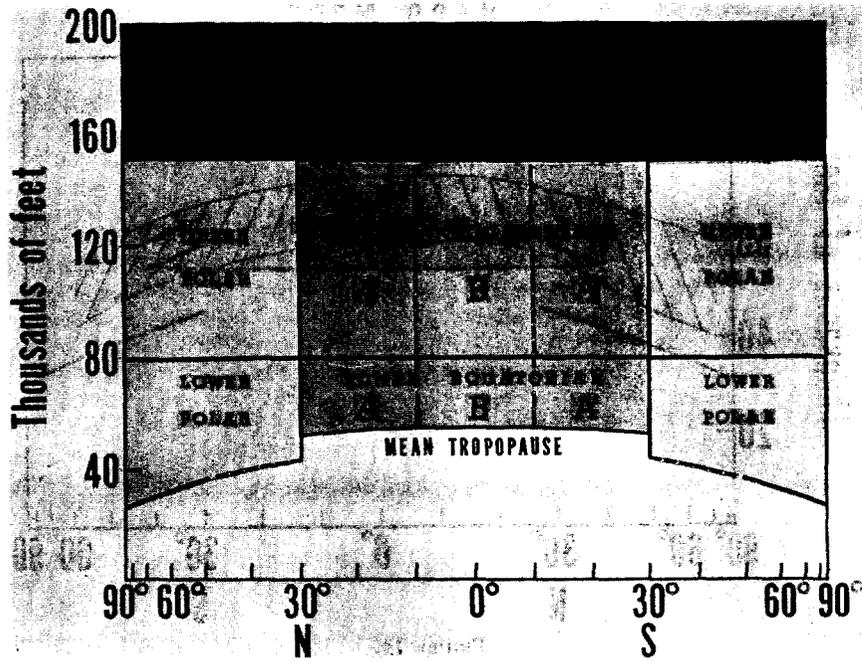


FIGURE 16.

Total deposition from lower stratospheric injections

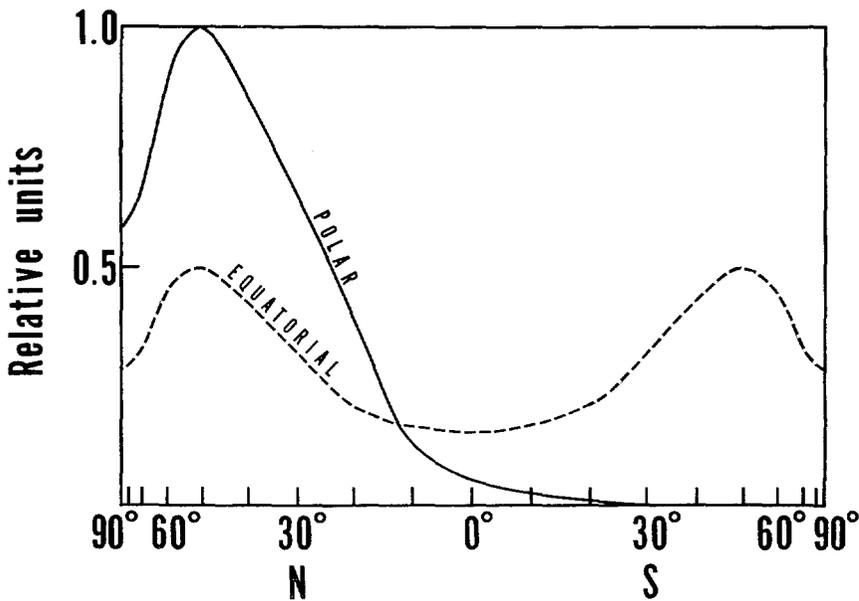


FIGURE 17.

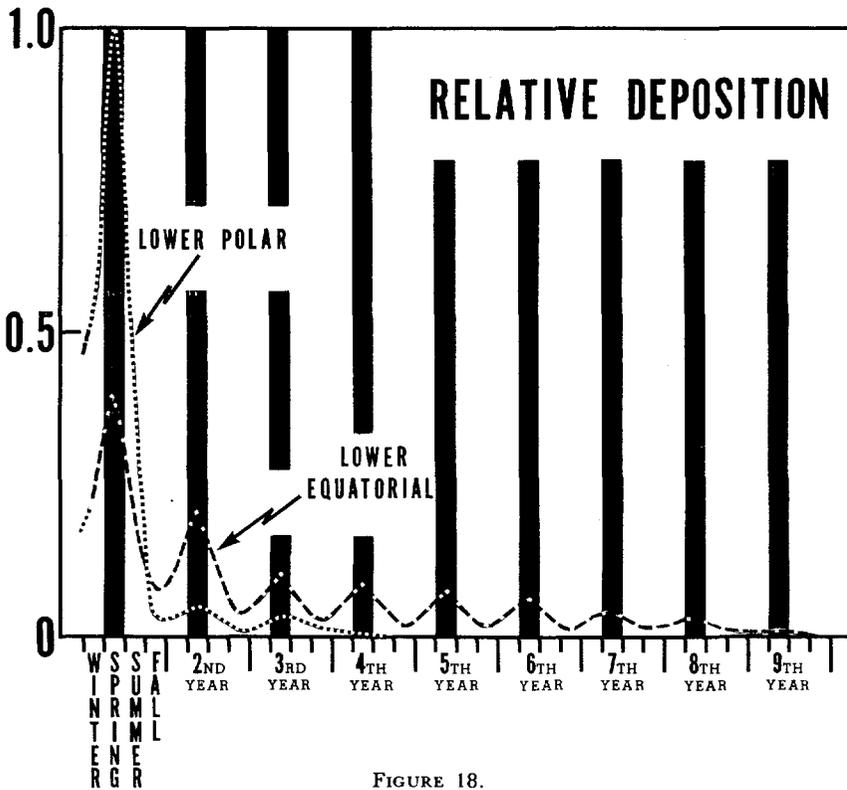


FIGURE 18.

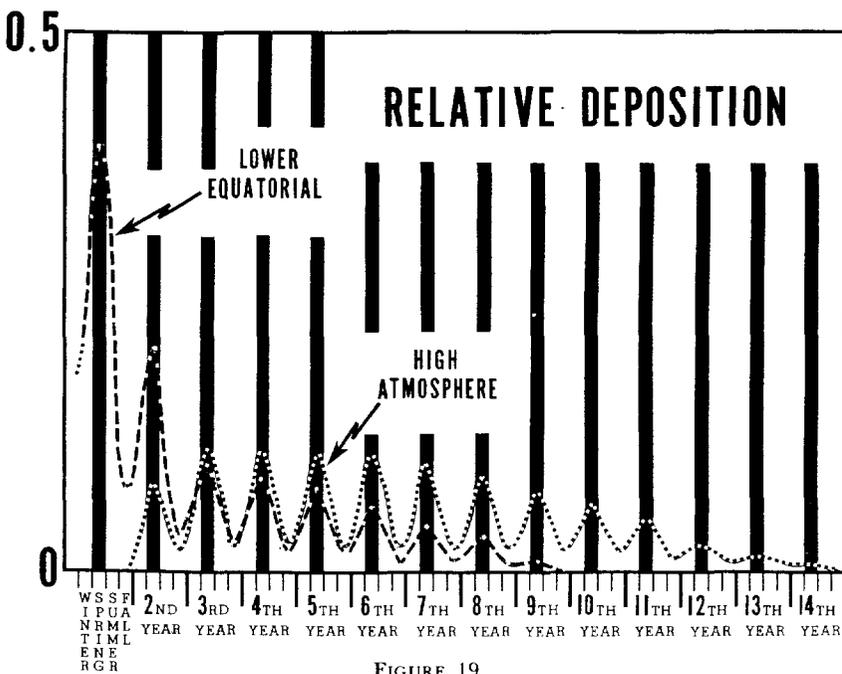


FIGURE 19.

Dr. MACHTA. I would like to discuss with you three aspects: First, the inventory of strontium 90 in the stratosphere and on the ground before the Russians started their testing in 1961 and the little information available concerning the Soviet 1961 test inventory; second, the geographical and seasonal variation of the stratospheric fallout on the ground; and finally, a discussion of predictions of fallout from areas of injection into the stratosphere which may be of current interest.

We will start with the first placard. The inventory as of May 1961, the last available one preceding September 1961, shows that the Northern and Southern Hemisphere stratosphere and the troposphere contained approximately 1 megacurie of strontium 90. The megacurie is a unit which was not introduced yesterday. Megacurie stands for millions of curies. The large numbers result from radioactivity in the entire atmosphere or deposition over the entire world. When we deal with fallout in a specific area, we revert to the units of millicuries.

One can notice on the first placard that as of May 1961, about 4.2 megacuries of a total of 5.2 had already been deposited. This amounts to 80 percent of that which was injected into the atmosphere still available for worldwide fallout.

Mr. RAMEY. How does that correspond to the amount of fission products in the atmosphere?

Dr. MACHTA. The total fission products in the atmosphere? One would have to go through an elaborate calculation in order to find the fraction of the various lived activities as of this date. Most of the shorter lived activities naturally have decayed away. So the bulk of the activity will be in half-lives of greater than 1 or 2 years as of this date.

Mr. RAMEY. But as of the time of our last hearings, there was approximately 50 megatons of fission yield, or something like that?

Dr. MACHTA. Yes. Let me explain the fact that one megacurie of strontium 90 corresponds to 10 megatons of fission yield.

Mr. RAMEY. That is what I was trying to get at.

Dr. MACHTA. The total number of megatons of fission yield which have been detonated prior to the resumption of nuclear tests in 1961 was approximately 92 megatons or 9.2 megacuries of strontium 90. The worldwide contribution appears to be 5.2 as of May 1961.

Representative PRICE. When you say "total amount," you include all?

Dr. MACHTA. Yes, sir.

Representative PRICE. United States, U.S.S.R., and even the French?

Dr. MACHTA. That is correct.

Chairman HOLIFIELD. Is it possible for us to put the amount of radioactive material represented by a millionth of a curie in perspective to the amount of radiation in terms of curies which are used in the laboratory experiments on mice in order to obtain observable or detectable mutations in the genetic field or somatic damage in the mouse that is being experimented upon? I know this is not in your field. I know you are a meteorologist. But, in order to be meaningful to the layman, I think they have to recognize what we are talking about when we are talking about a one-millionth of a curie and when we talk about forty-five millionths of a curie.

I am not directing that question to you, but I am wondering if Dr. Dunham or someone in the audience here could give us a feel for this before he goes on. I think it is important that these numbers be understood in relation to their practical application.

Dr. DUNHAM. In terms of cobalt 60 exposures which are the way most of the exposures are done—some are done with X-rays for mice in large-scale experiments—it is a matter of a few hundred curies of cobalt 60, and the mice have to be a certain distance from that source in order to get three-tenths of a roentgen a week and that sort of thing.

In terms of strontium 90 in people, or in mice, rather, I think it is in the region of a hundred microcuries per kilo that you begin to see regularly bone tumors and things of that sort. Dr. Langham may correct me on that, but I think that is about the lower level. How about the Utah dogs? Do you recall? I think it is in that general range.

Dr. LANGHAM. Around a hundred microcuries per kilo where you begin to get effects.

Dr. DUNHAM. It would be a hundred-millionths of a curie to produce regularly effects in mice and in dogs.

Chairman HOLIFIELD. I think that puts it in perspective so it could be understood, unless there is a confusion on microcurie and megacurie.

Dr. DUNHAM. A megacurie is a million curies. A microcurie is a millionth of a curie. A microcurie is a millionth of a millionth of a megacurie.

Chairman HOLIFIELD. Excuse the question.

Dr. MACHTA. I would simply like to point out that of the total amount of strontium 90 available for worldwide fallout approximately 80 percent had been deposited before the resumption of tests in 1961.

Another surprising feature, although based on very limited data in the Southern Hemisphere, is that the Southern Hemisphere stratosphere appears to have about as much strontium 90 as the Northern Hemisphere's stratosphere despite the fact that virtually all of the stratospheric injections have taken place in the Northern Hemisphere. This is one of the unexplained meteorological factors that we have yet to explain.

Representative PRICE. The limitation on the data from the Southern Hemisphere is due to the fact that we do not have the equipment down there.

Dr. MACHTA. We have one sampling point in southern Australia. I think the equality between hemispheres is probably real in view of the fact that many isotopes, not only strontium 90, but, for example, carbon 14 data seem to suggest that the Southern Hemisphere has essentially balanced and equaled the Northern Hemisphere in content. This may simply reflect the mixing of the debris between the hemispheres long after testing has ceased.

The second placard shows that one can compute inventories of strontium 90 at various times. The placard shows them as of May 1960, November 1960, and May 1961. The observed worldwide atmospheric content derived from U.S. aircraft sampling are given by the figures 5.3, 5.3, and 5.2. You will recall that strontium 90 has a 28-year half-life and should decrease about 2½ percent per year. Consequently, the observed small decrease is quite consistent with one's expectations.

On the lower line of the placards is the amount of strontium 90 available for worldwide depositions based on a different method of inventory calculation. The AEC has announced that approximately 92 megatons of fission yield or 9.2 megacuries have been released to the atmosphere. Estimates have been made that approximately 3 megacuries have fallen out locally, leaving 6.2 available for worldwide distribution. One can therefore decay the 6.2 to the indicated dates and estimate the amount left in the atmosphere and on the ground. The numbers in the lower line, 5.5, 5.4, and 5.3, are these values. The agreement between the two methods of inventory calculation is remarkably good considering the limited amount of sampling information.

At the present time there is considerable doubt whether there is as much as 3 megacuries actually deposited locally. If this was smaller than 3, and it might be as small as 1, then each of the AEC-derived inventories 5.5, 5.4, 5.3 would be higher and a discrepancy much greater. In such a case I think that the explanation for the discrepancy lies in the fact that more of the fallout occurred over the ocean where we have not properly measured the deposition. I will talk about this in a few moments again, since it will arise in connection with another matter.

Now, so far we have talked about the worldwide fallout before the Soviet resumption of testing. I would like to show the inventories of the fallout on the third placard for 1958 and 1961 Soviet tests; the 1958 findings are shown for purposes of comparison with the 1961 results. Up to the end of December 1959 approximately 0.63 megacurie had been deposited on the ground from the 1958 series. This has been identified as of Russian origin by using the ratios of short- to long-lived isotopes. Remaining in the stratosphere to the heights of the aircraft measurements was approximately 0.17. The total amount which we can account for is approximately 0.8 megacurie of strontium 90.

Mr. RAMEY. That would correspond to 8 megatons of fission yield?

Dr. MACHTA. Yes, sir. This compares with the amount which Dr. Libby has announced as having been injected in the stratosphere of 1.24 to 1.5 megacuries. There is a difference between the 0.8 and the 1.25 and the 1.5. We believe that the likely explanation is inadequate sampling. The deposition on the ground is probably low because we do not adequately sample the oceans. We think there is more fallout over the oceans than we are able to extrapolate from land stations. This is the first of two discrepancies.

Inventory computations from Soviet tests in the fall of 1961 are not nearly so good. The amount deposited on the ground is poor due to incomplete observations because the data has not been brought up to date due to analysis lag. As will be seen later, the fallout up to March 1962 is about the same after the 1961 test as following the 1958 Soviet tests. Using this information, we have estimated 0.2 megacurie of strontium 90 fallout. It has been calculated that up to 70,000 feet the inventory of strontium 90 is about 1.3 megacuries. The term "over" indicates that the values are probably greater than listed over this. The total amount is in excess of 1.5 megacuries of strontium 90.

The AEC announcement, according to the placard, calls for approximately 2.5 megacuries released to the atmosphere, and again there

is a discrepancy between the AEC estimate and that observed. However, in this case, the explanation lies not in incomplete ocean sampling, because you can double the value of 0.2 and not bring the inventory even close to 2.5 megacuries. It is either the fact that there has not been as much added by the Soviet test, or the following explanation.

Placard 4 is a plot in which the North Pole lies on the left end of the horizontal axis, the Equator is at the zero degree point and extends on the right to 10° in the Southern Hemisphere. The vertical axis is altitude in thousands of feet. The heavy black line without a numerical label, identified as "tropopause," represents the separation between the troposphere below and the stratosphere above. It has a break at approximately 30° N.

The solid and dashed lines are isolines of concentration of strontium 90 of Soviet 1961 debris. The highest concentration is at about 50,000 feet close to the North Pole. Near the Equator the values decrease and rise to higher altitudes. But there has been considerable mixing southward along the meridian, at which the stratospheric sampling has taken place, from the point of injection at 75° N. virtually to the Equator.

In fact, a month or so later some short-lived isotopes from the Soviet tests were observed in the stratosphere of southern Australia.

The inventory calculations above were based on this cross section. One can, in very straightforward fashion, determine the amount of Soviet 1961 strontium 90 in the atmosphere, assuming the concentration is the same around the circle of latitude as at the meridian of sampling. Above 60,000 feet, the concentrations become smaller, from the order of a hundred to less than 10 units. The dash lines reflect the lack of complete data.

It looks like the aircraft are over the tops of the nuclear clouds at 70,000 feet. However, at two points, San Angelo, Tex., and Thule, Greenland, we have obtained some balloon measurements. At San Angelo, Tex., where air is filtered and equipment carried on a very large plastic balloon, a large peak was found at 60,000 feet, corresponding to the aircraft maximum at the same altitude. This is indicated by the horizontal line at 60,000 feet on the placard at San Angelo, Tex.

At higher altitudes, the horizontal lines become shorter as the concentration decreases. At higher altitudes, the concentrations or the lengths of the horizontal lines increase in length again. There is apparently another cloud at higher altitudes above 70,000 feet.

The same picture, more or less, takes place at Thule, Greenland, where the peak concentration is slightly higher than that identified by the Stardust aircraft flights but decreases at about 80,000 feet and then increases again at 90,000 or 100,000 feet.

It is quite apparent, I think, that some of the larger Soviet weapons went to much higher altitudes than 70,000 feet, the ceiling of the Stardust aircraft sampling. For this reason, a satisfactory inventory of the total Soviet debris is unavailable.

The next subject is the geographical distribution of strontium 90 fallout on placard 5. This is a map showing the fallout in mid-1960 in millicuries of strontium 90 per square mile. Now one is discussing thousandths of a curie of strontium 90 dispersed over a square mile of

area. The points of observation are shown by the black dots. It does not show those in continental United States or Canada because there are too many; approximately 80 or 90.

The heavy shading shows the area of the heaviest fallout. The lines join points along which the fallout is equal. The interpolation has been performed by the Weather Bureau assuming that the amount of fallout is more or less proportional to the amount of rainfall in the same climatic region.

One can see that the highest fallout is clearly in the temperate zones of the Northern Hemisphere. There is a slight maximum in the temperate zone of the Southern Hemisphere.

The placard also shows that there is a minor peak in the Midwest and south-central part of the United States. It has been suggested that this may be due to additional fallout from the Nevada tests. This is probably partly true. But between 1959 and 1960, soil samples have been collected by Dr. Alexander of the Department of Agriculture, who has collected all the samples shown on this chart, and analyzed by the Health and Safety Laboratory of the AEC. The increase from the 1959 to the 1960 values showed that there was also a peak at about latitude  $40^{\circ}$  N., the same latitude at which the peak appears on the chart. During this interval there were no Nevada tests.

Apparently the worldwide fallout does tend to peak in the temperate zone at about  $40^{\circ}$  N. in the United States, possibly due to the fact that we have intense thundershowers, which may bring debris from higher altitudes in addition to other processes which generally increase fallout in the  $30^{\circ}$  to  $60^{\circ}$  N. band.

Representative PRICE. Mr. Ramey has a question.

Mr. RAMEY. This confirms the sort of theory you expressed in 1957, that this would be the case; is that not correct?

Dr. MACHTA. I am not sure I can take credit for having predicted this particular phenomena.

Mr. RAMEY. The so-called banding phenomena.

Dr. MACHTA. There is no question but there is a banding phenomena taking place, virtually all of which has been derived from the stratosphere. This much has now been amply confirmed. But whether or not one should have found a peak in the midsection of the country, this I don't think I have predicted.

The two oceanic maximums are associated with the storminess which occurs with the Icelandic and Aleutian low pressure areas. These are regions of very heavy rainfall.

Chairman HOLIFIELD. Fortunately, that fallout occurs over the ocean and very thinly populated islands.

Dr. MACHTA. Yes. I may point out that this chart shows fallout over the oceans based on a few stations, for example, in Scandinavia and Bermuda, but it is likely that the fallout is heavier than is shown.

Dr. Bowen, of Woods Hole Oceanographic Institution, has been sampling various depths of the ocean for the strontium 90 concentration in water. While the water is in constant motion and it is improper to integrate in the vertical to find the total amount of deposition at a given point, nevertheless he has enough sampling points to suggest that the fallout is greater than has been suggested by extrapolation from land-based stations by a factor of roughly two.

Similar studies in the Soviet Union have suggested the same over-water fallout excess. The best hypothesis for the extra fallout is that there are salt particles near the surface of the ocean to which the strontium 90 aerosols attach themselves, and these are brought back to the seas and oceans.

There are additional mechanisms besides rainfall which may deposit material over the oceans. There is evidence that fallout over the ocean is greater than extrapolation from land and rainfall data.

In placard 6, the North Pole lies on the left, the Equator on the center, and the South Pole on the right. This irregular scale is such that equal lengths cover equal areas on the earth rather than a linear latitude scale. The total amount of fallout to mid-1961 is the upper line. This has been derived from the previous placard plus fallout collected in the pots and funnels on a monthly basis. We have taken soil accumulation to mid-1960 and added this to the AEC pot results.

The peak occurs from 30° to 60° N. as already suggested yesterday by Dr. Dunham.

The middle curve shows the distribution of fallout from the U.S.S.R. fall 1958 test series. This likewise shows a peak in the temperate latitudes from 30° to 60° N. and virtually nothing appears in the Southern Hemisphere. The bottom curve shows the fallout from our Hardtack summer 1958 test series. This has been identified by the unique tracer, radiotungsten, which was injected into the lower equatorial atmosphere at the Eniwetok Proving Grounds.

Again there is a tendency for a peak in the temperate latitudes in the Northern Hemisphere and a suggestion of one in the Southern Hemisphere.

Representative PRICE. But you don't show much of a curve anyplace.

Dr. MACHTA. No. This fallout has been more uniformly distributed over the globe than the fall 1958 Soviet tests. The peak in the temperate latitudes of the Northern Hemisphere is about twice that of the Southern Hemisphere, although there is a paucity of data in the Southern Hemisphere. It is clear that no matter where the stratospheric injection takes place, whether it is near the Equator or the polar regions, it is the temperate zone which seems to get the greater bulk of the fallout. This placard is evidence for this conclusion.

Mr. RAMEY. That is the banding?

Dr. MACHTA. This is the banding referred to many years ago and which has now been definitely confirmed.

Placard 7 introduces the next subject; the seasonal variation of fallout. The month of the year is shown on the horizontal axis, and the amount of strontium 90 fallout is on the vertical axis. The units are megacuries because the total amount of fallout on the entire northern hemisphere is under consideration.

The spring period is shown in the shading. The total fallout in the year 1959 is shown by the uppermost curve labeled "total." It shows a peak in the months of March, April, and May. The second curve, labeled "U.S.S.R. fall 1958," shows a pattern very similar to the "total."

Using the radio tungsten data, one is able to obtain a seasonal trend in the fallout from the United States 1958 summer Pacific tests in the lower equatorial stratosphere. This is shown by the lower curve. It likewise tends to peak in the spring season of the year, but the peak is much less marked than the other two curves.

We therefore argue that, no matter whether the injection takes place in the polar or equatorial region, there is a definite tendency for peaking in the spring. However, when the injection is made in the polar region, there is more of a spring peak than in the case of the equatorial injection.

The figures in the upper righthand corner of the chart indicate the fraction of the total fallout attributed to each of the sources. For example, during the 3 spring months, March, April, and May, 73 percent of the fallout could be attributed to the Soviet 1958 October test series, 13 percent to the Hardtack tests in the summer of 1958, and all the other prior tests contributed only 14 percent. Most of the fallout in the spring of 1959 came from the rapid fallout of the Soviet Novoya Zemlya tests in the fall of 1958.

Placard 8 shows the fallout over a series of years from 1958 through 1961, and the zones for the spring of each year in the Northern Hemisphere have been labeled in one sector, and those in the Southern Hemisphere in another sector. March, April, May are the Northern Hemisphere's spring months, and September, October, November for the Southern Hemisphere spring months.

The upper curve, identified by "Northern Hemisphere," shows the fallout in the Northern Hemisphere, and during each spring season of the year you will find there is a definite peak. The most marked peak occurred after the October 1958 Soviet test series, in the spring of 1959.

In 1960 and 1961 there were also spring maximums despite the fact there were no previous tests in the autumn of 1959 or autumn of 1960, suggesting that the mechanism which brings the strontium 90 down from the stratosphere is a meteorological process.

In the Southern Hemisphere there is no evidence of any seasonal variation at least to 1960. The wiggles on the placard for the Southern Hemisphere curve show no seasonal trends. In 1960 there is a tendency for peak in the spring of the Southern Hemisphere, and the suggestion of another one in the spring of 1961. The realities of these are still open to question because they are not particularly marked.

The reason for the absence of a spring peak in the Southern Hemisphere, which meteorologists would have expected on the basis of the fact that the two hemispheres are similar, has two possible explanations. One is that there may be meteorological differences between the hemispheres. The more likely explanation is the one to which I hold. There may be another source of fallout for the Southern Hemisphere; namely, cross-equatorial flow from the troposphere of the more highly contaminated Northern Hemisphere into the less contaminated Southern Hemisphere. This transfer may be irregular in time. The Southern Hemisphere stratosphere may have a regular fallout pattern, but the radioactivity derived from the Northern Hemisphere troposphere may confuse this seasonal pattern. In 1960 and 1961 both hemispheres had about the same concentrations, hence the Northern Hemisphere source became unimportant.

The evidence for this thesis is shown in placard 9, which shows data collected by Dr. Gustafson of Argonne National Laboratory for an isotope, rhodium 102, which was injected during the U.S. high-altitude test of August 12, 1958. The fallout in both hemispheres was about equal for this particular isotope. One hemisphere is not more heavily contaminated than the other hemisphere.

In the Southern Hemisphere, the curve labeled "Santiago, Chile," shows definite evidence of a spring maximum in 1959 and a suggestion that the same trend is taking place in 1960 by the upward trend in the curve. This placard contains the latest data available for Santiago, Chile. The peak is delayed a little more than one might expect, but the fact that there is a seasonal trend is quite clear. At Argonne National Laboratory, one finds a definite peak in the spring of 1960 and a suggestion of another peak in the spring of 1961.

Here is a case where the Northern Hemisphere is not more heavily contaminated than the Southern Hemisphere, and one finds the expected seasonal variation in the Southern Hemisphere.

The next placard, No. 10, shows the cesium 137 air concentration in Argonne, Ill. The air concentration of cesium 137 permits one to view the latest available fallout information. Most of the other long-lived radionuclides do not extend beyond about February of 1962.

The horizontal axis is the month of the year, and the vertical axis is the air concentration. The uppermost curve is the 1958-59 fallout from the October 1958 U.S.S.R. test series. For this curve the first month, October, is October 1958, and the last month, on the right, is September 1959. We have seen previously that there was a definite peak in the spring of 1959, and that is again shown by the uppermost curve.

In 1960-61 the total fallout—the lowermost curve derives from all test series—had decreased by about a factor of 10 from 1959 because of the test moratorium and there were no new large-scale injections. A peak appears in this curve, displaced by a month or two from the maximum in 1959.

The fallout in 1962 attributed to the 1961 Soviet tests is shown by the middle curve. It is incomplete, extending only through May of 1962. In the early months, from October 1961 to about January or February 1962, the levels of fallout are about the same as October 1958 through February 1959. Values are a little higher or lower in one place or another. After February it looks like the levels of fallout are considerably lower than they were in 1959.

This may seem a little bit strange in view of the fact that the announced yields called for 25 megatons to have been injected in 1961 and only 12.5 to 15 megatons injected in 1958, both by the Soviet Union. Straight extrapolation would require the fallout to be higher in 1962 by a factor of 2, but apparently the fact that the clouds stabilized at higher altitudes and the possibility that the weather conditions were not exactly the same this year as they were in 1959 apparently have contributed to make our spring fallout up to this point not as heavy as we would expect it by the simple extrapolation if the injection numbers are correct.

I think I have used my time. I have a few other placards to show, if you are interested in any predictions of fallout, of events which would be of current interest.

Representative PRICE. I think you should go on.

Dr. MACHTA. May I please?

For the Prediction Panel and because of current interest, I would like to make some estimates of fallout for injections made into three places into the stratosphere.

Placard 16 shows the North Pole on the left, Equator on the center, and South Pole on the right, and the altitude in thousands of feet on the vertical scale as before. The tropopause is shown by the lowermost line. The stratosphere is divided into a series of zones. It is argued that in each zone the fallout will behave more or less the same, but fallout may be different from one zone to another.

Consider first the lower polar stratosphere. This would correspond to injections from Russian tests with yields up to a few megatons. Second, zone B is in the lower equatorial region. The Christmas Island tests in the lower megaton range will add debris here. Finally, in the very high atmosphere is a zone where rocket tests may be injecting their debris.

Our predictions are largely based on extrapolations from previous experience.

Placard No. 17 displays the North Pole on the left, the Equator in the center, and South Pole on the right. The relative amount of fallout is shown on the vertical axis.

For injections into the lower polar regions, the upper curve shows that most of the fallout is expected to take place in the 30° to 60° band and almost all of it in the northern hemisphere. For the Christmas Island tests, the stratospheric component is expected to partition equally between the hemispheres and peak in the 30° to 60° bands of both hemispheres.

For very high altitude explosions, those which inject debris to hundreds of thousands of feet of altitude, the geographical pattern will be about the same as the lower equatorial pattern, except that the levels would be somewhat lower because of its longer residence time. Further, there will be more time for radioactive decay and there should be virtually no short-lived isotopes.

Placard 18 shows the relative deposition for successive years after the time of injection. The horizontal scale is the number of years after the injection has taken place, and the ticks indicate the winter, spring, summer, and fall. The bars indicate the spring zone of each year showing the predicted maximum in each spring season.

The injections made in the lower polar stratosphere show a very marked peak in the first year and a decreasing fallout in successive years. After 4 years there won't be enough fallout to be measurable.

The injections made in the lower stratosphere from Christmas Island will fall out in much smaller amounts in the first year but will take much longer time to be deposited. Maxima will occur in the spring seasons perhaps as long as 9 years later.

And finally, we can compare the lower equatorial stratosphere with injections from the very high altitude on placard No. 19. This placard shows a peak in the first year for the lower equatorial injection and at the same time practically no material was brought down to the ground from the high atmosphere.

In later years nuclear clouds placed in the high atmosphere may actually produce more fallout than from clouds in the lower equatorial stratosphere for an equal injection.

I would like to conclude by stating that we have learned much in the years since 1959, mainly about the nature of the fallout. But I feel that the meteorological profession has not kept abreast of this progress. Our predictions, by and large, are based on extrapolations from past experience.

Representative PRICE. Doctor, has there ever been a recommendation about doing something to improve our adequacy of detecting fallout over the oceans?

Dr. MACHTA. Yes; this has been considered in the Division of Biology and Medicine. It is a tremendous job; not only is the radiochemistry difficult because of the low concentrations, but the oceans are very large and the sampling program expensive. A sea water sampling program is under consideration in the Fallout Studies Branch.

Representative PRICE. In your prepared statement you speak of a lack of unanimous agreement among meteorologists. What are the main points on which meteorologists have divergent views and what are their implications in regard to fallout?

Dr. MACHTA. One difference of opinion can be used as an example. Several people believe that there is a circulation, a net flow of air, from the equatorial region toward the polar regions of both hemispheres. There is another group which believe that the transfer takes place from the equatorial to the polar region by mixing processes. It would appear that the results which from the Soviet 1961 tests would tend to support those who believe that mixing is the main process.

However, in terms of practical results, the forecasts which are made by both of these groups appear to be similar. So it is more of an academic than a practical difference.

Representative PRICE. Mr. Ramey?

Mr. RAMEY. At the time of our 1957 hearings, the main theory or the official theory that was expounded was the so-called 10-year residence time and equal fallout in the Southern as well as the Northern Hemisphere. This was pretty much the theory, as we understood it, as expounded by Dr. Libby. What has happened to that theory? Is that theory the one that is being applied only for the highest altitude shots, and these in the lower stratosphere are not working out that way?

Dr. MACHTA. Very definitely the evidence now suggests that injections made in the polar regions are coming out much faster than with a mean residence time of 10 years. This is agreed upon by everyone, and you saw the data for this earlier today. Most people, I think, believe that even injections made in the equatorial region, except at very high altitudes, are probably deposited at a rate faster than the 10 years just referred to.

At the time Dr. Libby made his estimates many years ago, there were incomplete data and he made his predictions on the best information then available. The present data would suggest that the fallout is depositing faster than the fallout rate estimated by Dr. Libby many years ago.

Representative PRICE. Are there any questions?

Chairman HOLIFIELD. A very fine presentation, Doctor.

Representative PRICE. Are there any other questions?

If not, thank you very much, Doctor. You certainly presented a very valuable paper to the committee. We are glad to have it.

The next witness will be Dr. Cyril L. Comar, Department of Physical Biology, Cornell University.

Dr. Comar.

**STATEMENT OF DR. CYRIL L. COMAR,<sup>1</sup> DEPARTMENT OF PHYSICAL BIOLOGY, CORNELL UNIVERSITY**

Dr. COMAR. Thank you, Mr. Chairman. It is a privilege to appear before this committee and to acknowledge publicly the wholehearted support of our work by numerous Federal agencies, especially the Atomic Energy Commission, Public Health Service, and Departments of Defense and Agriculture.

Tribute is also due to many colleagues whose names are well known in the scientific literature.

Contamination of food and water represents the primary pathway by means of which the human population is exposed to radiation from worldwide fallout.

The principles governing the movement of fallout radio contaminants through the food chain have been described fully in the 1959 hearings of the Special Subcommittee on Radiation, and in the literature.

Recent developments have provided some refinement, but the basic principles as previously set forth have been supported and are still valid.

There has been much confusion regarding the comparative wholesomeness of various constituents of our diet, a confusion that could be dispelled easily by an understanding of a few basic facts. This report is an attempt to reemphasize in as simple and blunt a way as possible a few of the most important principles in relation to present-day matters of public concern; such concern seems to revolve about the undertaking of individual action to reduce the dietary intake of radioactivity and the prediction of future levels of dietary radioactivity.

For clarity, it has been desirable to oversimplify, but it should be noted that extensive research by many scientists and in many fields has been necessary in order to single out these few important factors and present a simple but realistic pattern of events.

Attention is here given primarily to iodine 131 and strontium 90, since these two nuclides are the ones likely to produce the largest radiation exposure.

It should be pointed out, however, that intensive research is being carried out on all aspects of fission product metabolism that may conceivably have any bearing on radiation exposure.

Iodine 131: Iodine 131 is produced by nuclear weapons in relatively large amounts, has a half-life of about 8 days, is transmitted efficiently

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Dr. Comar is a member of the Food Protection Committee of the National Academy of Sciences, has served on many international committees, and as a consultant on matters of radiation and health to the United Nations Food and Agriculture Organization, United Nations Scientific Committee on the Effects of Atomic Radiation, American Institute of Biological Sciences, Health and Safety Laboratories of the USAEC, U.S. Public Health Service, Oak Ridge Institute of Nuclear Studies, and the Stanford Research Institute.

Dr. Comar was one of the first to do radioisotope research with farm animals, and for many years has been conducting studies on the movement of fission products through the animal phase of the food chain. He is the author of over a hundred scientific papers dealing with these subjects and of a textbook entitled "Radioisotopes in Biology and Agriculture." He is also editor of an AAAS symposium volume entitled "Atomic Energy and Agriculture," and a book entitled "Mineral Metabolism—An Advanced Treatise."

through food chains, and is deposited within the body in a small gland—the thyroid. Because of its 8-day half-life,  $I^{131}$  injected into the stratosphere disappears by radioactive decay almost entirely before it can be returned to earth. It is likewise true that the  $I^{131}$  reaching the soil will disappear by radioactive decay before it can be taken up through the roots of growing plants and thereby be transmitted to the food of man.

Chart I shows the route of  $I^{131}$  through the food chain. There are two primary pathways. The radioiodine is deposited from the atmosphere on the surface of vegetation which is grazed by dairy animals, and the ingested radionuclide secreted into milk.

Man also inhales  $I^{131}$  that is present in the air. Exposure of man to  $I^{131}$  could also occur by consumption of fresh fruits and vegetables; however, such consumption is minor since it normally represents a very small surface area of plant compared to that grazed by an animal, and most often the surface contamination of fresh fruits and vegetables is removed by washing or skinning before consumption.

As supported by recent work of Eisenbud and coworkers, there seems little question but that fresh milk is the main contributor of  $I^{131}$  to the human diet. As indicated on the chart, for example, individuals in New York City in October 1961, who had from 300 to 700 picocuries (micromicrocuries) of  $I^{131}$  in the thyroid are estimated to have received only about 20 picocuries by inhalation.

If the need should ever arise, there are several factors that simplify the reduction of exposure to radioiodine: (1) only one item of the diet, fresh milk, is an important source of contamination; (2) the half-life is short enough so that substitution of processed milk or dairy products for fresh milk effectively reduces the level of contamination in the diet; (3) measurements are relatively simple and rapid because of the radiation characteristics; (4) the time periods during which  $I^{131}$  could be of importance can be predicted from knowledge of the detonation of nuclear devices.

Strontium 90: It is generally accepted that the movement of strontium through the food chain is to a large extent interrelated and governed by the simultaneous movement of calcium.

Stable strontium is normally present in the food chain and an understanding of the behavior of radioactive strontium added by man to the food chain can most easily be gained by consideration of the behavior of stable strontium and calcium.

As will be pointed out later,  $Sr^{90}$  will not exactly parallel the behavior of stable strontium until steady state conditions leading to comparable physical distribution are attained in the future.

As time passes after the cessation of testing or even after constant testing at about the same rate, there will be an approach to identical behavior.

Chart 2 shows some actual data primarily from extensive British surveys giving typical daily intakes and body contents of calcium and stable strontium expressed in milligrams.

I have put the numbers down here to give some feel for the actual amounts involved. These are now in the same units.

The sources of calcium are broken down into milk, plant foods, and "other" which includes fish, eggs, meat, and mineral sources. Values for the United States would be similar except that the "other"

category would contain about 250 milligrams less and the milk about 250 milligrams more calcium; the relative strontium-to-calcium relationship in milk would be about the same as indicated.

This difference comes about because the British enrich their bread with mineral calcium, whereas in the United States milk solids are used for this purpose.

The meaning and implications can better be grasped from chart 3, which presents the same information normalized to a Sr-Ca ratio in the diet of 1.

It is first noted that the Sr-Ca ratio of milk is one-tenth that of the plant foods. The milk value is 0.22 as compared to the plant value of 2.2. This is because the cow preferentially utilizes calcium over strontium by a factor of 10 for milk secretion. It is obvious from this diagram that if an individual reduced milk consumption to zero and derived all of his calcium from plant sources, the Sr-Ca ratio of his diet would be doubled.

In other words, if an individual reduced his milk consumption to zero and all of his strontium and calcium came from plant sources, the value would be 2.2 instead of what we see as 1 in the total diet.

Chairman HOLIFIELD. This is a very important comparison you are making there, Doctor. Those who advocate to stop drinking milk because of the content of it would be in the position of advocating the element in food which is only one-tenth of that which would be deposited on vegetable plants, if I understand your comparison.

Dr. COMAR. This is correct. This is a major point that I did want to bring home.

Chairman HOLIFIELD. Of course, the other side of the picture would be that because of the fact that milk is consumed more by infants and children rather than plants, that milk, still from the standpoint of children and infants, would be the greatest contributor to their absorption; is that not right?

Dr. COMAR. That is correct.

Chairman HOLIFIELD. Particularly young children that have not yet gone on solid diets?

Dr. COMAR. Yes. But if plant sources were substituted for milk, even for young children, this would then tend to raise the strontium-to-calcium intake.

Chairman HOLIFIELD. Would you state specifically the major point that you said you wanted to bring home here?

Dr. COMAR. I have repeated this several times, and it will come up again. It is this: That if an individual reduced milk consumption to zero and derived all of his calcium from plant sources, the strontium-to-calcium ratio of his diet would be doubled.

To carry on, conversely, if an individual derived all of his calcium from milk, his diet would have about one-fifth the typical strontium-to-calcium ratio.

In a minute we will talk about the actual situation in regard to strontium 90 which does not come up to this particular chart as yet, but will approach it with time.

Chairman HOLIFIELD. Will you give us the significance of the balance of that chart, Doctor, where you show mother's milk as one-tenth?

Dr. COMAR. I will come to that in a moment later in the statement. The significance of this point is emphasized by recognition of the fact that the amounts of strontium 90 and calcium in the total diet determine the body burden of strontium 90.

It should also be noted that value of the  $\text{Sr}^{90}$  content or the  $\text{Sr}^{90}/\text{Ca}$  ratio of any individual dietary constituent cannot by themselves be used to assess the degree of exposure: for such an evaluation it is necessary to know the total amounts of  $\text{Sr}^{90}$  and calcium in the diet.

The ratios of  $\text{Sr}/\text{Ca}$  in the body, the fetus and mother's milk reflect the usual biological discrimination against strontium in favor of calcium. This behavior is usually expressed in terms of the observed ratio; for example,

$$\frac{\text{OR}}{\text{body/diet}} = 0.25.$$

The variability in differential behavior, the processes involved and the application of these concepts have been studied most intensively in the laboratory, documented in the literature, and generally accepted.

I had not intended to go into this phase in any more detail unless there is some question on it.

Chairman HOLIFIELD. You, in effect, say here that this shows that although there is that reading of 0.22 in the milk, that does not necessarily mean that the body absorbs that.

It discriminates against some of that in favor of the collection of calcium and, therefore, there is a lesser absorption that the figures shown there, is that right?

Dr. COMAR. Yes. It is perhaps easier to consider it in terms of the ratios. If the total diet had a ratio of 1, then in the body the strontium to calcium would be 0.25.

If a person were consuming milk alone, his total diet would be 0.22 and the ratio in his body would be about a fourth of that, or 0.05.

Mr. RAMEY. Has there been any change since 1959 in your views as to what this ratio is based, on further evidence?

Chairman HOLIFIELD. The discrimination factor.

Mr. RAMEY. Yes.

Dr. COMAR. The value for adult man seems to be gaining more support; that is, the value of 0.25 seems to be supported by the newer evidence that is coming in.

As Dr. Dunham mentioned yesterday, for younger children the value may be up as high as 0.5. For infants it might even approach 1 for a short time. But these experiments are not yet in, in enough detail to make a firm statement.

Mr. RAMEY. How about the factor of pickup from the soil of strontium. In our prediction panels, I believe, in 1959, the estimate apparently was assumed that you would get it all from the soil.

Dr. COMAR. I am going to discuss that later on if I may defer the question?

Mr. RAMEY. Very well.

Chairman HOLIFIELD. Will you proceed, please, Doctor?

Dr. COMAR. The discussion so far has been concerned with the steady-state behavior and it is of interest to consider the actual state of affairs in the last 2 years.

Chart 4 presents values for  $\text{Sr}^{90}/\text{Ca}$  expressed as in previous diagrams. The differences between plant foods and milk are not as great as will be attained under steady-state conditions for reasons that will be discussed presently.

Nevertheless, plant foods have a higher  $\text{Sr}^{90}/\text{Ca}$  ratio than the typical diet, and milk has a lower value.

The next three charts present data that demonstrate this by the comparison in three cities of levels of  $\text{Sr}^{90}$  per gram of calcium in a typical total diet, in the milk contained in the diet, and in the non-milk components.

Senator AIKEN. May I ask, what do you mean when you say plant foods of a higher strontium 90 ratio in a typical diet and milk has a lower value?

What do you mean by lower value? Lower value as far as accumulation of strontium is concerned.

Dr. COMAR. This refers to the actual strontium 90 to calcium ratio in the milk as compared to plant foods. Carrying your question further, as far as we know, the ratio in the body will reflect that in the diet, whether it originates from the plant or whether it originates from the milk.

This is illustrated further by the charts which were taken from the Tri-City study carried out by the Health and Safety Laboratory of the AEC in New York. One can see very readily here that the milk values are lower in terms of strontium 90 per gram of calcium.

The nonmilk components of the diet were higher than the diet, itself.

Senator AIKEN. That chart was not prepared by the New York City Health Department, was it?

Dr. COMAR. This chart was prepared by our staff from the data that was published by the HASL laboratories.

Senator AIKEN. By what laboratory?

Dr. COMAR. The Health and Safety Laboratories of New York. It is an AEC laboratory. May I have the next chart? That was for New York.

The same situation for Chicago. And the same for San Francisco. The values on the ordinate are picocuries or micromicrocuries of strontium 90 per gram of calcium, and time on the abscissa, 1960 through 1961.

Representative PRICE. Doctor, I think what Senator Aiken is probably trying to get at, is whether or not this reflects a favorable situation for milk as against plants or a nonfavorable situation.

What does it reflect?

Dr. COMAR. I would think it would indicate that a person drinking more milk would develop a lower body burden of strontium 90.

Senator AIKEN. That is what I thought. I thought the New York City Board of Health issued a statement about a month ago to the contrary which was not well received throughout New York State, incidentally.

Dr. COMAR. The State board of health, of course, is an entirely different organization from the health and safety laboratory of the commission.

Senator AIKEN. I think it is the city laboratory that issued the statement.

Dr. COMAR. I am not familiar with the statement and I would have to read it to be able to comment on it.

Senator AIKEN. Can you explain why, we will say certain pacifist groups, concentrate on milk as being the principal malefactor in the diet.

For instance, I know that they have a sheet of poems they sing and stories they are supposed to tell to their groups. I can recall

one of them, "Oh where, oh where has the fallout gone, oh where can the poison be, why right in the milk and the other things that the milkman brings to me."

I can give you other items like that. Why do the ultrapacifists seize upon milk when obviously it is the less of the offenders, assuming that any of them are offenders at the present time?

Dr. COMAR. I would like in generosity to think that it is a lack of understanding on their part. They are just not familiar with the type of thing we are talking about.

Senator AIKEN. The result casts suspicions on their own motives by doing these things and concentrating on objects which are obviously the nonoffenders or the most so.

Dr. COMAR. That is right. If people want to strike because of radioactivity they should strike against food.

Senator AIKEN. I will be glad to furnish their sheet of jokes and poems for the record, if the chairman would like to have it.

Representative HOSMER. Let us put it in the file.

Senator AIKEN. Although I did not find anything educational or edifying in it.

Mr. RAMEY. Is it perhaps not part of the answer that the detection network has picked up milk and radioactivity in milk which is easier, perhaps, to measure initially and the network was distributing this information and it has been harder, perhaps, to get the scientific evidence on the other aspects of your diet that provide calcium.

It has been the purpose of this research and these hearings to try to bring this out.

Senator AIKEN. The explanation given to us about 4 years ago, as I recall it was this: That milk is a food which is available in every county in the United States and, therefore, the most convenient food to carry out the tests on.

That is why milk was selected.

Dr. COMAR. It is a good sample for the purpose and has been used. One has to understand that all foods contain strontium 90, milk the least of all. I think if people really understand this they can make their evaluation.

Chairman HOLIFIELD. Mr. Chairman, the lay reader who reads our hearings sometimes, if they do read them, sometimes makes the statement that this committee is attempting to minimize rather than maximize the danger of fallout.

I think the record of this committee is so outstanding in the fact that it has called upon all facets of scientific opinion to present their professional opinion on the subject of radiation that it stands pre-eminent in bringing to lay people as well as other people information on the subject of radiation.

I believe that the record shows that we have striven very hard to bring the facts to the people and then let them make their conclusions according to their own judgment based on the facts.

I find it, however, the same in this line of work as in any other line of work that the people who read the hearings pick out the points like they pick out the points in the President's speeches that happen to coincide with their particular philosophy and they ignore the points which do not coincide with their particular philosophy.

Representative PRICE. Will you proceed, Doctor?

Representative HOSMER. I have one question, Mr. Chairman. Do I understand, Dr. Comar, that the ratio of stable strontium to calcium is a little lower than the ratio of strontium 90 to calcium in your charts?

Dr. COMAR. Yes. As time goes on and we approach steady state these ratios should become identical. But that would take many, many years. So at the present time one of the earlier charts indicated the actual ratio as compared to the theoretical.

In other words, with the value of total diet equal to 1, milk now is running 0.6 to 0.9, whereas theoretically it would run 0.22. As time goes on it would approach this value.

Representative PRICE. Will you proceed, Dr. Comar?

Dr. COMAR. I would like to have in the record the next paragraph but it has been discussed among us and I think the point has been well made.

Representative PRICE. The complete statement will go into the record.

(Complete statement of Dr. Comar will be found at the end of his testimony, p. 95.)

Dr. COMAR. This concept is of such importance that I should like to restate it in terms of practical application. Human beings and animals of all ages must have a certain amount of calcium in the diet to build new bones and teeth or to remodel and rebuild bones already formed. Calcium in the diet comes primarily from dairy products and plant foods, both of which contain  $\text{Sr}^{90}$ . The calcium from dairy products will most always have less  $\text{Sr}^{90}$  than the calcium from plant foods because of discrimination by the cow.

If the consumption of dairy products is reduced without compensating addition of minerals, the body has to use plant sources of calcium for building and replacement of bone.

In effect, this means that reduction of the intake of dairy products will raise the  $\text{Sr}^{90}$ -Ca intake and therefore the body burden of  $\text{Sr}^{90}$ . At present and foreseeable levels of  $\text{Sr}^{90}$  it appears best to follow accepted nutritional practice.

The question is often raised as to the advisability of supplementation of diets with stable calcium or stable strontium, for purposes of reducing the body burden of  $\text{Sr}^{90}$ .

This matter is now considered, leaving aside the question as to whether reduction of present and foreseeable body levels of  $\text{Sr}^{90}$  would in fact improve health.

The  $\text{Sr}^{90}$ Ca ratio of the diet can be decreased by supplementation with uncontaminated stable calcium and this in principle should decrease the  $\text{Sr}^{90}$  levels produced in the body or milk. Although such reductions have been demonstrated in experiments with laboratory and domestic animals, there are many considerations and unknown variables that restrict practical application.

Experiments with dairy cows have shown that long-term supplementation of rations with stable calcium can reduce the  $\text{Sr}^{90}$  levels in milk, but probably not greater than a factor of 4 even under the best conditions, because of abnormality of diets.

There are uncertainties in regard to the effects on animal nutrition and health from high calcium intakes over long periods of time, and in regard to the length of time it requires for calcium supplementation to become effective.

Supplementation of human diets is not recommended. This is primarily because widespread excessive calcium intakes could lead to health problems; in addition, the effectiveness of such procedures and the proper balance of supplemental mineral intakes are not known.

It is especially important that individuals do not take medically unsupervised action. When calcium supplementation is required for medical or nutritional purposes, thought should be given to the fact that calcium supplements derived from animal bone contain  $\text{Sr}^{90}$ .

Experience has shown that there is no advantage in the use of stable strontium to reduce  $\text{Sr}^{90}$  deposition in the body or secretion into milk. This is because the  $\text{Sr}^{90}$  behavior is governed by the total level of both alkaline earths (calcium and strontium) and the amounts of strontium required to increase this total level appreciably are sufficient to produce side effects.

For purposes of prediction of future levels of  $\text{Sr}^{90}$  it is necessary to consider the two major pathways in the food chain. These are indicated in chart 8. The pathways are (1) surface contamination of plants which are then consumed by man or grazing animals (the dietary contamination produced by this pathway is entirely dependent upon the rate of fallout) and (2) the accumulation of  $\text{Sr}^{90}$  in the soil with subsequent uptake through the plant roots (contamination produced by this pathway is dependent upon the cumulative total in the soil).

When the fallout rate is high compared to the cumulative total, the first or rate-dependent pathway predominates as indicated in the chart.

For example, in 1957, when the milk contained about seven picocuries per gram of calcium, it is calculated that about four picocuries came from the rate dependent path and three from the cumulative dependent path. In 1961, however, one can see that the pathway from the cumulative total began to redominate when there was 9.5 picocuries per gram of calcium, 8 came from the cumulative pathway and 1.5 from the rate dependent pathway.

Because the plant foods that man eats are usually washed or skinned, the expected tenfold difference in the  $\text{Sr}^{90}/\text{Ca}$  ratio between milk and plant foods is decreased. As indicated, the cumulative-dependent pathway becomes dominant with time after the cessation of testing or even with a constant rate of testing.

Under these conditions, as implied in chart 9, plant foods are contaminated throughout and surface cleansing would not greatly reduce their  $\text{Sr}^{90}/\text{Ca}$  ratio.

Mathematical relationships have been derived from measurements of fallout rate, cumulative totals and levels in milk. The presently accepted factors are indicated in chart 10.

The picocuries of strontium 90 per gram of calcium in the milk equals a rate component plus a cumulative component. The rate component can be expressed as some factor, a factor that we now use as 0.3 times the millicuries per square mile per year, plus the cumulative component, the factor 0.12 times the total deposition which is millicuries per square mile.

This formula allows calculation for the future levels. It should be pointed out that these factors are quite variable, especially if converted to use with total diets, and should be applied only to large areas.

Another matter that needs to be taken into account is that  $\text{Sr}^{90}$  in

soil may become less available to plants by a few percent per year because of runoff, redistribution by wind, removal in crops, and possibly fixation in the soil.

Representative PRICE. Dr. Comar, Mr. Ramey has a question.

Mr. RAMEY. Is there any—in that formula that you gave there—change in that formula or the basis of it since 1959 when we had our last calculations?

Dr. COMAR. The basic form is the same. There is more evidence now for the numerical values of the constants. These have been determined in three ways.

One, by looking at the situation recently where the fallout rate has fallen to zero so that the total amount in the milk will be entirely dependent upon the cumulative factor.

Another, by doing regression analysis over past years.

And, finally, another method by using field experiments to determine these factors. So that the values are becoming narrower in their range and more reliable.

Representative PRICE. Dr. Comar, in this connection, do all the figures in your statement on different points of research and so forth reflect updating since 1958?

Dr. COMAR. Yes; they do, wherever possible. These have been supported in the bibliography.

Representative PRICE. Your bibliography will indicate to us whether or not these are different figures than we previously considered at other hearings?

Dr. COMAR. Yes. Either they are the latest figures that I have been able to get hold of, or if they are the same figures—as for example in the discrimination factor—they are on a firmer basis than previously.

Representative PRICE. Mr. Ramey.

Mr. RAMEY. In Dr. Langham's statement he is talking about the estimates made in 1959 by our panel and he noted that there was some discrepancy between then and now, that they were a little optimistic or pessimistic. They indicated that there would be a greater deposition of strontium 90.

He said that this discrepancy is readily explained. The 1959 predictions were based on the assumption that strontium 90 in the diet at that time was totally dependent on the integral surface deposition level. This assumption led to overprediction of the 70-year doses by approximately a factor of 2.

Do your figures bear that out?

Dr. COMAR. Yes; I think they do. There is general acceptance now—and I think Dr. Langham has taken this into account—that certainly in the early phases a considerable amount of the activity in the milk and in the total diet got there by the rate dependent process.

I think that is pretty firm. We didn't have good values on that 2 or 3 years ago.

Representative PRICE. Will you proceed, Doctor?

Dr. COMAR. I would like to say a word now about cesium 137. Cesium 137, much like Sr<sup>90</sup>, can enter plants both from surface contamination, a rate-dependent process, and from the soil, a cumulative-dependent process. Absorption of cesium 137 from soil, however, is inefficient, it being estimated that soil absorption of Cs<sup>137</sup> is only one-tenth to one twenty-fifth that of Sr<sup>90</sup>.

This means that the rate-dependent process will be dominant. The level of Cs<sup>137</sup> in the diet has not fallen as rapidly as expected from the decrease in fallout rate, probably because of a holdup in the root mat of pastures.

For future predictions it is probably best to base estimates of the cumulative component on comparison with Sr<sup>90</sup> assuming that absorption of Cs<sup>137</sup> from soil is less by a factor of 10 to 25, but that efficiency of secretion into milk is greater by a factor of 10.

The next chart shows the same type of approach for cesium 137, where the factors are 1.4 for the rate-dependent component and 0.05 for the cumulative-dependent component.

I must say, however, that this relationship is on nowhere near a firm a basis as the one for strontium. This is about the best we can do with the data at hand. It does bring out the point, though, at steady state one must not ignore the cumulative component because in the years to come the amount of cesium we see in the diet may come almost equally from the soil as compared to rate.

I would like to say a word about radioactivity in the total diet simply to give you a comparison of relative daily intakes of various radionuclides both naturally and man made.

The next chart, please. One notices that the daily intake expressed in terms of picocuries of natural potassium 40 is about 4,000 picocuries per day; cesium 137, about 50 in 1961; strontium 90, about 10, cerium 144, about 4; lead 210, which is a natural radionuclide, about 4; radium 226, which is a natural radionuclide, about 2; and plutonium 239, estimated at one-tenth.

Representative PRICE. Which of this group, aside from those you have gone into already in detail, do you consider of some importance?

Dr. COMAR. The Prediction Panel later on will present some dose predictions which will answer your question quantitatively.

There is no question that strontium 90 and, from the short-term standpoint, iodine 131 are the most important. Cesium 137 is of much lesser importance. The others are of even lesser importance.

It should be noted, of course, that possible effects on the population—

Chairman HOLIFIELD. Let me ask you a question. I am not quite sure.

Why do you rate potassium, K-40, along with these other radioactive materials? Is it radioactive, also?

Dr. COMAR. Potassium 40 is radioactive.

Chairman HOLIFIELD. It comes in the food naturally.

Dr. COMAR. It is in the food naturally.

Chairman HOLIFIELD. By a factor of 4,000 units or picocuries as against 40 from cesium 137.

Mr. RAMEY. That would be natural background?

Dr. COMAR. Yes.

Representative PRICE. What is the half-life?

Dr. COMAR. About 10 to the ninth year, I believe.

Representative HOSMER. It is excreted by the body?

Dr. COMAR. It is turned over by the body with a half time of something like 60 to 80 days.

Representative HOSMER. The difference, then, is that these other elements tend to remain in the body a longer period of time?

Dr. COMAR. Some of them do. Cesium behaves in the body like potassium and is turned over relatively rapidly whereas strontium behaves much like radium and is sequestered in the bone.

I wanted to drive home the point that for years we have been consuming radioactivity in the diet and these are the relative amounts. Many people don't seem to realize this.

Chairman HOLIFIELD. Is there a different deleterious effect, however, between the potassium or the amount of radiation in the potassium and the amount in the strontium 90 or the cesium 137.

Dr. COMAR. Yes. I was going to add that one has to take into account many other factors besides the amount ingested. We can't get into this here. This, again, is a rewording of the old problem of trying to compare the effects of natural background with the effects of an addition to the natural background, expressed in a slightly different way.

Chairman HOLIFIELD. When you don't know what the natural background effect is?

Dr. COMAR. That is right.

Chairman HOLIFIELD. It is a theory that the whole problem of natural background radiation having deleterious effects is a theory that has never been proved in a laboratory; is that not true?

Dr. COMAR. I think that is a fair statement. There is no evidence.

Chairman HOLIFIELD. They are trying to work it out. The point involved is that it is of such a low level that observable or detectable deleterious effects are not observable.

Dr. COMAR. They are not observable; that is correct.

Chairman HOLIFIELD. And the only way that you can get observable and detectable effects is to raise the rate of radiation much higher than background radiation; is that a fact?

Dr. COMAR. Yes. One would have to either do that or increase tremendously the number of individuals on which observations were made. It has been impossible to do this on an experimental basis.

Chairman HOLIFIELD. It is not proved, however, because we can't observe it and detect it, that there might not be damage involved.

It is merely a matter that we have not been able to prove.

Dr. COMAR. That is right. If one wants to make a deduction you have to invoke the linear hypothesis and extrapolate downward.

Chairman HOLIFIELD. Extrapolate into theory beyond the area of proven knowledge.

Dr. COMAR. That is right.

Representative PRICE. You do not have iodine 131 on that list. What is the reason for leaving it off?

Dr. COMAR. In this particular study the samples were taken when there was no iodine 131 in the diet.

Representative PRICE. How long ago were they taken?

Dr. COMAR. These were taken in January and in May of 1961, the samples that are represented by these values.

Chairman HOLIFIELD. Before the Russian tests?

Dr. COMAR. That is right.

Representative HOSMER. Since you are eating food every day, I take it, then, that the amount of radiation to which the body is subjected is equal to 4,006 picocuries, being the total of the potassium, lead, and radium from natural sources as against 64 picocuries from the test-created elements.

Dr. COMAR. It is not quite as simple as that because there is a differential rate of turnover in the body and one has to take into account the degree of absorption and the rate of elimination.

So that the evaluation is not quite as simple as you have stated.

Representative HOSMER. Since potassium remains in the body for 60 days, to give the same amount of exposure, cesium would have to remain in the body 80 times 60 days; is that right?

Dr. COMAR. For cesium and potassium the comparison would be a fairly valid one, but the others would have to be considered separately. I think later on when the Prediction Panel talks about dose commitments this type of information will be put in a form so that one can get a comparison.

Chairman HOLIFIELD. Will the gentleman yield?

Representative HOSMER. Yes.

Chairman HOLIFIELD. Is it also equally true that because of the daily intake that your level of potassium would remain high continuously. Therefore, it would not be taken into the body and then because of its short half-life disappear from the body at the end of the 60 or 80 days because your daily intake would keep your level up or the ratio of your level up continuously at that level that you show.

Dr. COMAR. That is right. Potassium has such a long physical half-life that removal by decay is insignificant. So it is only removed by biological processes that effect the situation.

Chairman HOLIFIELD. And the daily intake replenishes the amount of deterioration to the point where you can almost say that strikes a level?

Dr. COMAR. That is right. The body burdens of potassium 40 can easily be calculated. I don't have them at hand, but these are known.

Representative PRICE. Mr. Ramey.

Mr. RAMEY. In view of this large amount of radiation from potassium you would not advocate cutting potassium out of the diet, would you? It is an essential part of the human mechanism, isn't it?

Dr. COMAR. My feeling is that the levels of radioactivity are such that they should not cause anyone to make any modification in diet other than for health purposes. That is, health from a nutritional standpoint.

Mr. RAMEY. Potassium is a part of every fertilizer that is sold. It is essential to the structure of crops and so on.

Representative PRICE. Senator Aiken.

Senator AIKEN. Dr. Comar, in addition to the elements which you have shown on the chart, doesn't the human being carry around a considerable amount of phosphorus and arsenic and other deadly elements in his body at all times in addition to these?

Dr. COMAR. Yes. Of course, one has to be careful how you define "deadly." If a man is dropped in the middle of the ocean, water is deadly. But if he is on a desert, it is not.

Senator AIKEN. Nevertheless, the human body contains substantial amounts of phosphorus which would be deadly if taken by itself and also arsenic?

Dr. COMAR. Yes. This comparison has been restricted simply to radioactivity.

Senator AIKEN. Are there any other radioactive elements which are taken into the body?

Dr. COMAR. Carbon 14 probably should be included in this list, but I have not considered that.

Senator AIKEN. Is any of the potassium which is taken into the body in the form of cyanide, does the body contain any cyanide?

Dr. COMAR. I would think it must in very small amounts.

Chairman HOLIFIELD. I think the point the Senator makes is well taken. He points out that there are nonradioactive chemical poisons which are constantly taken into the body in addition to the poison of radioactivity.

Senator AIKEN. And are responsible for far greater disasters to the human race.

Representative HOSMER. Of course, we get back to the threshold question where there is a definite threshold established with respect to these poisons whereas the threshold has not been proved with respect to radioactivity; is that right?

Dr. COMAR. Undoubtedly there has been so much emphasis on radiation and radioactivity that the whole matter has caused other things to be lost sight of.

It is important to look at the totality of the picture.

Senator AIKEN. Do you not think, Doctor, it was a great calamity that the critics of the use of milk and other dairy products did not advise the Maker before He set up the original milk program?

Would that not have made the human race much better and healthier and more self-sufficient had He known about these things that we are being told now?

Dr. COMAR. I will accept your word.

Representative PRICE. Thank you very much, Dr. Comar, for a fine statement and a valuable contribution to these hearings.

Chairman HOLIFIELD. I know your biography will appear in the record but what is your position at Cornell, sir?

Dr. COMAR. I am head of the department of physical biology, which is a department in the university concerned primarily with the application of physical principles and concepts, biological research.

Most of our work at the present time is comprised of work with radiation, biological effects, fission product metabolism, but we have tried on an educational basis to look at the overall picture.

Chairman HOLIFIELD. Do you feel that the testimony you have given this morning before this committee is generally supported by competent scientists in the biological field?

Dr. COMAR. I would think so. There are still minor points of disagreement, which is very healthy. But the main points that I have made I feel are definitely supported.

Chairman HOLIFIELD. In other words, the presentation you have made is a true representation, as far as you know, of the consensus of scientific opinion in this field and the figures that you have given us would not be seriously challenged except in a minor degree possibly by other scientists of high repute?

Dr. COMAR. I would think that is the situation. I have not met very many people who I could not talk into some of these points if necessary.

Representative PRICE. Thank you very much. The next and concluding witness this morning will be Mr. Donald Chadwick, Chief, Division of Radiological Health, Public Health Service.

(Statement by Dr. Cyril L. Comar follows:)

STATEMENT OF DR. C. L. COMAR, CORNELL UNIVERSITY

It is a privilege to appear before this committee and to acknowledge publicly the wholehearted support of our work by numerous Federal agencies, especially the Atomic Energy Commission, Public Health Service, and Departments of Defense and Agriculture. Tribute is also due to many colleagues whose names are well known in the scientific literature.

Contamination of food and water represents the primary pathway by means of which the human population is exposed to radiation from worldwide fallout. The principles governing the movement of fallout radio-contaminants through the food chain have been described fully in the 1959 hearings of the Special Subcommittee on Radiation, and in the literature. Recent developments have provided some refinement, but the basic principles as previously set forth have been supported and are still valid.

There has been much confusion regarding the comparative wholesomeness of various constituents of our diet, a confusion that could be dispelled easily by an understanding of a few basic facts. This report is an attempt to reemphasize in as simple and blunt a way as possible a few of the most important principles in relation to present day matters of public concern; such concern seems to revolve about the undertaking of individual action to reduce the dietary intake of radioactivity and the prediction of future levels of dietary radioactivity. For clarity, it has been desirable to oversimplify, but it should be noted that extensive research by many scientists and in many fields has been necessary in order to single out these few important factors and present a simple but realistic pattern of events.

Attention is here given primarily to iodine 131 and strontium 90, since these two nuclides are the ones likely to produce the largest radiation exposure. It should be pointed out, however, that intensive research is being carried out on all aspects of fission product metabolism that may conceivably have any bearing on radiation exposure.

IODINE 131

Iodine 131 is produced by nuclear weapons in relatively large amounts, has a half-life of about 8 days, is transmitted efficiently through food chains, and is deposited within the body in a small gland, the thyroid. Because of its 8-day half-life,  $I^{131}$  is of significance only within weeks of the time of its production, and thus comes primarily from tropospheric fallout. The  $I^{131}$  injected into the stratosphere disappears by radioactive decay almost entirely before it can be returned to earth. It is likewise true that the  $I^{131}$  reaching the soil will disappear by radioactive decay before it can be taken up through the roots of growing plants and thereby be transmitted to the food of man.

Chart 1 shows the route of  $I^{131}$  through the food chain. There are two primary pathways. The radioiodine is deposited from the atmosphere on the surface of vegetation which is grazed by dairy animals, and the ingested radio-nuclide secreted into milk. Man also inhales  $I^{131}$  that is present in the air. Exposure of man to  $I^{131}$  could also occur by consumption of fresh fruits and vegetables; however, such consumption is minor since it normally represents a very small surface area of plant compared to that grazed by an animal, and most often the surface contamination of fresh fruits and vegetables is removed by washing or skinning before consumption. As supported by recent work of Eisenbud and coworkers, there seems little question but that fresh milk is the main contributor of  $I^{131}$  to the human diet. As indicated on the chart, for example, individuals in New York City in October 1961 who had from 300 to 700 picocuries (micromicrocuries) of  $I^{131}$  in the thyroid are estimated to have received only about 20 picocuries by inhalation.

If the need should ever arise, there are several factors that simplify the reduction of exposure to radioiodine: (1) Only one item of the diet, fresh milk, is an important source of contamination; (2) the half-life is short enough so that substitution of processed milk or dairy products for fresh milk effectively reduces the level of contamination in the diet; (3) measurements are relatively simple and rapid because of the radiation characteristics; (4) the time periods during which  $I^{131}$  could be of importance can be predicted from knowledge of the detonation of nuclear devices.

## STRONTIUM 90

It is generally accepted that the movement of strontium through the food chain is to a large extent interrelated and governed by the simultaneous movement of calcium. Stable strontium is normally present in the food chain and an understanding of the behavior of radioactive strontium added by man to the food chain can most easily be gained by consideration of the behavior of stable strontium and calcium.

As will be pointed out later,  $\text{Sr}^{90}$  will not exactly parallel the behavior of stable strontium until steady state conditions leading to comparable physical distribution are attained in the future. As time passes after the cessation of testing or even after constant testing at about the same rate, there will be an approach to identical behavior.

Chart 2 shows some actual data primarily from extensive British surveys giving typical daily intakes and body contents of calcium and stable strontium expressed in milligrams. The sources of calcium are broken down into milk, plant foods, and "other," which includes fish, eggs, meat, and mineral sources. Values for the United States would be similar except that the "other" category would contain about 250 milligrams less and the milk about 250 milligrams more calcium; the relative strontium to calcium relationship in milk would be about the same as indicated. This difference comes about because the British enrich their bread with mineral calcium, whereas in the United States milk solids are used for this purpose.

The meaning and implications can better be grasped from chart 3, which presents the same information normalized to a Sr/Ca ratio in the diet of 1.

It is first noted that the Sr/Ca ratio of milk is one-tenth that of the plant foods. This is because the cow preferentially utilizes calcium over strontium by a factor of 10 for milk secretion. It is obvious from this diagram that if an individual reduced milk consumption to zero and derived all of his calcium from plant sources, the Sr/Ca ratio of his diet would be doubled. Conversely, if an individual derived all of his calcium from milk, his diet would have about one-fifth the typical Sr/Ca ratio. The significance of this is emphasized by recognition of the fact that the amounts of  $\text{Sr}^{90}$  and calcium in the total diet determine the body burden of  $\text{Sr}^{90}$ .

It should also be noted that values of the  $\text{Sr}^{90}$  content or the  $\text{Sr}^{90}/\text{Ca}$  ratio of any individual dietary constituent cannot by themselves be used to assess the degree of exposure: for such an evaluation it is necessary to know the total amounts of  $\text{Sr}^{90}$  and calcium in the diet.

The ratios of Sr/Ca in the body, the fetus and mother's milk reflect the usual biological discrimination against strontium in favor of calcium. This behavior is usually expressed in terms of the observed ratio—for example,

$$\frac{\text{OR}}{\text{body/diet}} = 0.25.$$

The variability in differential behavior, the processes involved and the application of these concepts have been studied most intensively in the laboratory, documented in the literature, and generally accepted.

The discussion so far has been concerned with the steady-state behavior and it is of interest to consider the actual state of affairs in the last 2 years. Chart 4 presents values for  $\text{Sr}^{90}/\text{Ca}$  expressed as in previous diagrams. The differences between plant foods and milk are not as great as will be attained under steady-state conditions for reasons that will be discussed presently. Nevertheless, plant foods have a higher  $\text{Sr}^{90}/\text{Ca}$  ratio than the typical diet, and milk has a lower value.

The next three charts present data that demonstrate this by the comparison in three cities of levels of  $\text{Sr}^{90}$  per gram of calcium in a typical total diet, in the milk contained in the diet, and in the nonmilk components.

This concept is of such importance that I should like to restate it in terms of practical application. Human beings and animals of all ages must have a certain amount of calcium in the diet to build new bones and teeth or to remodel and rebuild bones already formed. Calcium in the diet comes primarily from dairy products and plant foods, both of which contain  $\text{Sr}^{90}$ . The calcium from dairy products will most always have less  $\text{Sr}^{90}$  than the calcium from plant foods because of discrimination by the cow. If the consumption of dairy prod-

ucts is reduced without compensating addition of minerals, the body has to use plant sources of calcium for building and replacement of bone. In effect, this means that the reduction of the intake of dairy products will raise the  $\text{Sr}^{90}/\text{Ca}$  intake and therefore the body burden of  $\text{Sr}^{90}$ . At present and foreseeable levels of  $\text{Sr}^{90}$  it appears best to follow accepted nutritional practice.

The question is often raised as to the advisability of supplementation of diets with stable calcium or stable strontium, for purposes of reducing the body burden of  $\text{Sr}^{90}$ . This matter is now considered, leaving aside the question as to whether reduction of present and foreseeable body levels of  $\text{Sr}^{90}$  would in fact improve health.

The  $\text{Sr}^{90}/\text{Ca}$  ratio of the diet can be decreased by supplementation with uncontaminated stable calcium and this in principle should decrease the  $\text{Sr}^{90}$  levels produced in the body or milk. Although such reductions have been demonstrated in experiments with laboratory and domestic animals, there are many considerations and unknown variables that restrict practical application.

Experiments with dairy cows have shown that long-term supplementation of rations with stable calcium can reduce the  $\text{Sr}^{90}$  levels in milk, but probably not greater than a factor of four even under the best conditions, because of abnormality of diets. There are uncertainties in regard to the effects of animal nutrition and health from high calcium intakes over long periods of time, and in regard to the length of time it requires for calcium supplementation to become effective.

Supplementation of human diets is not recommended. This is primarily because widespread excessive calcium intakes could lead to health problems; in addition, the effectiveness of such procedures and the proper balance of supplemental mineral intakes are not known. It is especially important that individuals do not take medically unsupervised action. When calcium supplementation is required for medical or nutritional purposes, thought should be given to the fact that calcium supplements derived from animal bone contain  $\text{Sr}^{90}$ .

Experience has shown that there is no advantage in the use of stable strontium to reduce  $\text{Sr}^{90}$  deposition in the body or secretion into milk. This is because the  $\text{Sr}^{90}$  behavior is governed by the total level of both alkaline earths (calcium and strontium) and the amounts of strontium required to increase this total level appreciably are sufficient to produce side effects.

For purposes of prediction of future levels of  $\text{Sr}^{90}$  it is necessary to consider the two major pathways in the food chain. These are indicated in chart 8. The pathways are (1) surface contamination of plants which are then consumed by man or grazing animals (the dietary contamination produced by this pathway is entirely dependent upon the rate of fallout) and (2) the accumulation of  $\text{Sr}^{90}$  in the soil with subsequent uptake through the plant roots (contamination produced by this pathway is dependent upon the cumulative total in the soil). When the fallout rate is high compared to the cumulative total, the first or rate-dependent pathway predominates as indicated in the chart.

Because the plant foods that man eats are usually washed or skinned, the expected tenfold difference in the  $\text{Sr}^{90}/\text{Ca}$  ratio between milk and plant foods is decreased. As indicated, the cumulative-dependent pathway becomes dominant with time after the cessation of testing or even with a constant rate of testing. Under these conditions, as implied in chart 9, plant foods are contaminated throughout and surface cleansing would not greatly reduce their  $\text{Sr}^{90}/\text{Ca}$  ratio.

Mathematical relationships have been derived from measurements of fallout rate, cumulative totals and levels in milk. The presently accepted factors are indicated in chart 10. It should be pointed out that these factors are quite variable, especially if converted to use with total diets, and should be applied only to large areas.

Another matter that needs to be taken into account is that  $\text{Sr}^{90}$  in soil may become less available to plants by a few percent per year because of runoff, redistribution by wind, removal in crops, and possibly fixation in the soil.

## CESIUM 137

Cesium 137, much like  $\text{Sr}^{90}$ , can enter plants both from surface contamination, a rate-dependent process, and from the soil, a cumulative-dependent process. Absorption of cesium 137 from soil, however, is inefficient, it being estimated that soil absorption of  $\text{Cs}^{137}$  is only one-tenth to one-twenty-fifth that of  $\text{Sr}^{90}$ . This

means that the rate-dependent process will be dominant. The level of  $Cs^{137}$  in the diet has not fallen as rapidly as expected from the decrease in fallout rate, probably because of a holdup in the root mat of pastures.

For future predictions it is probably best to base estimates of the cumulative component on comparison with  $Sr^{90}$  assuming that absorption of  $Cs^{137}$  from soil is less by a factor of 10 to 25, but that efficiency of secretion into milk is greater by a factor of 10. Estimates of the rate component are best determined by comparison of known fallout rates and milk levels in the past.

Roughly, 60 percent of the dietary  $Cs^{137}$  has been contributed by dairy products, 25 percent by meat, and 15 percent by plant foods.

#### RADIOACTIVITY IN TOTAL DIET

It is of interest to compare the relative daily intakes of various radionuclides, both natural and man made. Typical values expressed in picocuries per day are listed as follows (I. Michelson, personal communication) :

$K^{40}$	4,000.0	Natural.
$Cs^{137}$	50.0	1961.
$Sr^{90}$	10.0	1961.
$Ce^{144}$	4.0	1961.
$Pb^{210}$	4.0	Natural.
$Ra^{226}$	2.0	Natural.
$Pu^{239}$	0.1	1961.

It should be noted, however, that possible effects on the population must take into account many other factors besides the amounts ingested. It is beyond the scope of this report to consider such an assessment.

CHART 1

Iodine - 131 (Oct. 1961)

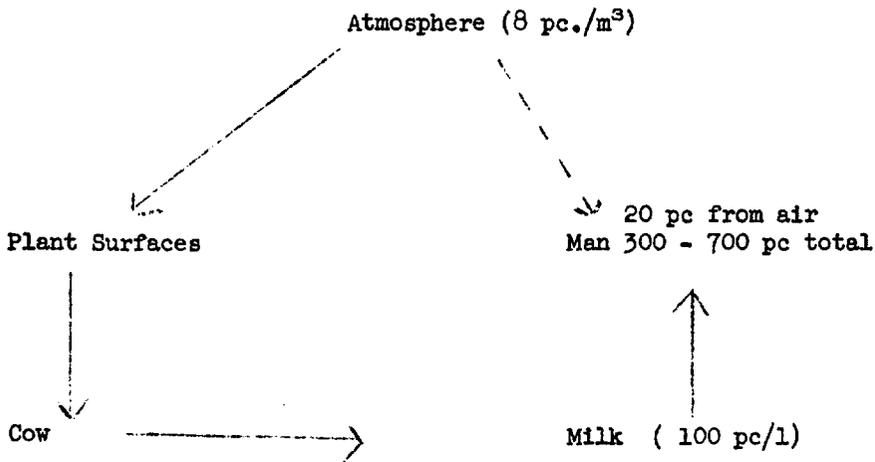


CHART 2

Milligrams/day  
Stable Sr and Ca

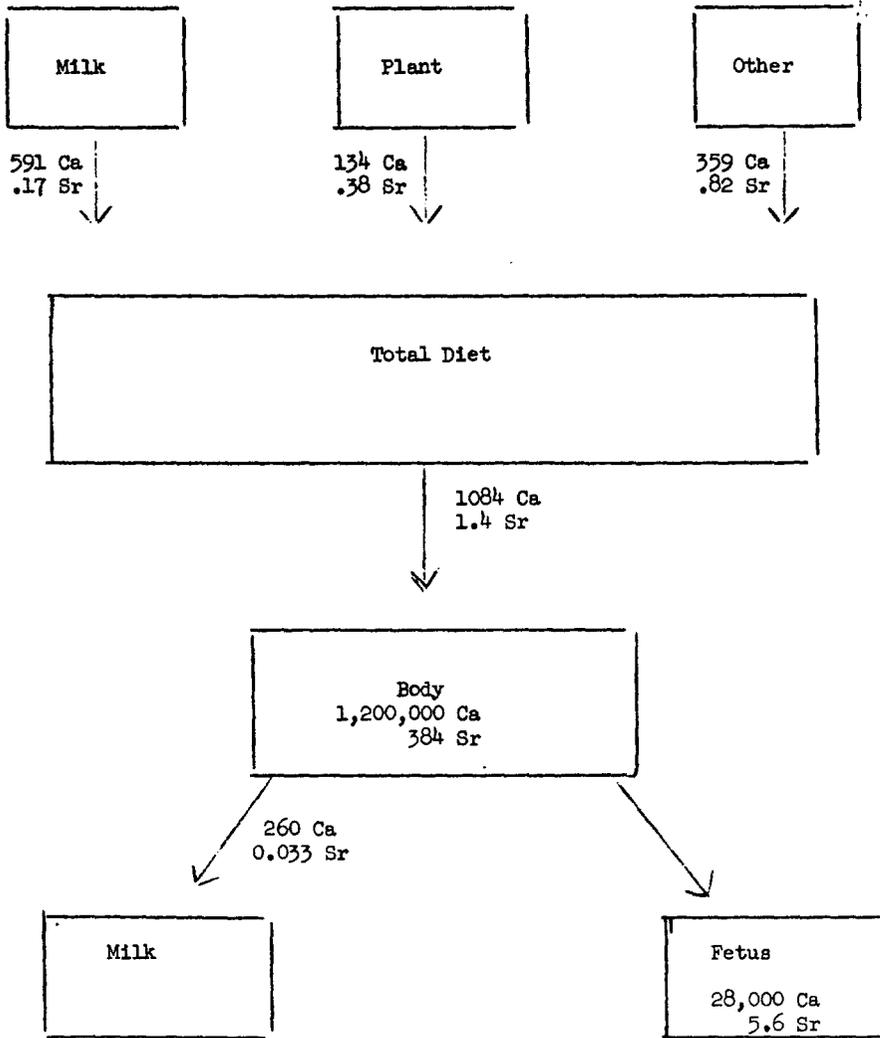


CHART 3

Sr/Ca of Diet = 1

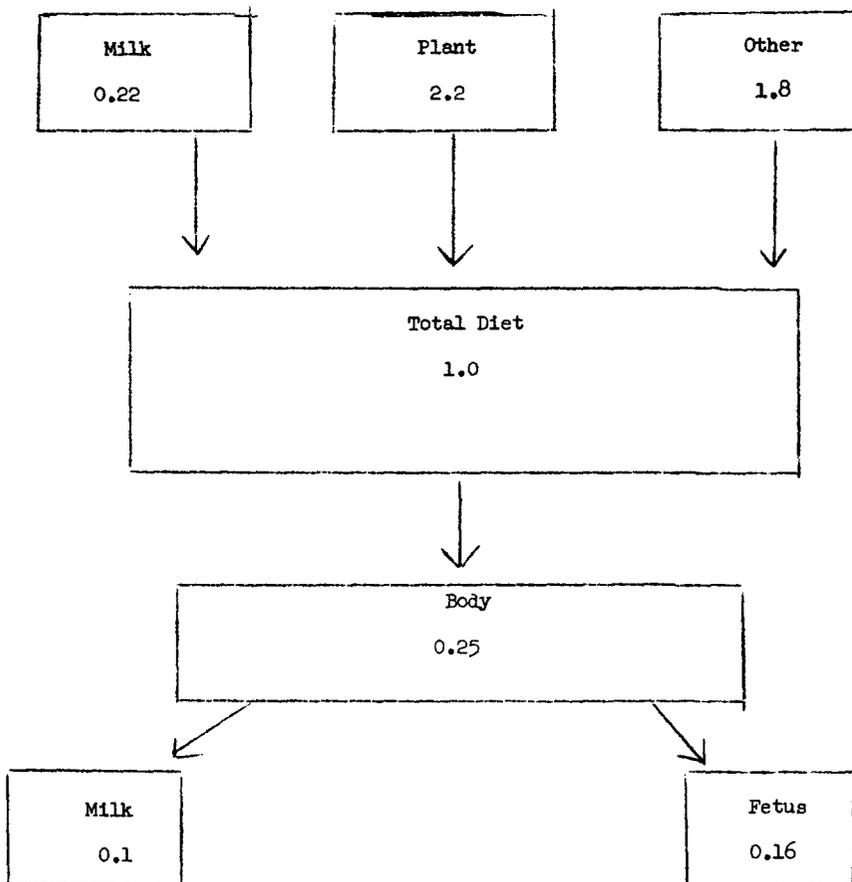
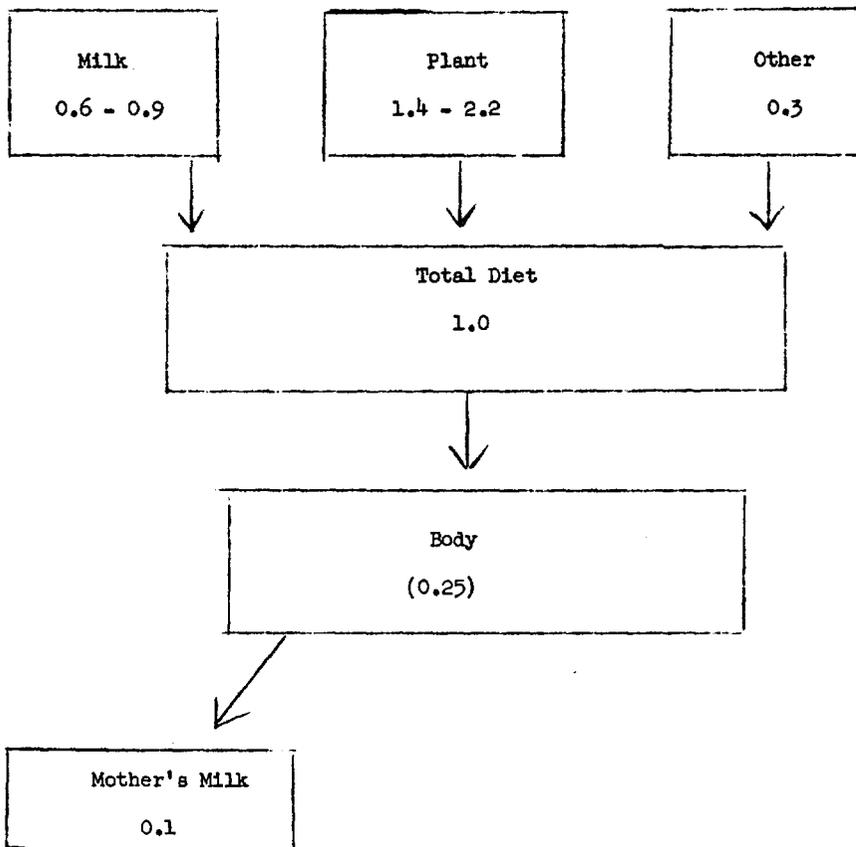
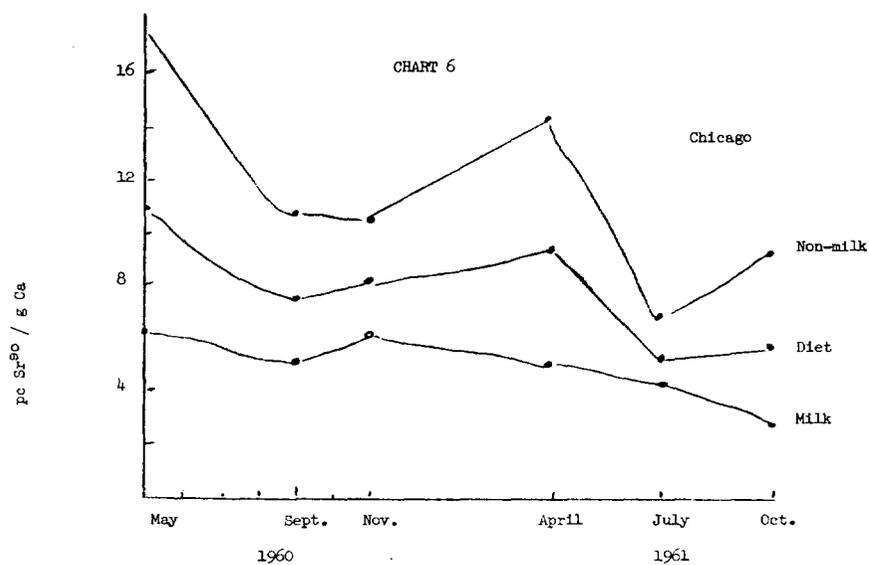


CHART 4

$\text{Sr}^{90}/\text{Ca}$  of Diet = 1  
1959 - 1961





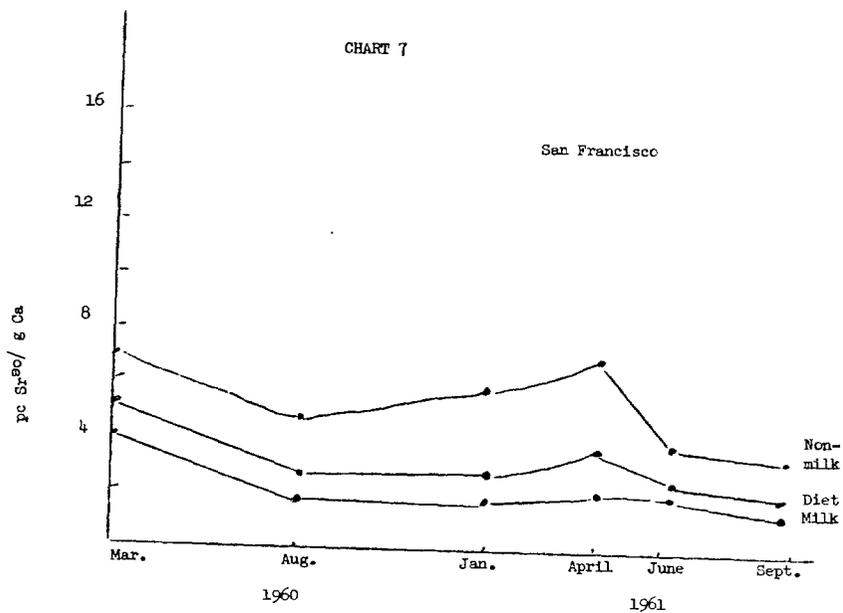
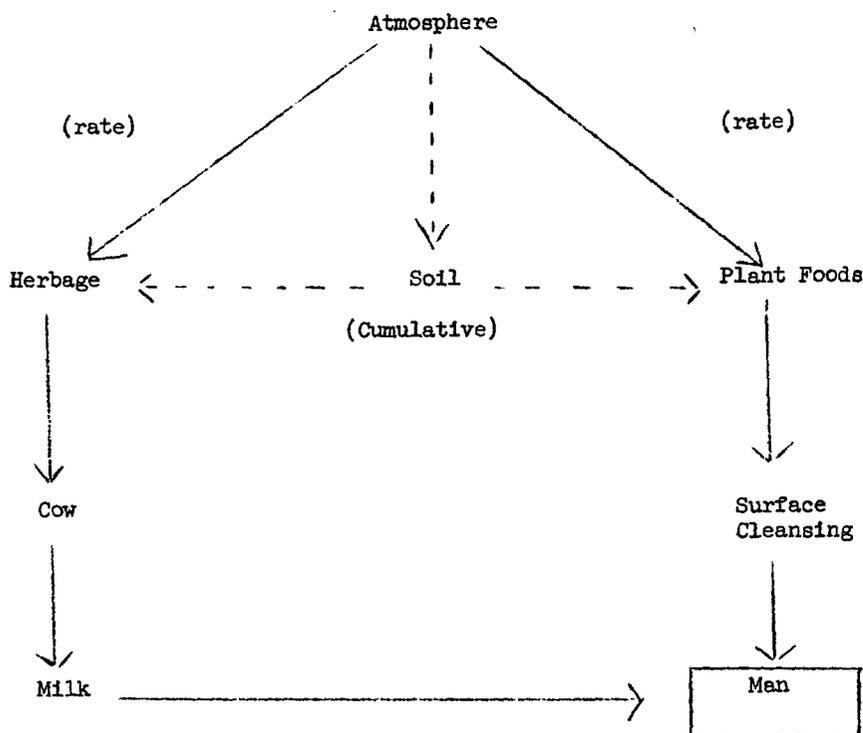


CHART 8  
 Strontium 89 and 90  
 FALLOUT RATE HIGH



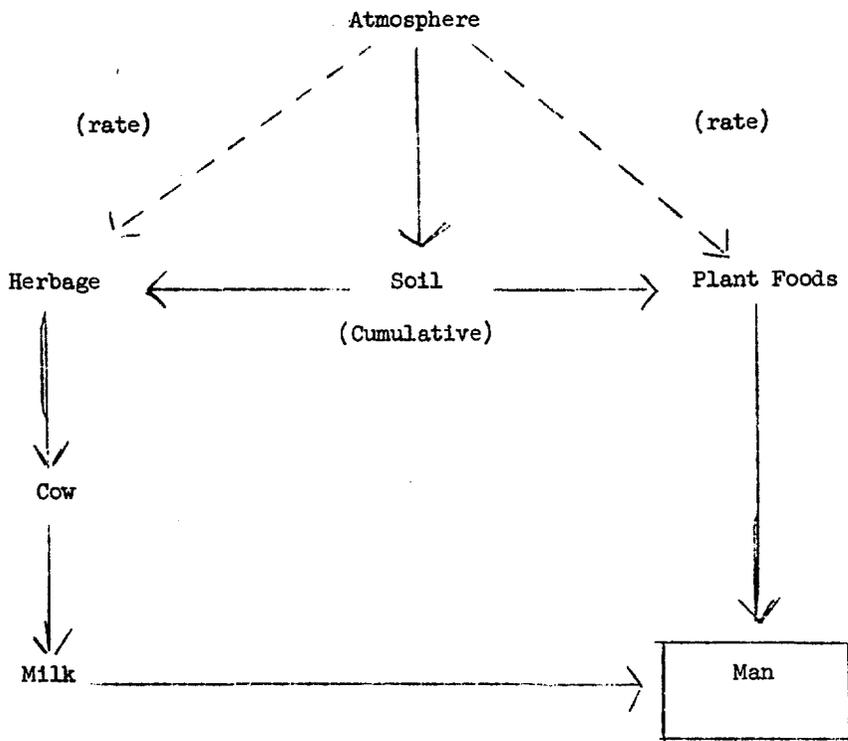
1957      4 (rate) + 3 (cum.) = 7 pc/g Ca in milk

1961      1.5 (rate) + 8 (cum.) = 9.5 g Ca in milk

CHART 9

Strontium 89 and 90

Cumulative Component High



## CHART 10

pc of Sr<sup>90</sup> / g Ca in milk

= rate component + cumulative component

= factor A (mc/mi<sup>2</sup>/yr) + factor B (mc/mi<sup>2</sup>)

= 0.3 (mc/mi<sup>2</sup>/yr) + 0.12 (mc/mi<sup>2</sup>)

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**STATEMENT OF DONALD R. CHADWICK, M.D.,<sup>1</sup> CHIEF, DIVISION OF  
RADIOLOGICAL HEALTH, U.S. PUBLIC HEALTH SERVICE**

Dr. CHADWICK. Thank you, Mr. Chairman. My discussion this morning is entitled "The Intake of Radioactive Contaminants by the U.S. Population."

The U.S. Public Health Service has in recent years been developing surveillance systems to measure the levels of radioactivity in the environment.

The purpose of these systems is to provide quantitative data from which exposures of the U.S. population to radiocontaminants in the environment can be compared with appropriate radiation protection standards.

The details of these surveillance systems will be described in other testimony before this committee. It will be the purpose of this discussion to present briefly some of the more pertinent findings from these surveillance systems since the previous hearings held before this committee in May 1959.

PHS milk network: Milk is an important source of information on human intake of many significant radionuclides from the environment. There are several reasons for this. (1) Many of the radionuclides considered to be of principal health interest occur in milk. Indeed, milk is often the most important source of the radioactive material in the diet.

I think the discussion during the previous testimony brought out the fact that radioiodine in milk is perhaps virtually the only source of this nuclide in the diet.

Second, milk and milk products represent a significant part of the diet for all age groups, and a very large portion of the total diet in infants and children. (3) The production of milk throughout the

<sup>1</sup>Biographical sketch, Donald R. Chadwick, M.D.: Dr. Chadwick, a native of Boston, Mass., after graduating from Harvard Medical School and after internship in Philadelphia, worked as a local health officer in North Carolina from 1951 to 1953. He entered the Public Health Service in 1953, and after serving an assignment in South Carolina, received special training in radiological health at Reed College, Oregon. In 1955, he was assigned to the occupational health program in Cincinnati, Ohio. This was followed by assignment as Chief, Program Services, in the field of radiological health, and then an assignment as liaison officer for radiation, Office of the Surgeon General, Public Health Service. With the establishment of the Division of Radiological Health in 1958, Dr. Chadwick became Chief, Program Operations Branch. From 1959 to 1961, Dr. Chadwick served as secretary, Federal Radiation Council. Then in November 1961, he was named Chief of the Division of Radiological Health in the Public Health Service.

country at all seasons permits a continuous surveillance program showing both geographic and time variations.

I did wish to point out that the use of milk as an indicator was not necessarily a matter of convenience. I think there are very important other reasons why it is used as an indicator.

The Public Health Service, in 1957, established a raw milk sampling network composed of five milksheds. This network was expanded to 12 stations by 1958.

The experience gained here led to the establishing, in 1960, of a pasteurized milk sampling program by the Division of Radiological Health and the Division of Environmental Engineering and Food Protection. This network is now composed of some 60 stations, set up to measure the radioactivity content of milk consumed by approximately 60 million Americans.

The samples are weighted with respect to the contribution of the major processing plants to the total supply and represent 90 percent or more of the milk marketed in the area sampled. Samples are collected by State and local milk sanitation authorities and are analyzed quantitatively at the Division of Radiological Health's regional laboratories at Winchester, Mass.; Montgomery, Ala., and Las Vegas, Nev.

The analyses are for those nuclides of largest potential health importance, including iodine 131, cesium 137, barium 140, strontium 89, and strontium 90.

Senator AIKEN. When the samples of milk are taken, they are taken of pasteurized milk. How is that pasteurized? Do they take samples of irradiated milk or the milk as it comes from the farm pasteurized by heat or what form of pasteurization is used?

Dr. CHADWICK. Whatever system is used—in other words, the milk sample is taken after the milk has been pasteurized—and whatever process is used in the dairy plant is the one.

Senator AIKEN. Would there be any difference in the analysis of milk which has been pasteurized by heat and irradiated milk—I don't know what ray they use—they pass it under these rays and charge 3 cents a quart more.

Is there any difference in the radioactivity of milk which has been pasteurized simply by heat and milk which has been irradiated?

Dr. CHADWICK. To the best of my knowledge, the difference in these two processes would not make any difference in the radioactivity content.

Senator AIKEN. In irradiated milk you do not thereby enhance the radioactivity of the product?

Dr. CHADWICK. No, sir.

Senator AIKEN. That is what I wanted to know.

Representative HOSMER. Is there any essential difference between pasteurized and nonpasteurized milk in relation to radioactive content?

Dr. CHADWICK. There are some small differences between the two. Some of these differences can be accounted for simply on the basis of time. For instance, in the case of iodine there is decay because of the 8-day half-life, and anything that extends the time before consumption obviously reduces the iodine content.

There are other small differences that result from the standardization of the milk.

Senator AIKEN. In each case is the sample taken from homogenized milk?

Dr. CHADWICK. I really can't answer that question, sir. I would assume it is, since I assume that most of the milk sold now is homogenized. This is processed milk. That is, after the completion of the process. So I would certainly assume that it is homogenized.

Senator AIKEN. Would you say that the higher the butterfat content the lower the probable amount of radioactive material would be?

Dr. CHADWICK. I would doubt, sir, if there would be any consistent relationship between butterfat content and radioactivity.

Representative PRICE. Will you proceed, Dr. Chadwick?

Dr. CHADWICK. The results of the milk monitoring network have been published regularly in Radiological Health Data since it was first published in April 1960. The data prior to 1959 were presented to this committee during the fallout hearings in 1959.

All of the data since 1959 have been summarized in two reports which I would like to submit for the record. These are "Intake of Iodine 131 by U.S. Population, Fall of 1961," and "The Intake of Strontium 90 and Certain Other Radionuclides by the U.S. Population."

I should like to summarize these reports.

Representative PRICE. They will be received.

(Documents referred to follow:)

#### INTAKE OF IODINE 131 BY U.S. POPULATION, FALL OF 1961

##### BACKGROUND

It was not generally appreciated iodine 131 released by nuclear fission would appear in the thyroids of livestock until 1954 when data were published by Van Middlesworth (1) that iodine 131 from 1953 atomic test series had appeared in thyroid glands of cattle. This work was confirmed by other investigators, references 2 to 5. Wolff (6) suggested that milk might be a major vector in the transmittal of iodine 131 to the human population. This has since been confirmed by the Public Health Service milk-sampling program. Van Middlesworth (7) reported human thyroid glands from autopsies in Memphis, Tenn., examined for radioiodine from November 1954 through August 1955. There were 175 glands and the iodine 131 content varied from 1 to 100  $\mu\text{c/g}$  thyroid tissue.

In the 1959 hearings on fallout from nuclear weapons tests attention was drawn to radioactive iodine as a possible significant factor in human radiation exposure. Dr. E. B. Lewis, in a statement prepared for the record, said that from "data supplied by Campbell et al. (8) on the amount of  $\text{I}^{131}$  in fresh cow's milk during a 16-month period between June 1957 and ending September 1958 it can be estimated that the thyroid glands of the average infant and young child in the United States have received doses of beta radiation from  $\text{I}^{131}$  that amount to roughly 0.1 rad to 0.2 rad per year. There is some reason to believe that such doses have been delivered annually over the past 4 to 5 years of weapons testing."

##### PUBLIC HEALTH SERVICE MILK MONITORING

When the Public Health Service in 1957 undertook to assess the amounts of radioactive fission products being ingested by the population of the United States, milk was selected as the first item to be surveyed. This was a logical choice for the following reasons:

1. Milk is a major element of the diet of infants and children.
2. Milk is a food used extensively by all segments of the population.
3. The biochemistry of milk production is such that it would be expected to contain some of the most important radioisotopes that might enter the total diet.

4. The production of milk throughout the country at all seasons permits a continuous testing program.

5. Reliable analytical methods could be devised for analysis of the isotopic content of milk.

The Public Health Service, in 1957, established a raw milk sampling network composed of five milksheds. This network was expanded to 12 stations by 1959. The experience gained here led to the establishing, in 1960, of a pasteurized milk sampling program by the Division of Radiological Health and the Division of Environmental Engineering and Food Protection. This network is now composed of some 60 stations, set up to measure the radioactivity content of milk consumed by approximately 60 million Americans. The samples are weighted with respect to the contribution of the major processing plants to the total supply and represent 90 percent or more of the milk marketed in the area sampled. Samples are collected by State and local milk sanitation authorities and are analyzed quantitatively at the Division of Radiological Health's regional laboratories at Winchester, Mass., Montgomery, Ala., and Las Vegas, Nev. The analyses are for those nuclides of largest potential health importance including iodine 131, cesium 137, barium 140, strontium 89, and strontium 90.

#### APPEARANCE OF IODINE 131 IN MILK IN FALL OF 1961

From the initiation of the pasteurized milk sampling network in 1960 to September 1961, iodine 131 was not detectable in milk. Iodine 131 was found in milk samples obtained at Montgomery, Ala., and New Orleans, La., on September 19, 1961, and in that obtained at Atlanta, Ga., Charleston, S.C., New Orleans, La., St. Louis, Mo., and Tampa, Fla., on September 20. This was 3 weeks after the beginning of the Russian atomic test series. By September 21 the Russians had detonated at least 14 bombs with at least 3 estimated by the Atomic Energy Commission to be on the order of several megatons. While iodine 131 in fallout was first detected September 11, 1961, on air filters from Medford, Oreg., iodine 131 in milk was detected first in the milk of the Southern and Southeastern States. These iodine levels in milk were detected some 2 or 3 days after a weather phenomenon, which consisted of a hurricane off the east coast of the United States, and a ridge of high pressure over the eastern one-half of the country. This tremendous ridge of high pressure persisted over the eastern one-half of the United States for the period September 17-20. The gross beta radioactivity in air was markedly elevated over the south and southeastern portions of the United States and the highest levels reported by the radiation surveillance network was  $700 \mu\mu\text{c}/\text{m}^3$  of air at Little Rock, Ark., on September 19, 1961. On the basis of the air sampling results, the milk sampling stations intensified their operations, and during the period of the highest iodine level 20 stations were on a daily sampling schedule, and the remaining stations were on a twice-a-week schedule.

#### SOURCES OF EXPOSURE TO IODINE 131

Iodine 131 produced in nuclear detonations can be carried relatively long distances depending on the tropospheric air currents. It becomes deposited on vegetation directly as well as by rain. Unwashed vegetation consumed relatively promptly following deposition of the iodine fallout could be a source of radioiodine intake by humans. Several factors reduce the likelihood of this being a significant source of intake. A relatively small amount of the consumption of fresh vegetables occurs rapidly enough after deposition for this to be a factor. The transit time for fresh vegetables, and certainly that for canned or frozen, is sufficient to have allowed most, if not all, of the radioiodine to decay. Furthermore, even when fresh vegetables are consumed very soon after fallout, the ordinary household preparation of washing and peeling will remove most of the iodine 131, since it is in the form of surface deposition.

The sequence of events in the production and distribution of milk, however, make it a significant source of intake. Dairy cows at pasture consume iodine 131 deposited on the surface of forage crops. The iodine 131 appears in the milk. The processing and marketing of milk is designed to bring the freshest possible product to the public, and the time between cow and consumer is of the order of 2 to 4 days. Thus, only a relatively small amount of decay of the iodine 131 in the milk has taken place. In the case of other dairy products, however, the time for processing and marketing is sufficient to permit decay of the iodine 131.

Iodine 131 exposure can occur as a result of inhalation of the radionuclide and absorption from the lungs. It is useful to provide some estimate of the contribution of this source of intake. The average contribution of iodine 131 to the total gross beta activity in air as reported by the radiation surveillance network for October 1961 was 20 percent. The highest average gross beta activity in air for October was  $19\mu\mu\text{C}/\text{m}^3$  in Phoenix, Ariz. If 20 percent of this was iodine 131, then 20 percent  $\times 19\mu\mu\text{C}/\text{m}^3 = 3.8\mu\mu\text{C I}^{131}/\text{m}^3$ . Assuming that a 1-year-old infant breathes 1 cubic meter of air daily, his intake would be  $3.8\mu\mu\text{C I}^{131}$  per day from inhalation. On the other hand, if an adult breathes  $20\text{m}^3$  air per day then his average daily intake would have been  $20\text{m}^3 \text{ air} \times 3.8\mu\mu\text{C I}^{131}/\text{m}^3 \text{ air} = 76\mu\mu\text{C I}^{131}$ .

The average level of iodine 131 in milk for Phoenix for October 1961 was  $60\mu\mu\text{C I}^{131}$  per liter. If both the child and the adult consumed 1 liter of milk daily, intake by ingestion for both would have been  $60\mu\mu\text{C}$ . In the case of the child, inhalation would have represented a very small fraction of the total daily intake ( $4\mu\mu\text{C}$  out of a total of  $64\mu\mu\text{C}$ ). It can be seen that theoretically inhalation could be a significant contributor to total intake of iodine 131 in the case of adults. It must be remembered, however, that for an adult it takes 10 times the daily intake of iodine 131 to deliver the same radiation dose to the thyroid gland. It would thus appear that inhalation in the situation encountered during the fall of 1961 was not a significant source of radiation exposure to the thyroid gland.

There are some direct data to support the conclusion that fresh milk was the only significant source of radiation exposure to the thyroid gland of the population during the period of Soviet nuclear weapons test in the fall of 1961. Eisenbud studied in vivo six adults who reported drinking from 1 pint to more than 1 quart of milk daily. These averaged  $57 \pm 33\mu\mu\text{C I}^{131}$  per thyroid, while three adults who were not milk drinkers averaged only an insignificant amount of iodine 131  $4.3 \pm 4.9\mu\mu\text{C I}^{131}$  per thyroid.

#### DATA ON RADIOIODINE IN MILK

The results of the iodine 131 analyses from the milk-sampling network are published regularly in radiological health data. The early results were presented in previous Joint Committee on Atomic Energy hearings. The data for the fall of 1961 are summarized in table I. The following averages for the daily iodine 131 concentration per liter of milk are given.

1. The average for each station for each month during the period September 1961 through January 1962.
2. The average for each station during the entire period.
3. The average for all of the stations during each month.
4. The average for all stations during the entire period.

To estimate the average daily concentration of radioiodine in the milk at each of the reporting stations during the months of October, November, December, and January, a simple average of the measurements reported during the month was derived. For those stations reporting no milk samples during the second half of September, the October average was used a second time for the September value. These monthly averages at each station constitute the basis for estimating the average daily intake of a person consuming a liter of milk per day in the vicinity of the reporting station.

#### ESTIMATE INTAKES OF RADIOIODINE

Some evaluation of the significance of these iodine 131 concentrations in milk can be obtained by comparing estimated total intakes of iodine 131 with the guidance of the Federal Radiation Council. For the purposes of estimating intake, it has been assumed that (1) the average consumption of fresh milk in the critical age group is 1 liter per day and (2) that milk is the only significant source of intake of radioiodine in this group. On the basis of these assumptions the values in table 1 can be considered as representing the average daily intake of iodine 131.

Federal Radiation Council Report No. 2 gives the following guidance for iodine 131.

- Range I — 0-10  $\mu\mu\text{c}$  per day
- Range II — 10-100  $\mu\mu\text{c}$  per day
- Range III—100-1000  $\mu\mu\text{c}$  per day

An average daily intake at the upper limit of range II corresponds to the radiation does which is considered to represent an acceptable exposure level from normal peacetime operations (the RPG).

It can readily be seen that average iodine 131 intakes during certain periods were in range III. Federal Radiation Council Report No. 2 states, "Transient rates of intake within this range (range III) could occur without the population group exceeding the RPG if the circumstances were such that the annual average intake fell within range II or lower." It can be shown that such was the case for all of the stations as well as the national average during the period. Additionally it is useful to consider estimates of the radiation dose to the thyroid from iodine 131 during this period and compare these estimates with the RPG.

#### ESTIMATES OF THYROID DOSE

The Federal Radiation Council Report No. 2 provides a relationship between iodine 131 intake and the thyroid dose. This report estimates that an annual average daily intake of 80  $\mu\mu\text{c}$  of iodine 131 would result in a dose of 500 milliroentgens in 1 year to infants in which the thyroid weight is taken as 2 grams.

The dose estimates in table II were developed on the basis of the above relationship between intake and dose assuming 1 liter of fresh milk consumption per day for the 5-month period of iodine 131 fallout and that milk is the only significant source of intake.

It must be clearly recognized that these dose estimates apply only to infants who consume a liter of fresh milk daily and whose thyroid weight is 2 grams. These conditions apply approximately to the age group from 6 to 18 months. Children under 6 months of age usually consume some type of formula other than whole fresh milk. With children above approximately 18 months of age, the dose to the thyroid would become progressively smaller with the increase in size of the thyroid to a value in the adult of approximately one-tenth the value in infants. Using data from the U.S. census of 1960<sup>12</sup> it is estimated that the age group from 6 to 18 months represents approximately 2.3 percent of the total population, or approximately 4 million infants. On this basis, the estimated infant population covered by the pasteurized milk network is 1,387,900.

Since the network samples are collected from processing plants, and the iodine 131 activity is extrapolated back to the time of collection of the sample, the interval between production of milk and the time samples are collected at the processing plant is approximately 2 days. Infants living on farms and drinking raw milk could have had somewhat higher intakes of iodine 131, since the time interval between production and consumption could have been a matter of hours. This might, in some instances, have resulted in as much as 25-percent increase in the iodine 131 intake and the resultant thyroid doses.

The average thyroid dose to infants with a 2-gram thyroid during the period of September through January 1962 was 160 milliroentgens. Figure 1 provides a percentage distribution of the infant population according to estimated thyroid dose from iodine 131, September 1961-January 1962. It can be seen that the highest average doses were less than four times the average. Figure 1 also shows the annual RPG for the thyroid to be applied to the averages of suitable samples of exposed population groups. All of the estimated thyroid doses were less than the annual RPG.

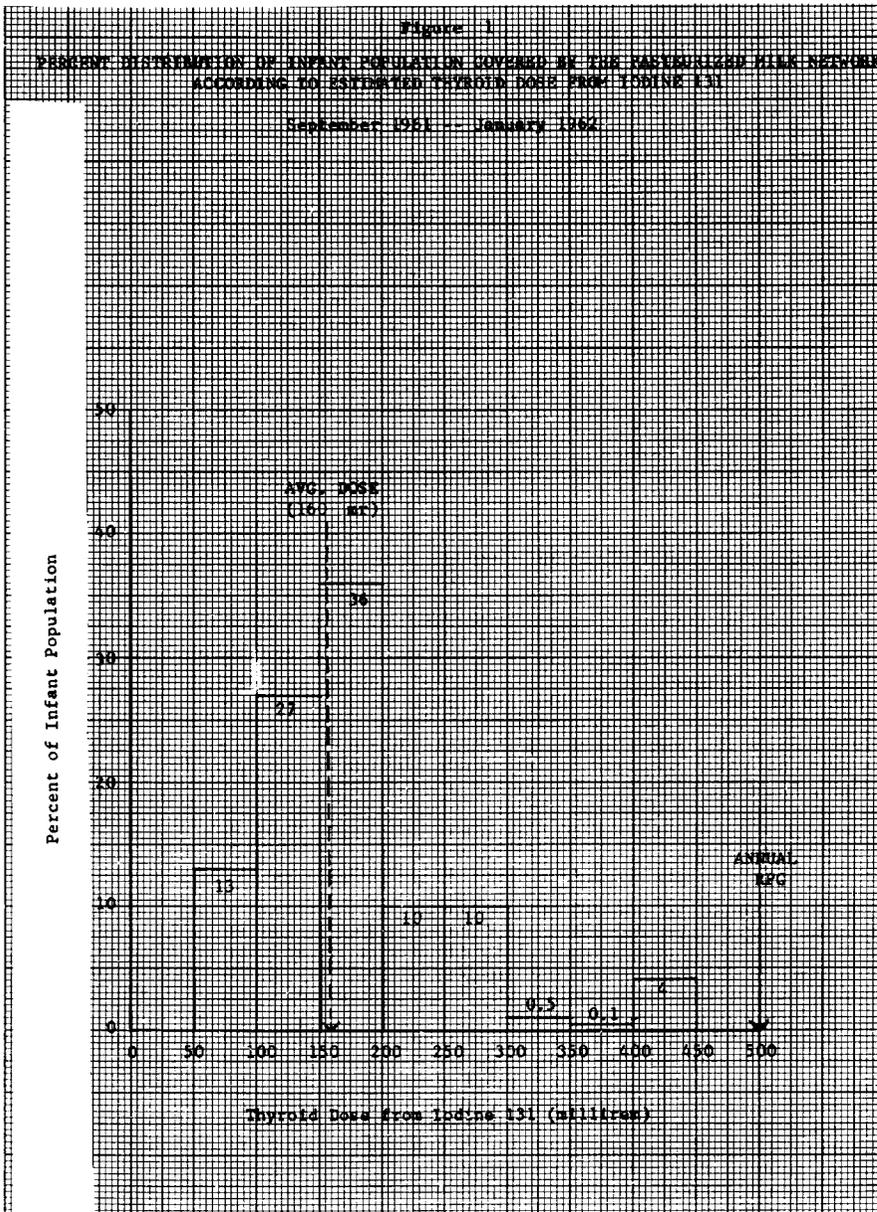
TABLE I.—Radioiodine concentration of U.S. milk, September 1961 to January 1962

Station location	Iodine 131 ( $\mu\text{mc}$ per liter)					Average
	1961				January 1962	
	September <sup>1</sup>	October	November	December		
Alaska: Palmer.....	(330)	330	40	<10	<10	140
Arizona: Phoenix.....	(60)	60	80	10	10	40
Arkansas: Little Rock.....	(120)	120	150	20	<10	80
California:						
Sacramento.....	10	20	30	10	<10	20
San Francisco.....	(20)	20	20	<10	20	20
Colorado: Denver.....	60	90	40	10	10	40
Connecticut: Hartford.....	(60)	60	30	<10	<10	30
Delaware: Wilmington.....	(60)	60	60	<10	<10	40
District of Columbia.....	40	60	30	10	<10	30
Florida: Tampa.....	40	40	40	20	<10	30
Georgia: Atlanta.....	80	80	40	30	<10	50
Hawaii: Honolulu.....	(20)	20	20	10	<10	20
Idaho: Idaho Falls.....	(140)	140	100	10	<10	80
Illinois: Chicago.....	110	150	70	<10	<10	70
Indiana: Indianapolis.....	(70)	70	60	10	<10	40
Iowa: Des Moines.....	(200)	200	210	30	10	170
Kansas: Wichita.....	(130)	130	140	30	10	90
Kentucky: Louisville.....	(90)	90	80	20	<10	60
Louisiana: New Orleans.....	90	80	60	30	<10	50
Maine: Portland.....	20	120	30	<10	<10	40
Maryland: Baltimore.....	(70)	70	30	10	<10	40
Massachusetts: Boston.....	(130)	130	40	10	<10	60
Michigan:						
Detroit.....	(210)	210	90	<10	<10	100
Grand Rapids.....	(90)	90	60	<10	<10	50
Minnesota: Minneapolis.....	(340)	340	150	10	<10	170
Mississippi:						
Jackson.....	150	90	60	50	<10	70
Pascagoula.....	200	100	50	40	<10	80
Missouri:						
Kansas City.....	(150)	150	190	40	10	110
St. Louis.....	180	160	100	10	<10	90
Montana: Helena.....	(160)	160	110	20	<10	90
Nebraska: Omaha.....	(250)	250	120	40	<10	130
New Hampshire: Manchester.....	(100)	100	40	<10	<10	50
New Jersey: Trenton.....	(90)	90	30	<10	<10	40
New Mexico: Albuquerque.....	(30)	30	40	<10	10	20
New York:						
Buffalo.....	(100)	100	20	<10	<10	50
New York.....	140	100	40	<10	<10	60
Syracuse.....	(140)	140	30	<10	<10	60
North Carolina: Charlotte.....	(40)	40	20	<10	<10	20
North Dakota: Minot.....	30	140	20	<10	<10	40
Ohio:						
Cincinnati.....	(100)	100	80	20	<10	60
Cleveland.....	(100)	100	50	<10	<10	50
Oklahoma: Oklahoma City.....	(90)	90	160	40	<10	80
Oregon: Portland.....	(60)	60	170	10	<10	60
Pennsylvania:						
Philadelphia.....	(80)	80	40	<10	<10	40
Pittsburgh.....	(90)	90	30	<10	<10	40
Puerto Rico: San Juan.....	(20)	20	20	30	<10	20
Rhode Island: Providence.....	(80)	80	50	<10	<10	40
South Carolina: Charleston.....	90	60	20	10	<10	40
Tennessee:						
Chattanooga.....	(80)	80	40	30	<10	50
Memphis.....	(160)	160	80	40	<10	90
Texas:						
Austin.....	20	30	60	20	<10	30
Dallas.....	20	40	100	10	<10	40
Utah: Salt Lake City.....	140	120	60	10	10	70
Vermont: Burlington.....	(100)	100	50	<10	<10	50
Virginia: Norfolk.....	(80)	80	30	10	<10	40
Washington:						
Seattle.....	10	120	120	10	10	50
Spokane.....	(120)	120	60	<10	<10	60
West Virginia: Charleston.....	(60)	60	20	<10	<10	30
Wisconsin: Milwaukee.....	(150)	150	80	<10	<10	80
Wyoming: Laramie.....	(40)	40	30	10	10	30
Network average.....	100	100	60	10	<10	60

<sup>1</sup> Numbers in parentheses are estimates for September 1961.

TABLE II.—Estimated thyroid doses to infants, September 1961 to January 1962

Station location	I-131 ( $\mu\text{mc/liter}$ ) pasteurized milk	Estimated thyroid dose (in mr)	Percent of annual RPG to thyroid	Estimated population 6 to 18 months (in thousands)
Des Moines, Iowa.....	170	440	88	12.0
Minneapolis, Minn.....	170	440	88	45.6
Palmer, Alaska.....	140	360	72	1.6
Omaha, Nebr.....	130	340	68	7.5
Kansas City, Mo.....	110	290	58	43.6
Detroit, Mich.....	100	260	52	89.5
Wichita, Kans.....	90	230	46	13.2
St. Louis, Mo.....	90	230	46	61.6
Helena, Mont.....	90	230	46	.5
Memphis, Tenn.....	90	230	46	13.4
Little Rock, Ark.....	80	210	42	5.5
Idaho Falls, Idaho.....	80	210	42	1.6
Pascagoula, Miss.....	80	210	42	.4
Oklahoma City, Okla.....	80	210	42	9.9
Milwaukee, Wis.....	80	210	42	34.5
Chicago, Ill.....	70	180	36	147.4
Jackson, Miss.....	70	180	36	4.2
Salt Lake City, Utah.....	70	180	36	19.7
Louisville, Ky.....	60	160	32	10.1
Boston, Mass.....	60	160	32	29.7
New York, N. Y.....	60	160	32	231.4
Syracuse, N. Y.....	60	160	32	5.8
Cincinnati, Ohio.....	60	160	32	23.0
Portland, Oreg.....	60	160	32	20.7
Spokane, Wash.....	60	160	32	5.2
Atlanta, Ga.....	50	130	26	23.0
New Orleans, La.....	50	130	26	15.2
Grand Rapids, Mich.....	50	130	26	6.4
Manchester, N. H.....	50	130	26	2.4
Buffalo, N. Y.....	50	130	26	18.5
Cleveland, Ohio.....	50	130	26	40.3
Chattanooga, Tenn.....	50	130	26	3.7
Burlington, Vt.....	50	130	26	1.3
Seattle, Wash.....	50	130	26	15.8
Phoenix, Ariz.....	40	100	20	14.5
Denver, Colo.....	40	100	20	20.0
Wilmington, Del.....	40	100	20	6.2
Indianapolis, Ind.....	40	100	20	10.9
Portland, Maine.....	40	100	20	3.2
Baltimore, Md.....	40	100	20	37.9
Trenton, N. J.....	40	100	20	5.8
Minot, N. Dak.....	40	100	20	2.3
Philadelphia, Pa.....	40	100	20	63.8
Pittsburgh, Pa.....	40	100	20	22.7
Providence, R. I.....	40	100	20	10.7
Charleston, S. C.....	40	100	20	2.8
Dallas, Tex.....	40	100	20	32.7
Norfolk, Va.....	40	100	20	11.9
Hartford, Conn.....	30	80	16	6.9
District of Columbia.....	30	80	16	45.8
Tampa, Fla.....	30	80	16	23.4
Austin, Tex.....	30	80	16	5.4
Charleston, W. Va.....	30	80	16	3.9
Laramie, Wyo.....	30	80	16	.5
Sacramento, Calif.....	20	50	10	17.6
San Francisco, Calif.....	20	50	10	33.5
Honolulu, Hawaii.....	20	50	10	7.2
Albuquerque, N. Mex.....	20	50	10	9.8
Charlotte, N. C.....	20	50	10	7.1
San Juan, P. R.....	20	50	10	17.2
Network average.....	60	160	32	
Network total.....				1,387.9



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THE INTAKE OF STRONTIUM 90 AND CERTAIN OTHER RADIONUCLIDES BY THE U.S. POPULATION

INTRODUCTION

The Public Health Service has in recent years been developing surveillance systems with the objective of measuring and evaluating the levels of radioactivity in the environment. This program is described in other material submitted for the record. Among the radionuclides of health significance which have been determined in this surveillance effort is strontium 90. Milk has been used as the principal index to strontium 90 intake. Before summarizing the results of the program for monitoring of strontium 90, it is important to consider the relative contributions of different sources of intake to total human intake of this radionuclide in order to evaluate the use of milk as an indicator.

SOURCES OF INTAKE OF STRONTIUM 90

In the situation of general environmental contamination strontium 90 may enter the human body from all three of the environmental media: air, water, and food. Various studies have provided estimates of the relative contributions of these three media, and within the category of food the relative contribution of various food items. The results of one such study by Straub, Murthy, and Campbell are summarized in table III.

The estimate for air is based upon analysis of composite Cincinnati air samples from February to June 1959. Similarly, the contribution of water is based upon an analysis of strontium 90 content of drinking water in Cincinnati during this period. The contribution from various kinds of foods is based upon composite analysis of typical diets and data on food samples purchased in the Cincinnati area. These data indicate that milk and dairy products consumed at the rate of approximately 550 grams per day would contribute about 50 percent of the total daily intake of strontium 90. These data agree in general with results of similar studies in other countries in which milk and dairy products represent an important element in the diet.

MILK AS AN INDICATOR OF STRONTIUM 90

The data on contributions of various sources of intake of strontium 90 suggest that milk can serve as a useful indicator of the levels of total daily intake of strontium 90. There are several advantages of milk as such an indicator: (1) The biochemistry of milk production is such that it serves as a biological sampling and concentration mechanism, drawing its raw materials from the environment serving as sources for air, water, and food for the cow. Thus,

fluctuations of radioactivity levels in a wide range of environmental sources possibly related to levels in even the nonmilk fraction of the human diet might also be expected to be reflected in the levels in milk. (2) Milk and milk products represent a significant part of the diet for all age groups and a very large proportion of the total diet in infants and children, for whom susceptibility to radiation injury is believed to be greater than in adults. For the younger age groups, the rate of deposition of bone mineral is greater than for adults, and this warrants special interest in the strontium 90 content of their diet. It has been logical to give attention to a dietary source which supplies much of the essential protein and most of the calcium in the diet for the age groups most susceptible to radiation injury. (3) It is convenient and relatively inexpensive to obtain representative samples of milk consumed by the population, compared with obtaining samples of the total diet. (4) Milk is produced the year around in all areas of the United States. (5) Methodology is available for the analysis of strontium 90 in samples of milk.

#### PUBLIC HEALTH SERVICE MILK SAMPLING NETWORK

For these reasons the Public Health Service in 1957 initiated steps to estimate strontium 90 along with other substances in milk consumed by the U.S. population. The first milk monitoring program used raw milk and was established to develop suitable sampling methods and radiochemical analytical proficiencies. Early in 1960 a processed (or pasteurized) milk sampling program was established to provide a sampling program more directly related to the milk consumed by large population groups.

At present the Public Health Service, in cooperation with State and local agencies, maintains a processed milk monitoring network of more than 60 stations. (See fig. 1.) These stations sample milk consumed by an estimated one-third of the U.S. population. Each sample is composited in proportion to the volume of milk sold by those plants supplying not less than 90 percent of the milk supply of the city where the sample is taken. Prior to September 15, 1961, the sample for each station was taken from 1 day's sales per month. Since September 15 the sampling schedule has been accelerated to one sample per week.

#### RESULTS OF MILK ANALYSES FOR STRONTIUM 90

The results of the strontium 90 analyses in the milk network are published regularly in Radiological Health Data. The data are summarized in table IV, in which annual average strontium 90 concentrations in milk have been computed for each of the stations as well as an estimated annual average for the United States. For 1962 individual monthly averages are included through March. Table IV also contains estimates of the populations served by each of the sampling stations. Table V contains the values of strontium 90 in milk from the original raw milk network.

#### INTAKE OF STRONTIUM 90 BY THE POPULATION

Some evaluation of the significance of these concentrations of strontium 90 in milk may be obtained by comparisons of estimates of total daily intake of strontium 90 derived from them with the guidance of the Federal Radiation Council. For strontium 90 the Federal Radiation Council gives the following ranges:

Range I	0 to 20 $\mu\text{c}$ per day.
Range II	20 to 200 $\mu\text{c}$ per day.
Range III	200 to 2,000 $\mu\text{c}$ per day.

The Federal Radiation Council also provides some guidance which is useful in estimating total daily intake from milk concentrations. In giving the ranges for total daily intake expressed in  $\mu\text{c}/\text{day}$ , the Council makes use of an assumption of a total daily intake of calcium of 1 gram. Since 1 liter of milk supplies about 1 gram of calcium per day, it might be appropriate to use the strontium 90 content of 1 liter of milk as an estimate of total intake of this radionuclide. Actually, a diet including other sources of calcium may have a somewhat higher

strontium 90/Ca ratio than a diet in which milk is the only source of calcium. Indeed, estimates of the factor by which the strontium 90/Ca ratio of milk must be multiplied to give that in total diet range from 1.2 to 1.3.<sup>1</sup> Results of calcium measurements in our pasteurized milk network indicate a value slightly greater than one for the calcium content. However, for purposes of calculating the ranges, this difference is ignored. Applying these factors, a range of estimates of annual average daily intake of strontium 90 may be obtained from the annual average strontium 90 concentrations in milk. These are given in table I.

TABLE I.—*Estimates of average daily intakes of strontium 90 for each year, 1957-61*

Year	Strontium 90		
	Average milk concentration ( $\mu\text{c}/\text{l}$ )	Daily intake range ( $\mu\text{c}$ )	
		Conversion factor, 1.2	Conversion factor, 1.3
1957.....	16	7	8
1958.....	18	10	10
1959.....	11	13	14
1960.....	8	10	10
1961.....	8	10	10

<sup>1</sup> Raw milk network.

It is worth noting that greater strontium 90 intakes which involve proportionately greater calcium intakes would not result in greater concentrations of strontium 90 in the bone (and subsequent radiation doses). This results from the fact that the concentration of strontium 90 in bone is related to the strontium/Ca ratio in the diet rather than the strontium 90 content alone.

#### TOTAL DIET SAMPLING

Before comparing these estimates of intake with Federal Radiation Council guidance it is useful to consider a more direct estimate of average intakes for 1961 from the Public Health Service institutional food sampling network. During 1961, the Public Health Service has operated an institutional diet sampling program which studies the dietary intake of strontium 90 by young people between the ages of 5 and 18. This program, now consisting of 21 sampling points, collects a full 7-day-week diet of 21 meals plus soft drinks, candy bars, etc., on a monthly basis at boarding schools or institutions throughout the United States. The analytical program for this study is designed around three procedures: (1) Strontium 90, (2) total radium, and (3) gamma scan for the estimate of other gamma-emitting radionuclides.

This program was initiated in December 1960. The results of the calendar year 1961 representing the first full year of operation of the program are available for seven stations. These are shown in table VI. The annual average daily intake of strontium 90 for the stations varied between 5 and 10  $\mu\text{c}/\text{day}$  with an overall annual average intake for the population group under study of 7  $\mu\text{c}/\text{day}$ . It can be seen, then, that the average daily intake of strontium 90 measured by this system is somewhat lower than that predicted from the values for strontium 90 in milk. Comparisons of these estimated average daily intakes with the guidance of the Federal Radiation Council shows that all of the intakes were in range I. Intakes at the upper limit of range I continued indefinitely would result in radiation doses to bone and marrow one-thirtieth of the RPG's for normal peacetime operations.

<sup>1</sup> HASL 88, 1960.

## DATA ON STRONTIUM 90

The milk networks described above also provide data on the concentrations of strontium 89. These data have been published regularly in Radiological Health Data. Since the inception of these networks there have been two periods when strontium 89 has been present in measurable levels in milk. The data for these periods are summarized in tables VII and VIII. The tables give the monthly average concentrations of strontium 89 in milk collected at each of the processed milk stations from September 1961 through March 1962, and the quarterly values from the raw milk network from the fall of 1957 to the spring of 1961. They also give an average for all the stations for each period.

## ESTIMATED INTAKE OF STRONTIUM 89

In order to evaluate the significance of these concentrations of strontium 89 in milk, it is necessary to compare estimates of total daily intake of this radionuclide derived from the milk concentrations with the guidance of the Federal Radiation Council. For strontium 89 the FRC gives the following ranges:

Range I	0 to 200 $\mu\mu\text{c}$ per day.
Range II	200 to 2,000 $\mu\mu\text{c}$ per day.
Range III	2,000 to 20,000 $\mu\mu\text{c}$ per day.

Using the same assumptions specified for converting strontium 90 concentrations in milk to total intake figures, the data on tables VII and VIII can be used to estimate average U.S. intakes for strontium 89 for each period. These are presented in table II.

TABLE II.—*Estimates of average daily intake of strontium 89 for specified periods, 1957-62*

Date	Strontium 89		
	Average milk concentration ( $\mu\mu\text{c/l}$ )	Daily intake range ( $\mu\mu\text{c}$ )	
		Conversion factor, 1.2	Conversion factor, 1.3
1957 <sup>1</sup> —3d quarter.....	80	96	104
4th quarter.....	50	60	65
1958 <sup>1</sup> —1st quarter.....	5	6	6
2d quarter.....	50	60	65
3d quarter.....	90	108	117
4th quarter.....	50	60	65
1959 <sup>1</sup> —1st quarter.....	30	36	39
2d quarter.....	40	48	52
3d quarter.....	10	12	13
4th quarter.....	<5	3	3
(Essentially no strontium 89 detected through August 1961.)			
1961—September.....	10	12	13
October.....	40	48	52
November.....	55	66	72
December.....	35	42	46
1962—January.....	25	30	32
February.....	30	36	39
March.....	35	42	46

<sup>1</sup> Raw milk network.

Comparison of these estimated average daily intakes with the guidance of the Federal Radiation Council shows that all of the intakes were in range I. Intakes at the upper limit of range I continued indefinitely would result in radiation doses to bone and bone marrow one-thirtieth of the RPG's for normal peacetime operations.

## OCCURRENCE OF CESIUM 137 AND BARIUM 140

Data on milk content of cesium 137 and barium 140 are regularly reported in Radiological Health Data. The estimated intake of cesium 137 and barium 140 based upon the analysis of these radionuclides in milk has been considerably lower in relation to accepted guides than those of strontium 89 and strontium 90.

TABLE III.—Daily intake of calcium and strontium 90 from environmental sources

Source	Estimated intake	Calcium		Strontium 90	
		Milligrams	Percent	Micromicrocuries	Percent
Air.....cubic meters..	20			0.8	5.2
Water.....grams..	1,000	60	5.2	.8	5.2
Food:					
Milk.....do....	500	600	52.0	6.0	39.0
Dairy products, other.....do....	45	145	12.5	1.8	11.7
Vegetables.....do....	370	145	12.5	3.4	22.0
Meat, fish, and eggs.....do....	370	100	8.7	.8	5.2
Cereal products.....do....	130	60	5.2	1.4	9.1
Other.....do....	130	45	3.9	.4	2.6
Food total.....do....	1,545	1,095	94.8	13.8	89.6
Total.....do....		1,155	100.0	15.4	100.0

NOTE.—This table presents an estimate of the amounts of strontium 90 and calcium that might be ingested or inhaled daily by man from environmental radiation sources such as air, water, and food. These data were taken from studies conducted in 1958-59 on the above sources by the research group at the Robert A. Taft Sanitary Engineering Center, Public Health Service, Cincinnati, Ohio. (Radiological Health Data, vol. 7, October 1960.)

TABLE IV.—Strontium 90 concentration in pasteurized milk

Station location	Micromicrocuries per liter					Estimated population served (millions)
	1960	1961	1962			
			January	February	March	
Alabama: Montgomery		6	10	(1)	14	(2)
Alaska: Palmer	7	8	5	6	6	0.069
Arizona: Phoenix	4	4	3	3	3	.632
Arkansas: Little Rock	13	16	21	22	23	.240
California:						
Sacramento	5	4	2	3	4	.766
San Francisco	4	4	2	4	8	1.458
Colorado: Denver	7	6	6	4	5	.870
Connecticut: Hartford	9	8	10	10	7	.298
Delaware: Wilmington	8	9	10	11	9	.270
District of Columbia	8	8	9	7	7	1.992
Florida: Tampa	5	6	6	9	6	1.016
Georgia: Atlanta	10	10	11	15	14	1.000
Hawaii: Honolulu	5	4	4	8	4	.315
Idaho: Idaho Falls	5	6	4	3	4	.068
Illinois: Chicago	6	6	6	6	5	6.410
Indiana: Indianapolis	6	7	9	9	8	.475
Iowa: Des Moines	8	8	5	5	5	.521
Kansas: Wichita	6	8	6	7	7	.573
Kentucky: Louisville	9	10	12	12	9	.445
Louisiana: New Orleans	13	12	24	31	28	.662
Maine: Portland	11	9	9	13	10	.137
Maryland: Baltimore	8	8	10	9	8	1.646
Massachusetts: Boston	12	9	9	10	10	1.290
Michigan:						
Detroit	7	6	6	6	6	3.890
Grand Rapids	7	6	8	7	8	.280
Minnesota: Minneapolis	8	9	6	6	6	1.981
Mississippi:						
Jackson	12	12	24	21	25	.184
Pascagoula		16				.017
Missouri:						
Kansas City	8	8	7	8	7	1.895
St. Louis	7	8	8	7	8	2.677
Montana: Helena	6	6	4	4	4	.021
Nebraska: Omaha	7	7	5	5	5	.325
New Hampshire: Manchester	11	10	10	11	10	.104
New Jersey: Trenton	8	8	8	9	8	.250
New Mexico: Albuquerque	4	5	6	2	3	.425
New York:						
Buffalo	7	8	11	7	7	.806
New York	9	8	12	8	8	10.063
Syracuse	7	7	6	8	6	.250
North Carolina: Charlotte	12	11	11	11	13	.308
North Dakota: Minot	10	10	7	8	8	.100
Ohio:						
Cincinnati	8	8	10	11	10	1.000
Cleveland	8	7	8	8	8	1.750
Okahoma: Oklahoma City	8	7	9	11	8	.431
Oregon: Portland	10	12	7	7	7	.898
Pennsylvania:						
Philadelphia	8	8	8	9	10	2.775
Pittsburgh	12	10	12	13	8	.989
Puerto Rico: San Juan	4	4	10	4	9	.747
Rhode Island: Providence	11	10	8	10	9	.464
South Carolina: Charleston	10	11	14	13	15	.123
South Dakota: Rapid City			6	7	6	(2)
Tennessee:						
Chattanooga	10	11	10	16	20	.162
Memphis	10	11	15	14	16	.583
Texas:						
Austin	2	3	4	5	7	.234
Dallas	6	7	8	12	10	1.420
Utah: Salt Lake City	6	5	5	4	3	.858
Vermont: Burlington	9	8	8	8	6	.057
Virginia: Norfolk	9	9	11	12	10	.519
Washington:						
Seattle	8	10	6	7	6	.688
Spokane	7	8	6	6	6	.224
West Virginia: Charleston	9	9	10	10	8	.170
Wisconsin: Milwaukee	6	6	6	6	5	1.500
Wyoming: Laramie	5	6	4	4	4	.021
Network average	8	8	8	9	9	
Network total						60.337

<sup>1</sup> No sample.  
<sup>2</sup> Not available.

TABLE V.—Average concentration of strontium 90 in monthly raw milk samples, 1957-61

[Micromicrocuries per liter]

Station	1957	1958	1959	1960	1961 <sup>1</sup>
Sacramento, Calif.	<sup>2</sup> 4.3	5.2	5.0	3.2	4.0
Austin, Tex.		<sup>2</sup> 3.0	5.5	4.2	3.5
Salt Lake City, Utah	<sup>2</sup> 4.7	4.5	6.5	6.2	3.5
Chicago, Ill.		<sup>2</sup> 7.5	8.8	9.2	6.5
New York, N.Y.	<sup>2</sup> 5.7	6.5	9.2	9.5	8.5
Cincinnati, Ohio	<sup>2</sup> 6.0	8.5	12.8	10.0	9.0
Spokane, Wash.		<sup>2</sup> 9.0	12.2	11.2	7.5
Atlanta, Ga.		<sup>2</sup> 12.0	15.5	14.5	13.0
Fargo-Moorhead, N. Dak.		<sup>2</sup> 14.0	14.2		
St. Louis, Mo.	<sup>2</sup> 9.7	13.0	22.2	18.0	17.5
Average	6.0	8.0	11.0	10.0	8.0

<sup>1</sup> Through June 1961.<sup>2</sup> Approximately last half of year.

Source: "Radiological Health Data," vol. II, Nos. 8 and 11.

TABLE VI.—Average daily intake of strontium 90 via the total diet of children under 18<sup>1</sup>

[Micromicrocuries per day]

Location	Number of weekly samples	Strontium 90
Los Angeles, Calif.	11	5
Denver, Colo.	12	7
Atlanta, Ga.	10	7
St. Louis, Mo.	8	9
New York, N.Y.	10	6
Austin, Tex.	11	10
Seattle, Wash.	11	7
Average		7

<sup>1</sup> Computed from measured strontium 90 content of weekly composite samples, exclusive of drinking water but including all beverages and snacks. Samples collected at boarding schools for children at locations shown between January and December 1961.

Source: "Radiological Health Data," vol. III, No. 7 (to be published).

TABLE VII.—Average concentration of strontium 89 in monthly raw milk samples, 1957-59

[Micromicrocuries per liter]

Area	1957			1958				1959			
	2d quarter	3d quarter	4th quarter	1st quarter	2d quarter	3d quarter	4th quarter	1st quarter	2d quarter	3d quarter	4th quarter
Atlanta, Ga.				<sup>1</sup> 35	75	45	75	90	15	< 5	< 5
Austin, Tex.				<sup>1</sup> 25	30	40	45	45	5	< 5	< 5
Chicago, Ill.					70	45	< 5	30	10	< 5	< 5
Cincinnati, Ohio		<sup>2</sup> 75	65	< 5	65	130	65	20	40	10	< 5
Fargo-Moorhead, N. Dak.				<sup>1</sup> 80	110	80	20	25	20	< 5	< 5
New York, N.Y.		<sup>2</sup> 80	55	< 5	30	65	50	5	20	10	< 5
Overton, Nev.								15	< 5	< 5	< 5
Sacramento, Calif.		<sup>2</sup> 20	15	5	50	20	15	30	25	< 5	< 5
Salt Lake City, Utah		<sup>2</sup> 65	45	5	30	40	15	5	20	5	< 5
Spokane, Wash.						<sup>2</sup> 55	35	15	50	20	< 5
St. George, Utah								15	15	<sup>2</sup> < 5	< 5
St. Louis, Mo.		<sup>2</sup> 160	80	20	90	285	130	95	125	15	< 5
Average		80	50	5	50	90	50	30	40	10	< 5

<sup>1</sup> Average based on 1 month.<sup>2</sup> Average based on 2 months.

Source: "Radiological Health Data," vol. II, No. 8, August 1961.

TABLE VIII.—Average daily strontium 89 levels in processed milk, September 1961 to March 1962

[Micromicrocuries per liter]

Station location	Strontium 89						
	1961				1962		
	Sep-tember	Octo-ber	No- vember	Decem-ber	Janu-ary	Febru-ary	March
Alaska: Palmer		105	50	20	10	5	<5
Arizona: Phoenix		<5	10	20	30	15	25
Arkansas: Little Rock		35	85	85	50	110	160
California:							
Sacramento	<5	10	15	10	10	5	35
San Francisco		<5	5	15	10	25	90
Colorado: Denver	5	15	25	25	15	10	<5
Connecticut: Hartford		30	40	10	<5	<5	<5
Delaware: Wilmington		45	85	20	<5	<5	10
District of Columbia	10	35	50	20	<5	<5	<5
Florida: Tampa	<5	15	30	10	15	25	20
Georgia: Atlanta	5	20	15	40	80	150	130
Hawaii: Honolulu		<5	10	20	35	80	30
Idaho: Idaho Falls		35	35	5	5	5	<5
Illinois: Chicago	20	55	90	15	<5	<5	<5
Indiana: Indianapolis		30	65	20	<5	<5	20
Iowa: Des Moines		65	80	50	10	5	<5
Kansas: Wichita		30	45	40	15	15	30
Kentucky: Louisville		15	70	50	10	15	35
Louisiana: New Orleans	10	40	85	205	300	365	315
Maine: Portland	20	120	60	<5	<5	<5	<5
Maryland: Baltimore		30	40	30	<5	5	<5
Massachusetts: Boston		120	90	<5	<5	<5	<5
Michigan:							
Detroit		50	65	15	<5	<5	<5
Grand Rapids		75	90	15	5	5	<5
Minnesota: Minneapolis		170	140	20	10	5	<5
Mississippi:							
Jackson	10	40	70	175	210	300	220
Pascagoula		30	70	145			
Missouri:							
Kansas City		85	75	70	15	15	20
St. Louis	30	30	50	20	10	10	10
Montana: Helena		15	25	5	5	5	5
Nebraska: Omaha		125	100	70	15	15	5
New Hampshire: Manchester		40	65	5	<5	<5	<5
New Jersey: Trenton		40	45	15	<5	<5	<5
New Mexico: Albuquerque		<5	5	10	20	10	<5
New York:							
Buffalo		45	60	5	<5	<5	<5
New York	10	50	60	5	<5	<5	<5
Syracuse		90	55	5	<5	<5	5
North Carolina: Charlotte		30	20	30	10	35	35
North Dakota: Minot	15	40	5	5	5	<5	<5
Ohio:							
Cincinnati		25	80	50	5	20	25
Cleveland		40	55	10	<5	<5	<5
Oklahoma: Oklahoma City		30	80	70	40	40	40
Oregon: Portland		<5	180	20	40	15	20
Pennsylvania:							
Philadelphia		35	50	10	<5	<5	<5
Pittsburgh		65	50	5	<5	<5	5
Puerto Rico: San Juan		10	25	130	125	110	90
Rhode Island: Providence		60	90	15	<5	<5	<5
South Carolina: Charleston	5	15	15	15	60	85	95
Tennessee:							
Chattanooga		25	45	80	55	80	190
Memphis		30	65	85	105	135	125
Texas:							
Austin	<5	10	20	65	20	25	30
Dallas	5	20	55	60	40	50	80
Utah: Salt Lake City	10	25	20	15	5	<5	<5
Vermont: Burlington		50	60	5	5	<5	<5
Virginia: Norfolk		85	50	40	10	15	40
Washington:							
Seattle	25	75	80	30	20	10	10
Spokane		10		5	5	5	<5
West Virginia: Charleston		70	70	20	5	10	10
Wisconsin: Milwaukee		40	65	5	<5	<5	<5
Wyoming: Laramie		<5	<5	5	5	<5	<5
Network average	10	40	55	35	25	30	35



DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE,  
PUBLIC HEALTH SERVICE,  
Washington, D.C., May 24, 1962.

The Public Health Service announced today that preliminary field reports received from its radiation surveillance networks show increased amounts of radioactive iodine ( $I^{131}$ ) have appeared in pasteurized milk samples from a number of States located mostly in midcontinent sections of the United States. The States, date of sample, and micromicrocuries of  $I^{131}$  per liter of milk are as follows:

	Date	Micro- micro- curies per liter		Date	Micro- micro- curies per liter
Arkansas: Little Rock.....	May 14	30	Missouri:		
Colorado: Denver.....	May 17	45	Kansas City.....	May 18	600
Illinois: Chicago.....	May 15	90	St. Louis.....	May 16	80
Iowa: Des Moines.....	May 17	300	New York: Syracuse.....	May 18	40
Kansas: Wichita.....	May 15	660	Ohio: Cincinnati.....	May 17	50
Minnesota: Minneapolis.....	May 18	290	Tennessee: Chattanooga.....	May 15	30
			West Virginia: Charleston.....	May 18	40

Previous levels at all points in the 61-station network had been below 20 micromicrocuries per liter, the Public Health Service said.

Under Federal Radiation Council guidelines an annual average  $I^{131}$  intake of 110 micromicrocuries per day, or a total of 36,500 micromicrocuries for the year (range II), is considered acceptable under normal peacetime conditions. The Council recommends that consideration be given to protective countermeasures when indications are that average daily intake for a year will be in range III, which for  $I^{131}$  is 100 to 1,000 micromicrocuries total daily intake, or a total of 36,500 to 365,000 micromicrocuries for the year.

A micromicrocurie is one-millionth of one-millionth of a curie. A curie is equivalent to the radioactivity given off by 1 gram of radium. Iodine 131 has a half-life of 8 days, which means that its radioactivity decreases by half every 8 days.

The Public Health Service said that the recently detected increases are believed to be transient, but in order to evaluate the situation more completely milk sampling had been increased from the normal weekly schedule to a twice-weekly basis in the affected areas.

Dr. CHADWICK. I should now like to very briefly summarize the material presented in these reports.

The iodine report summarizes the information on iodine 131 exposure during the fall of 1961. Previous periods during which iodine 131 levels have been detectable in milk were reported in the 1959 hearings. Iodine 131 from the Soviet atmospheric weapons testing series began appearing in milk during September 1961.

By January the levels in general had returned to a value at or below the lower limit of detectability of 10 micromicrocuries per liter. The data on the iodine concentrations in milk are summarized in table I of the first report submitted for the record.

Some evaluation of reported iodine 131 concentrations in milk can be obtained by comparing estimated total intakes of iodine 131 with the guidance of the Federal Radiation Council.

For purposes of estimating intake, it has been assumed that (1) the average consumption of fresh milk in the critical age group is 1 liter per day, and (2) milk is the only significant source of intake of radioiodine in this group.

These assumptions are discussed in some detail in the background report, I might say.

The report shows that the average iodine 131 intakes during certain periods were in range III of the Federal Radiation Council guidance.

Mr. RAMEY. Could you outline what you mean by "range III" of the three ranges so we can get the picture of that.

Dr. CHADWICK. Yes, sir. To start as a kind of anchor point in the range system, the upper limit of range II is a daily intake which if sustained constantly, or if values were to average at that level, would correspond to a dose equal to the radiation protection guide or the radiation dose that is considered acceptable for normal peacetime operations.

The other two ranges could be described as follows: The upper limit of range I is a factor of 10 below this intake and the upper limit of range III is a factor of 10 above. The Council indicates that operations should be conducted in such a manner that the total daily intake of the average daily intake over the year does not exceed the upper value of range II.

It indicates that when intakes are in range III, an effort should be made to reduce intake to a lower level.

Mr. RAMEY. That is for a whole year?

Dr. CHADWICK. That is right.

Chairman HOLIFIELD. That is qualified by the fact that your sentence says that the average iodine 131 intakes during certain periods were in range III of the Federal Radiation Council guidance. You say certain periods. Was this a matter of a few days out of the year?

Dr. CHADWICK. I am going to develop this in a little bit more detail, sir; and perhaps I will cover in general your question.

Representative PRICE. Will you proceed, please.

Dr. CHADWICK. The Council states:

Transient rates of intake within range III could occur without the population group exceeding the RPG if the circumstances were such that the average annual intake fell within range II or lower.

The report shows that this was the case for all the stations as well as for the national average during the 5-month period, which was 60  $\mu\mu\text{c}$  (micromicrocuries) per day.

It is useful to consider estimates of the radiation dose to the thyroid from iodine 131 during this period and compare these estimates with the RPG.

Using the above assumptions and the relationship between intake and thyroid dose provided by the Federal Radiation Council Report No. 2, doses were estimated for infants with a 2-gram thyroid, consuming milk from each of the sampling stations.

The results to each station are given in table II of the iodine 131 report, and are summarized in figure 1, which gives a percentage distribution of the infant population according to the estimated thyroid dose from iodine 131, September 1961 to January 1962.

From these data, it can be estimated that for the country as a whole an average year-old infant received about 160 milliroentgens during the 5-month period.

To date all of the estimated thyroid doses are less than the annual RPG.

**Strontium 90:** The results of the strontium 90 analyses in milk have been summarized in the second report submitted for the record, the intake of strontium 90 and certain other radionuclides by the population. In tabular form the report gives the annual average strontium 90 concentrations in milk for each of the stations as well as an estimated annual average for the United States.

To obtain some measure of the significance of these concentrations of strontium 90 in milk, comparisons were made of estimated total daily intakes of strontium 90 derived from the milk concentrations with the guidance of the Federal Radiation Council.

These estimates are presented in table I. The assumptions underlying the estimates of intake are summarized in the report. Comparisons of these estimated average daily intakes with the guidance of the Federal Radiation Council shows that all of the intakes were in range I, the upper limit of which is 20 micromicrocuries per day.

Intakes at the upper limit of range I continued indefinitely would result in radiation doses to bone and bone marrow one-thirtieth of the RPG's for normal peacetime operations.

**Strontium 89:** Since the inception of the PHS milk sampling program, there have been two periods when strontium 89 has been present in measurable levels in milk.

The data for these periods are summarized in the report. Table II shows estimated monthly average daily intakes of the U.S. population for the periods of late 1961 and early 1962, and quarterly average daily intake for 1957, 1958, and 1959. Again, comparison of these estimated average daily intakes with the guidance of the Federal Radiation Council shows that all of the intakes were in range I.

**Cesium 137 and barium 140:** Data on milk content of cesium 137 and barium 140 are regularly reported in Radiological Health Data. The estimated intake of cesium 137 and barium 140, based on the analyses of these radionuclides in milk, has been considerably lower in relation to accepted guides than those of strontium 89 and strontium 90.

TABLE I

Percent Distribution of Infant Population  
According To Estimated Thyroid Dose From I-131  
Sept. 1961 - Jan. 1962

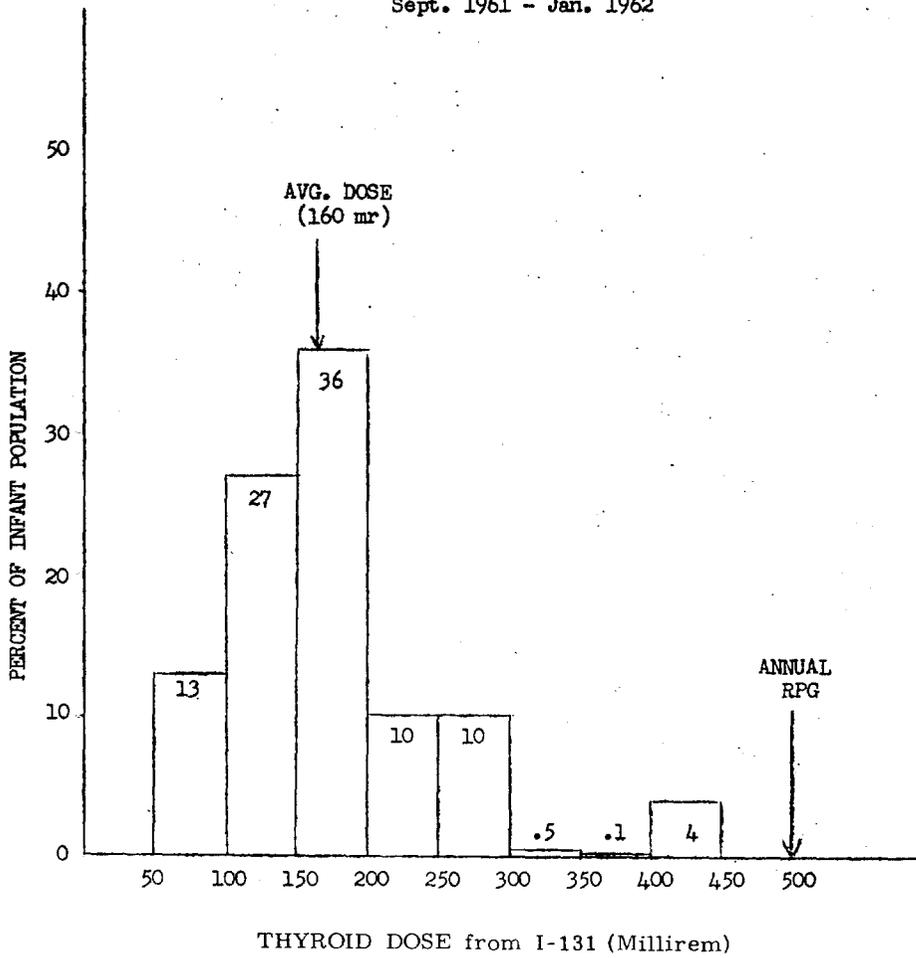


TABLE II.—Estimated annual average daily intake of strontium 90 by U.S. population, 1957-61

Year	Average milk concentration ( $\mu\text{c}/\text{l}$ )	Average daily intake of Sr 90 (in microcuries)
1957.....	16	8
1958.....	18	16
1959.....	11	14
1960.....	9	17
1961.....	9	12

<sup>1</sup> From raw milk network.

TABLE III.—Estimated monthly average daily intake of strontium 89 by U.S. population, September 1961 to March 1962

Month	Average milk concentration (microcuries/l)	Average daily intake of Sr 89 (in microcuries)
1961—September.....	10	13
October.....	40	32
November.....	53	72
December.....	35	46
1962—January.....	25	37
February.....	30	35
March.....	35	45

Representative PRICE. Dr. Chadwick, on page 2 you speak of weighing samples with respect to the contribution of the major processing plant to the total supply.

Do you have data for the individual farm in outlying districts to record hotspot information, or are these samples taken from large batches?

Dr. CHADWICK. These are taken from large batches. In other words, these are taken after processing in the milk processing plant. Of course, a given plant draws from a large number of farms.

Representative PRICE. You speak of the monthly publication, Radiological Health Data. Does the dissemination of information by this publication on a monthly basis prove to be as timely as it might, and how soon after data is compiled is it published?

Dr. CHADWICK. There is an appreciable lag period between the availability of the results of the analyses and the publication of the Radiological Health Data. This is partially compensated for by the policy of the Public Health Service to release the data as soon as we have checked out the data.

In other words, they are made available in the form of periodic issuances to the public in addition to their publication in Radiological Health Data.

Representative PRICE. Mr. Holifield.

Chairman HOLIFIELD. Mr. Chairman, a lady came up to me yesterday after the meeting and said she had had trouble in obtaining this data from the public health agency in Milwaukee.

Is there any policy on the part of the Public Health Service not to release this to local people upon request?

Dr. CHADWICK. No, sir. We release any and all data upon request. In other words, as soon as we have the laboratory-approved findings.

Chairman HOLIFIELD. You transmit it to Washington to your central coordinator, I suppose?

Dr. CHADWICK. Yes, sir.

Chairman HOLIFIELD. But it is also made available upon request to local newspapers and local people?

Dr. CHADWICK. Yes, sir. Indeed, the local health departments get the results as soon as they are available. Of course, they are participating in the networks, as you know, in terms of sample collection.

Representative PRICE. You see frequent news stories based on this report.

Dr. CHADWICK. Yes, sir.

Chairman HOLIFIELD. I could not understand this complaint because it has always been my understanding that any figures that are developed in the Public Health laboratories in this field, particularly, are public information and should be made available, if it is not, to the people of each locality as well as to the Washington office.

Dr. CHADWICK. They are made on a regular basis, sir.

Representative HOSMER. This monthly publication, Radiological Health Data, is something you have to pay for if you want to get it?

Dr. CHADWICK. Yes, sir. There is a small charge for Radiological Health Data. But many libraries and newspapers have it.

Representative HOSMER. A public health office would not necessarily have copies on hand like a newsstand?

Dr. CHADWICK. The State health departments have copies of Radiological Health Data. Each State health department gets a certain number. I can't remember offhand, but they get a certain number of copies on a regular basis.

Representative HOSMER. If I went into the health department of my hometown and wanted a copy of this, it would be rather unlikely that they would just have copies for sale to anyone who wandered in?

Dr. CHADWICK. Probably they would not. They would undoubtedly have a copy available for you to look at and would be able to tell you where to get one of your own. I wouldn't expect them to have it available for sale there.

Representative PRICE. Can anyone secure a copy by writing to the Public Health Service here and paying the cost? What is the cost?

Dr. CHADWICK. I will have to ask someone. I have been informed \$5 per year from the Superintendent of Documents.

Representative PRICE. What areas were affected first when iodine 131 began appearing in milk during September 1961?

Dr. CHADWICK. In general, it was the Southeastern United States where we observed the levels in milk first. Then it swept from that area on through the rest of the country.

Representative PRICE. How much control do you have on stopping milk consumption, if need be, by the public when unusual high levels of iodine 131 first appear? In other words, how long is it from taking the samples and receiving the data?

Dr. CHADWICK. As far as iodine 131 is concerned, it is extremely rapid. It is a matter of 24 or 48 hours from the time the milk sample is collected until the time when we have the results from the laboratory.

Representative PRICE. What about other fallout debris?

Dr. CHADWICK. In terms of the other materials it is considerably longer. Of course, by the same token, the other materials do not tend to show the kinds of wide variations from day to day or even month to month that iodine 131 shows.

The fluctuations in strontium 90, for instance, tend to be very much less. They are much more gradual, whereas the iodine, by virtue of its short half-life, shows very wide variations.

Representative PRICE. Has there been any area of the country so far where the fallout has been considered to the point where you even thought about the necessity of stopping the milk consumption?

Dr. CHADWICK. No, sir; it has not. As indicated in the paper submitted for the record, "Intake of Iodine 131 by U.S. Population," table II, which shows estimated thyroid doses to infants, even the highest values for estimated thyroid dose were below the annual RPG of the Federal Radiation Council.

Representative PRICE. We frequently read press stories as to the extent of fallout in given areas.

Would you care to comment on the significance of the period of high dosages? For instance, the most recent one was in the Midwest.

Dr. CHADWICK. The significance of any daily value can only be evaluated in terms of what you expect the annual average to be. This is particularly true for the case of iodine where the total amount of radiation dose from any given activity is delivered over a very short period of time.

So the only way that one can make any evaluation of these high values is on the basis of expectation and predictions as to what the annual accumulated doses are going to be.

Chairman HOLIFIELD. You see where we get a lot of excitement and a lot of fear is because a headline will say, "Radioactive Iodine Found in Milk Doubles That of Previous Measurements."

They may be talking about a millionth of a millionth of a curie goes to twenty-millionths. But the word "doubles" indicates to the person who does not have access to the annual average that here is something that is startling and this makes a headline and it scares the mothers to death, and they cancel their milk orders.

In a case of Minnesota a year or two ago, even the purchase of bread fell off because of a headline which was taken completely out of context of its scientific meaning. But this is something you can't control and wouldn't control in a free society.

But it does cause alarm. One of the reasons for this committee's hearings is to try to put these values in proper perspective so that at least people who want to be informed can be informed on the relative meaning of these headlines.

Representative PRICE. Dr. Chadwick, you state that range III could occur without exceeding the average annual range II intake.

Is this not a rather confusing form of guidance for the public?

Dr. CHADWICK. Of course, the Federal Radiation Council guidance really was not addressed to the public. In other words, the guidance was directed to Federal agencies with responsibilities in radiological health to give them some basis for the kinds of actions which might be appropriate in the situation of different transient rates of intake.

I suspect that it is somewhat complicated, but I am not sure I know exactly how it can be simplified. In other words, it is a matter of

trying to consider both the actual estimated intake for a given day and also estimations of what this will be over the space of a year.

Representative PRICE. Mr. Ramey.

Mr. RAMEY. Do you consider that the FRC guides, which are essentially prepared for normal peacetime operations, to be applicable to fallout and to your iodine 131 situation?

Dr. CHADWICK. I will be discussing this to some extent in testimony on Thursday. I think it depends on what one means by "the guides." I think the guidance and the method of approach and the general way that you consider the matter is indeed sound.

The specific numerical values I think one might have to look at more carefully in a situation of this sort.

Mr. RAMEY. Yet, the way it is set out, you would seem to have your normal peacetime values applicable to your fallout situation. I am not saying this is right or wrong.

Dr. CHADWICK. You mean the way this paper is written?

Mr. RAMEY. Yes, and just looking at the guides.

Dr. CHADWICK. I think they serve as a benchmark, as it were, for comparisons. Indeed, they are the only benchmarks we have for comparisons.

To that extent I think one would continue to use them as some measure of what the present situation was to try to relate it to something. You would relate it to the guides for normal peacetime operations.

Representative PRICE. You mention the subject of strontium 90. When will you have the data from the 1961 Soviet test series published?

Dr. CHADWICK. We publish regularly. The values for strontium 90—for strontium 89—are included through March of this year. We have already published and released the values through March.

The values for April will be coming fairly soon. In other words, we are just seeing now the peak first year values from the Soviet tests of last fall.

Representative PRICE. What data do you plan to publish concerning the short-lived nuclear debris other than those you have covered?

Dr. CHADWICK. We have covered in our report—we have covered completely—the iodine situation because that is complete as of now from the tests last fall. As far as strontium 89 is concerned, we have covered that fairly completely also in the background papers which have been submitted for the record.

Representative PRICE. I wonder if because of the great amount of interest that at least those of us in the Midwest have found about the

recent stories of the high level radioactive iodine that showed up recently all through the Midwest, in the St. Louis area, in Kansas and Minnesota, if you could supplement your statement with a comment showing the significance of that incident.

Dr. CHADWICK. Yes, sir; I would be glad to do so. We put out a public release on this about 10 days ago, as I recall, which summarized the first series of values that we had from the various stations in that general area.

Since that time there have been additional determinations done on radioiodine.

Representative PRICE. I think you should submit a further statement to the committee treating on that matter, and also furnish the committee with copies of any releases that you put out.

Dr. CHADWICK. I believe we regularly supply the committee with all of our publications.

Representative PRICE. I mean specifically for the purpose of these hearings.

Dr. CHADWICK. Yes, sir; I will certainly do that.  
(Statement referred to above follows:)

STATEMENT ON IODINE 131 REPORTED IN MAY 1962 FROM THE PASTEURIZED MILK NETWORK, PUBLIC HEALTH SERVICE<sup>1</sup>

By Donald R. Chadwick, M.D., Chief, Division of Radiological Health, Public Health Service

Previously reported elevated iodine 131 levels in pasteurized fluid milk from the Public Health Service's pasteurized milk network during May 1962 are submitted herewith for the record.

1. All iodine 131 reports for each station for May 1962 are included in table I (preliminary report).
2. Table II presents the monthly average iodine 131 levels for all pasteurized milk network stations for the 12-month period ending May 31, 1962, and the yearly average for each station.
3. Also attached are charts showing "Accumulated 12-Month Iodine 131 Levels in Micromicrocuries From 1-Liter Per Day of Pasteurized Fluid Milk" from June 1961 through May 1962, for the seven stations with the highest iodine 131 intake as presented in my background statement submitted June 5, "Intake of Iodine 131 by U.S. Population, Fall of 1961." The stations are Des Moines, Iowa; Minneapolis, Minn.; Palmer, Alaska; Omaha, Nebr.; Kansas City, Mo.; Detroit, Mich.; and Wichita, Kans.

These charts also show the 12-month iodine 131 accumulation levels in terms of the FRC ranges. The charts show the May 1962 accumulated 12-month iodine 131 levels were within range II.

<sup>1</sup> Prepared at the request of the Joint Committee on Atomic Energy hearings on radiation standards, including fallout, June 5, 1962.

## RADIATION STANDARDS, INCLUDING FALLOUT

DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE - PUBLIC HEALTH SERVICE  
 Division of Radiological Health --- Radiation Surveillance Center  
 Washington 25, D.C.

Report of: Iodine-131 Concentrations in Pasteurized Milk<sup>1/</sup>  
 PASTEURIZED MILK NETWORK  
 For Period: May 1962

Date: June 6, 1962

STATION LOCATION	DATE	micromicrocuries per liter													
		1	2	3	4	5	6	7	8	9	10	11	12	13	14
Alabama, Montgomery															
Alaska, Palmer *	<10								20					<10	
Arizona, Phoenix *		<10						<10							
Arkansas, Little Rock							<10								30
California, Sacramento *				<10							15				
California, San Francisco*							<10								<10
Colorado, Denver *		<10								<10					
Connecticut, Hartford	<10							<10							
Delaware, Wilmington				<10							<10				
District of Columbia			<10							<10					
Florida, Tampa			<10												
Georgia, Atlanta	<10							40							
Hawaii, Honolulu *	<10							10							
Idaho, Idaho Falls *	<10							<10							
Illinois, Chicago	<10								10						
Indiana, Indianapolis							<10								<10
Iowa, Des Moines *			<10							<10					
Kansas, Wichita *						<10								670	
Kentucky, Louisville	<10							<10							
Louisiana, New Orleans															10
Maine, Portland				20							<10				
Maryland, Baltimore	<10														
Massachusetts, Boston				<10				<10			<10				
Michigan, Detroit				<10							<10				
Michigan, Grand Rapids							<10								<10
Minnesota, Minneapolis *				<10							<10				
Mississippi, Jackson							<10								10
Missouri, Kansas City *				<10								45			
Missouri, St. Louis *		<10							15						

STATION LOCATION	DATE	micromicrocuries per liter													
		1	2	3	4	5	6	7	8	9	10	11	12	13	14
Montana, Helena *		<10													<10
Nebraska, Omaha *			<10								<10				
Nevada, Las Vegas *				<10								<10			
New Hampshire, Manchester					<10										
New Jersey, Trenton		<10						<10							
New Mexico, Albuquerque *			<10		10									15	
New York, Buffalo					<10							<10			
New York, New York								<10							
New York, Syracuse				30								<10			
North Carolina, Charlotte		<10							<10						
North Dakota, Minot *								<10							
Ohio, Cincinnati				<10							<10				
Ohio, Cleveland					<10							<10			
Oklahoma, Oklahoma City					<10				10						
Oregon, Portland *		<10							<10						
Pennsylvania, Philadelphia					<10							<10			
Pennsylvania, Pittsburgh		<10													
Puerto Rico, San Juan															
Rhode Island, Providence				<10								<10			
South Carolina, Charleston		<10								<10					
Tennessee, Chattanooga		<10							<10						
Tennessee, Memphis				<10							<10				
Texas, Austin		<10						<10							
Texas, Dallas			<10							<10					
South Dakota, Rapid City *		<10													
Utah, Salt Lake City *									<10						
Vermont, Burlington					<10							<10			
Virginia, Norfolk		<10						<10							
Washington, Seattle *		<10							<10						<10
Washington, Spokane *		<10						10							<10
West Virginia, Charleston		<10										<10			
Wisconsin, Milwaukee				<10							<10				
Wyoming, Laramie *						15									10

Milk samples are collected with the assistance of State and local health and milk sanitation agencies. Samples are shipped for analyses to either the Southwestern or South-eastern Radiological Health Laboratories located in Las Vegas, Nevada and Montgomery, Alabama, respectively. Stations shipping milk samples to the Southwestern Laboratory are identified with an asterisk (\*).

DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE - PUBLIC HEALTH SERVICE  
 Division of Radiological Health --- Radiation Surveillance Center  
 Washington 25, D.C.

Report of: Iodine-131 Concentrations in Pasteurized Milk <sup>1/</sup>  
 PASTEURIZED MILK NETWORK

For Period: May 1962

Date: June 6, 1962

STATION LOCATION	DATE	micromicrocuries per liter													
		15	16	17	18	19	20	21	22	23	24	25	26	27	28
Alabama, Montgomery			20					<10	<10	<10	<10	10			20
Alaska, Palmer *							<10								
Arizona, Phoenix *			<10							15					
Arkansas, Little Rock								<10	40						
California, Sacramento *				<10								35			
California, San Francisco							<10								<10
Colorado, Denver *				45						<10					
Connecticut, Hartford		<10							20						
Delaware, Wilmington					<10							<10			
District of Columbia				<10							<10				
Florida, Tampa				<10							<10				
Georgia, Atlanta			<10						<10						<10
Hawaii, Honolulu *		<10							30						
Idaho, Idaho Falls *		<10							<10						
Illinois, Chicago		80							40		60				
Indiana, Indianapolis						20		<10			50				<10
Iowa, Des Moines *				300							60				75
Kansas, Wichita *		660				215			165					250	
Kentucky, Louisville		20							30						
Louisiana, New Orleans									<10						<10
Maine, Portland					<10							<10			
Maryland, Baltimore		20							30						
Massachusetts, Boston					<10							<10			
Michigan, Detroit					10							30			
Michigan, Grand Rapids								<10							<10
Minnesota, Minneapolis *					290							170			
Mississippi, Jackson								<10							<10
Missouri, Kansas City *					605							150			
Missouri, St. Louis *			80					50		<10					75

STATION LOCATION	DATE	micromicrocuries per liter													
		15	16	17	18	19	20	21	22	23	24	25	26	27	28
Montana, Helena *					15										
Nebraska, Omaha *			<10					110			125				
Nevada, Las Vegas *			15							<10					
New Hampshire, Manchester				<10							10				
New Jersey, Trenton															
New Mexico, Albuquerque *				<10								50			
New York, Buffalo				<10							<10				
New York, New York								55							
New York, Syracuse				40							15				
North Carolina, Charlotte	<10								10						
North Dakota, Minot *				25			30								50
Ohio, Cincinnati			50								20				
Ohio, Cleveland				<10						<10	10				<10
Oklahoma, Oklahoma City		<10						50			100				
Oregon, Portland *	<10							<10							
Pennsylvania, Philadelphia				10											
Pennsylvania, Pittsburgh	<10										15				45
Puerto Rico, San Juan			40												
Rhode Island, Providence				<10							55				
South Carolina, Charleston		<10								<10					
Tennessee, Chattanooga	30							<10							
Tennessee, Memphis			<10							<10					
Texas, Austin	<10						<10			<10					<10
Texas, Dallas	60							20							
South Dakota, Rapid City *															
Utah, Salt Lake City *		<10						20							
Vermont, Burlington				<10							10				
Virginia, Norfolk	20							<10							
Washington, Seattle *								<10							
Washington, Spokane *							<10								<10
West Virginia, Charleston				40							50				
Wisconsin, Milwaukee			10					20		10					<10
Wyoming, Laramie *						60									

Milk samples are collected with the assistance of State and local health and milk sanitation agencies. Samples are shipped for analyses to either the Southwestern or Southeastern Radiological Health Laboratories located in Las Vegas, Nevada and Montgomery, Alabama, respectively. Stations shipping milk samples to the Southwestern Laboratory are identified with an asterisk (\*).



STATION LOCATION	DATE	micromicrocuries per liter						
		29	30	31				
Montana, Helena *	55							
Nebraska, Omaha *	50							
Nevada, Las Vegas *	<10							
New Hampshire, Manchester								
New Jersey, Trenton								
New Mexico, Albuquerque *								
New York, Buffalo								
New York, New York								
New York, Syracuse								
North Carolina, Charlotte	20							
North Dakota, Minot *								
Ohio, Cincinnati	20		50					
Ohio, Cleveland								
Oklahoma, Oklahoma City	460		390					
Oregon, Portland *	<10							
Pennsylvania, Philadelphia								
Pennsylvania, Pittsburgh								
Puerto Rico, San Juan								
Rhode Island, Providence								
South Carolina, Charleston	<10							
Tennessee, Chattanooga	<10							
Tennessee, Memphis			20					
Texas, Austin			10					
Texas, Dallas	60		90					
South Dakota, Rapid City *								
Utah, Salt Lake City *								
Vermont, Burlington								
Virginia, Norfolk	20							
Washington, Seattle *	<10							
Washington, Spokane *								
West Virginia, Charleston	10							
Wisconsin, Milwaukee			30					
Wyoming, Laramie *								

✓ Milk samples are collected with the assistance of State and local health and milk sanitation agencies. Samples are shipped for analyses to either the Southwestern or Southeastern Radiological Health Laboratories located in Las Vegas, Nevada and Montgomery, Alabama, respectively. Stations shipping milk samples to the Southwestern Laboratory are identified with an asterisk (\*).

TABLE II

RADIOIODINE CONCENTRATION OF UNITED STATES MILK  
JUNE 1961 - MAY 1962DHEW - PHS - DRH  
Radiation Surveillance Center  
June 7, 1962

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RADIATION STANDARDS, INCLUDING FALLOUT

Station Location	IODINE 131 (µmc per liter)												AVERAGE past 12 mos.
	1961						1962						
	JUNE	JULY	AUG.	SEPT.*	OCT.	NOV.	DEC.	JAN.	FEB.	MAR.	APR.	MAY #	
Alaska, Palmer	ND	ND	ND	(330)	330	40	↘10	↘10	↘10	10	↘10	↘10	60
Arizona, Phoenix	ND	ND	ND	(60)	60	80	10	10	↘10	10	↘10	↘10	20
Arkansas, Little Rock	ND	ND	ND	(120)	120	150	20	↘10	↘10	↘10	↘10	20	40
California, Sacramento	ND	ND	ND	10	20	30	10	↘10	↘10	↘10	↘10	20	↘10
California, San Fran.	ND	ND	ND	(20)	20	20	↘10	20	↘10	10	10	↘10	↘10
Colorado, Denver	ND	ND	ND	60	90	40	10	10	10	↘10	↘10	20	20
Connecticut, Hartford	ND	ND	ND	(60)	60	30	↘10	↘10	↘10	↘10	↘10	↘10	20
Delaware, Wilmington	ND	ND	ND	(60)	60	60	↘10	↘10	↘10	↘10	↘10	↘10	20
District of Columbia	ND	ND	ND	40	60	30	10	↘10	↘10	↘10	↘10	↘10	10
Florida, Tampa	ND	ND	ND	40	40	40	20	↘10	↘10	↘10	↘10	↘10	10
Georgia, Atlanta	ND	ND	ND	80	80	40	30	↘10	↘10	↘10	↘10	10	20
Hawaii, Honolulu	ND	ND	ND	(20)	20	20	10	↘10	↘10	20	↘10	10	↘10
Idaho, Idaho Falls	ND	ND	ND	(140)	140	100	10	↘10	20	10	↘10	↘10	40
Illinois, Chicago	ND	ND	ND	110	150	70	↘10	↘10	↘10	↘10	↘10	40	30
Indiana, Indianapolis	ND	ND	ND	(70)	70	60	10	↘10	↘10	↘10	↘10	↘10	20
Iowa, Des Moines	ND	ND	ND	(290)	290	210	30	10	↘10	10	↘10	90	80
Kansas, Wichita	ND	ND	ND	(130)	130	140	30	10	↘10	↘10	↘10	220	60
Kentucky, Louisville	ND	ND	ND	(90)	90	80	20	↘10	↘10	↘10	↘10	20	30
Louisiana, New Orleans	ND	ND	ND	90	80	60	30	↘10	↘10	↘10	↘10	↘10	20
Maine, Portland	ND	ND	ND	20	120	30	↘10	↘10	↘10	↘10	↘10	↘10	20
Maryland, Baltimore	ND	ND	ND	(70)	70	30	10	↘10	↘10	↘10	↘10	20	20
Massachusetts, Boston	ND	ND	ND	(130)	130	40	10	↘10	↘10	↘10	↘10	↘10	30
Michigan, Detroit	ND	ND	ND	(110)	210	90	↘10	↘10	↘10	↘10	↘10	10	40
Michigan, Gr. Rapids	ND	ND	ND	(90)	90	60	↘10	↘10	↘10	↘10	↘10	↘10	20
Minnesota, Minneapolis	ND	ND	ND	(340)	340	150	10	↘10	↘10	20	↘10	120	80
Mississippi, Jackson	ND	ND	ND	150	90	60	50	↘10	↘10	↘10	↘10	↘10	30
Mississippi, Pascagoula	ND	ND	ND	200	100	50	40	↘10	--	--	--	--	50
Missouri, Kansas City	ND	ND	ND	(150)	150	190	40	10	10	10	↘10	200	60
Missouri, St. Louis	ND	ND	ND	180	160	100	10	↘10	↘10	10	↘10	30	40
Montana, Helena	ND	ND	ND	(160)	160	110	20	↘10	20	20	↘10	↘10	40

TABLE II (Continued)

Station Location	IODINE 131 ( $\mu\text{c}$ per liter)												AVERAGE past 12 mos.
	1961						1962						
	JUNE	JULY	AUG.	SEPT.*	OCT.	NOV.	DEC.	JAN.	FEB.	MAR.	APR.	MAY	
Nebraska, Omaha	ND	ND	ND	(250)	250	120	40	<10	10	10	<10	30	60
New Hampshire, Manchester	ND	ND	ND	(100)	100	40	<10	<10	<10	<10	<10	<10	20
New Jersey, Trenton	ND	ND	ND	( 90)	90	30	40	<10	<10	<10	<10	<10	20
New Mexico, Albuquerque	ND	ND	ND	( 30)	30	40	40	<10	10	20	10	20	20
New York, Buffalo	ND	ND	ND	(100)	100	20	<10	<10	<10	<10	<10	<10	20
New York, New York	ND	ND	ND	140	100	40	<10	<10	<10	<10	<10	20	30
New York, Syracuse	ND	ND	ND	(140)	140	30	<10	<10	<10	<10	<10	20	30
North Carolina, Charlotte	ND	ND	ND	( 40)	40	20	<10	<10	<10	<10	<10	<10	10
North Dakota, Minot	ND	ND	ND	30	140	20	<10	<10	<10	10	<10	20	20
Ohio, Cincinnati	ND	ND	ND	(100)	100	80	20	<10	<10	<10	<10	20	30
Ohio, Cleveland	ND	ND	ND	(100)	100	50	<10	<10	<10	<10	<10	30	20
Oklahoma, Oklahoma City	ND	ND	ND	( 90)	90	160	40	<10	<10	<10	<10	30	40
Oregon, Portland	ND	ND	ND	( 60)	60	170	10	<10	<10	<10	<10	<10	30
Pennsylvania, Phil.	ND	ND	ND	( 80)	80	40	<10	<10	<10	<10	<10	<10	20
Pennsylvania, Pitts.	ND	ND	ND	( 90)	90	30	<10	<10	<10	<10	<10	<10	20
Puerto Rico, San Juan	ND	ND	ND	( 20)	20	20	30	<10	<10	<10	<10	20	10
Rhode Island, Providence	ND	ND	ND	( 80)	80	50	<10	<10	<10	<10	<10	20	20
South Carolina, Charleston	ND	ND	ND	90	60	20	10	<10	<10	<10	<10	> 10	20
Tennessee, Chattanooga	ND	ND	ND	( 80)	80	40	30	<10	<10	<10	<10	10	20
Tennessee, Memphis	ND	ND	ND	(160)	160	80	40	<10	<10	<10	<10	<10	40
Texas, Austin	ND	ND	ND	20	30	60	20	<10	<10	<10	<10	> 10	10
Texas, Dallas	ND	ND	ND	20	40	100	10	<10	<10	<10	<10	20	20
Utah, Salt Lake City	ND	ND	ND	140	120	60	10	10	10	10	<10	<10	30
Vermont, Burlington	ND	ND	ND	(100)	100	50	<10	<10	<10	<10	<10	<10	20
Virginia, Norfolk	ND	ND	ND	( 80)	80	30	10	<10	<10	<10	<10	<10	20
Washington, Seattle	ND	ND	ND	10	120	120	10	10	<10	10	<10	<10	20
Washington, Spokane	ND	ND	ND	(120)	120	60	<10	<10	<10	20	<10	<10	30
West Va., Charleston	ND	ND	ND	( 60)	60	20	<10	<10	<10	<10	<10	30	20
Wisconsin, Milwaukee	ND	ND	ND	(150)	150	80	<10	<10	<10	<10	<10	10	30
Wyoming, Laramie	ND	ND	ND	( 40)	40	30	10	10	10	10	<10	20	10
Network Average	ND	ND	ND	100	100	60	10	<10	<10	<10	<10	20	30

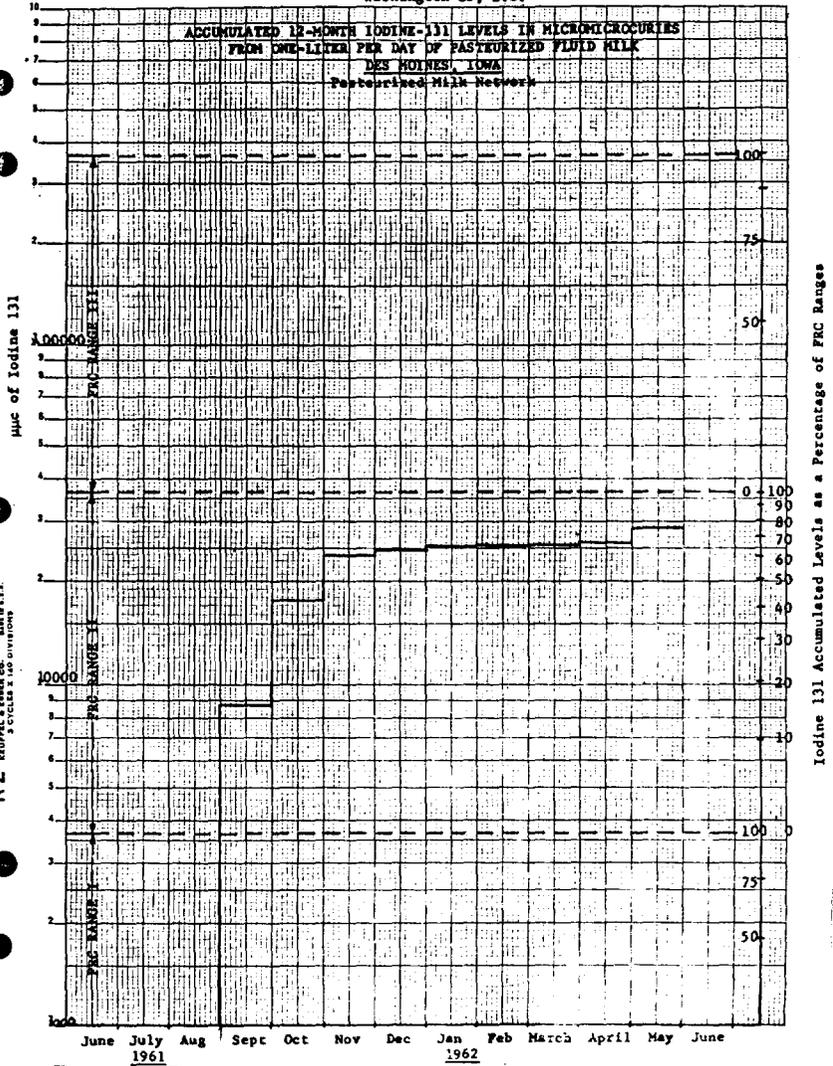
\* Numbers in parenthesis for Sept. are estimates based on October levels.

# Preliminary data

ND - Non-detectable.

DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE - PUBLIC HEALTH SERVICE  
Division of Radiological Health --- Radiation Surveillance Center  
Washington 25, D.C.

ACCUMULATED 12-MONTH IODINE-131 LEVELS IN MICROMICROCURIES  
FROM ONE-LITER PER DAY OF PASTEURIZED FLUID MILK  
DES MOINES, IOWA  
Pasteurized Milk Network

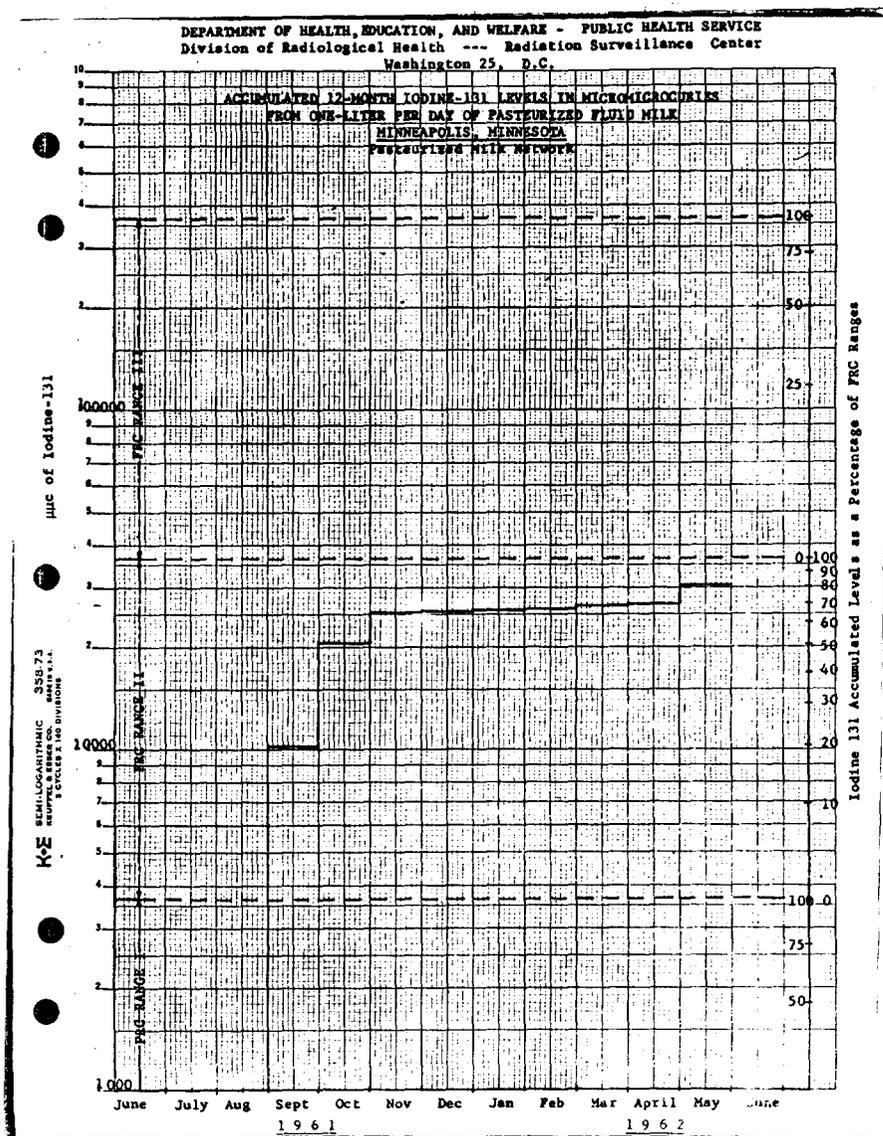


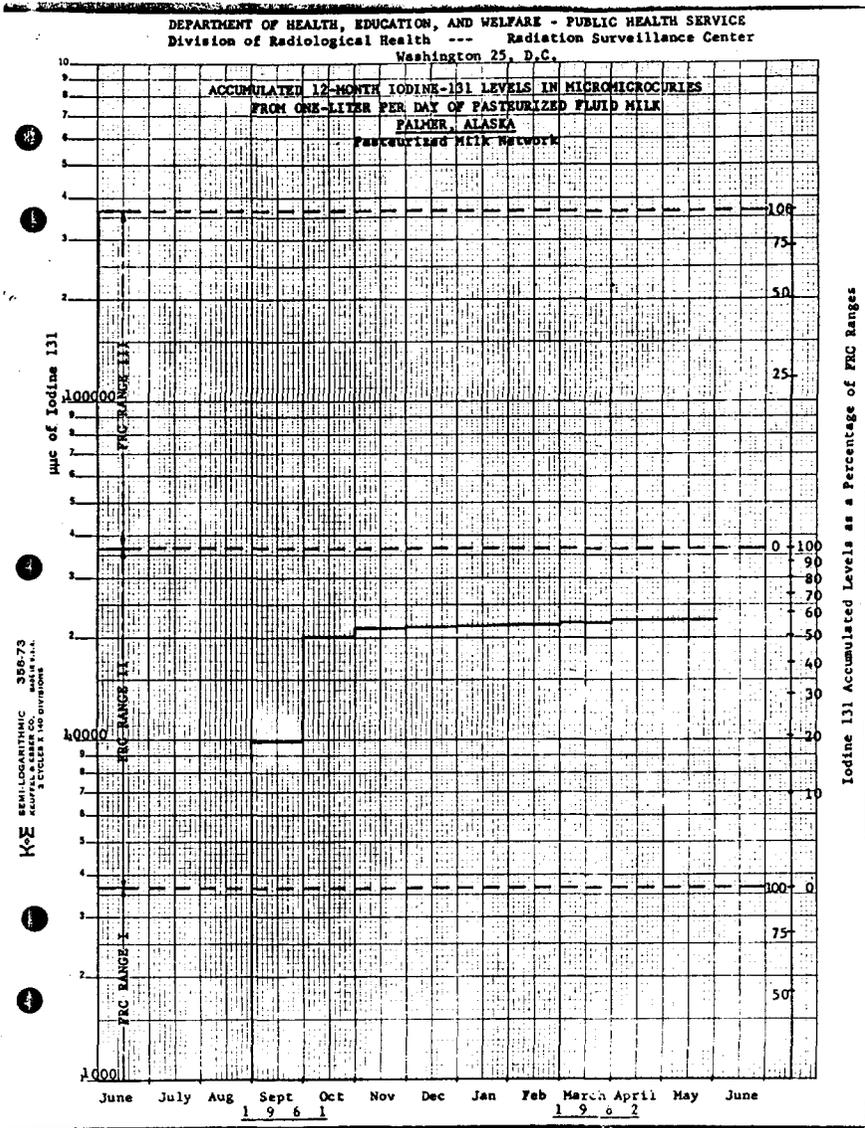
µc of Iodine 131

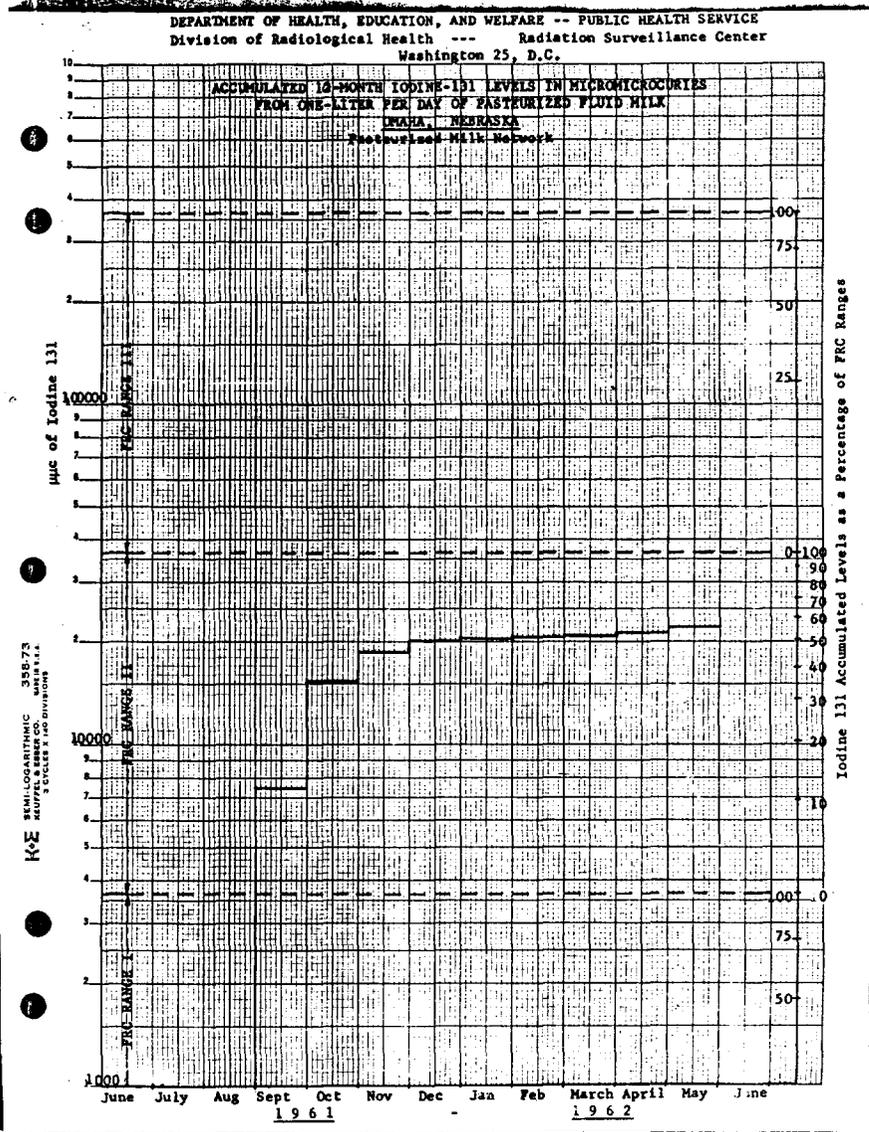
SEMI-LOGARITHMIC 358-73  
KREFFEL & BERRY CO. BOSTON, U.S.A.  
K&B

Iodine 131 Accumulated Levels as a Percentage of FRC Ranges

June 1961 July Aug Sept Oct Nov Dec Jan 1962 Feb March April May June

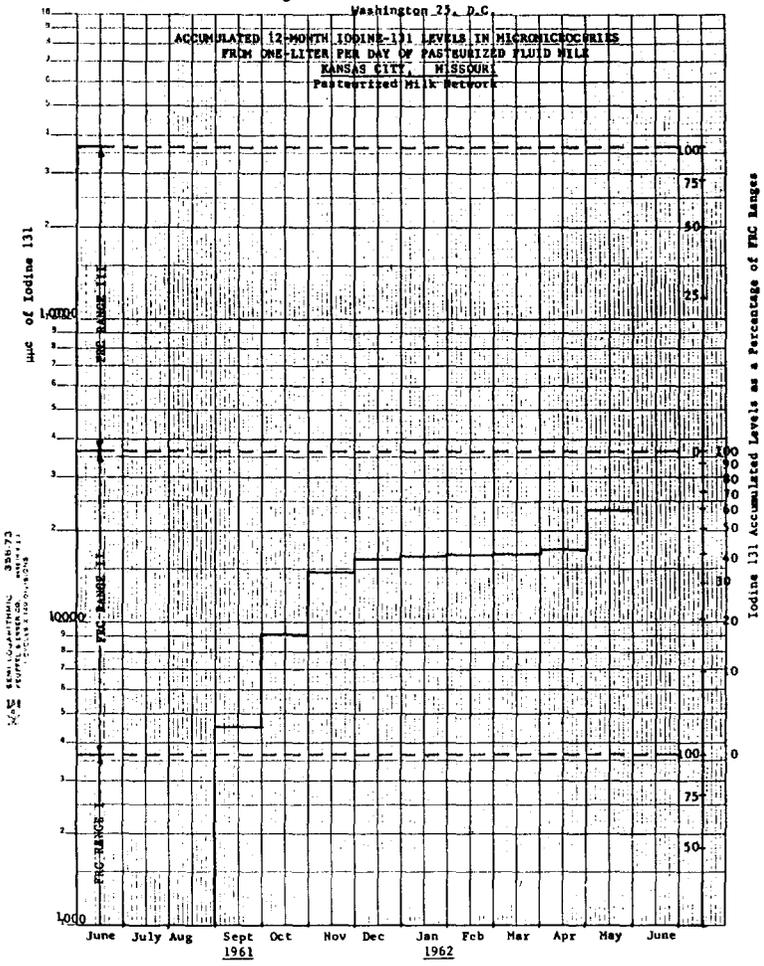






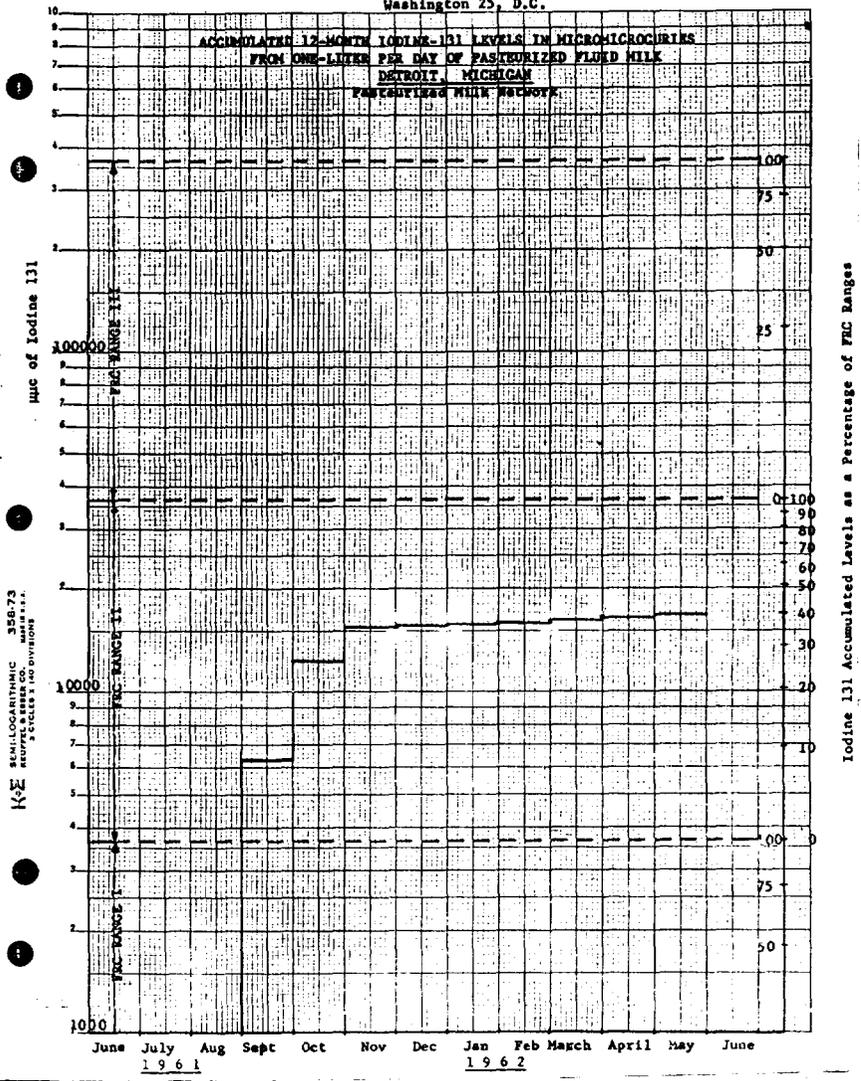
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 Division of Radiological Health --- Radiation Surveillance Center  
 Washington 25, D.C.

ACCUMULATED 12-MONTH IODINE-131 LEVELS IN MICROWICROGRAPHS  
 FROM ONE LITER PER DAY OF PASTEURIZED FLUID MILK  
 KANSAS CITY, MISSOURI  
 Pasteurized Milk Network



SENT LOUISIANA 33673  
 PEOPLE'S PARTY OF MISSOURI

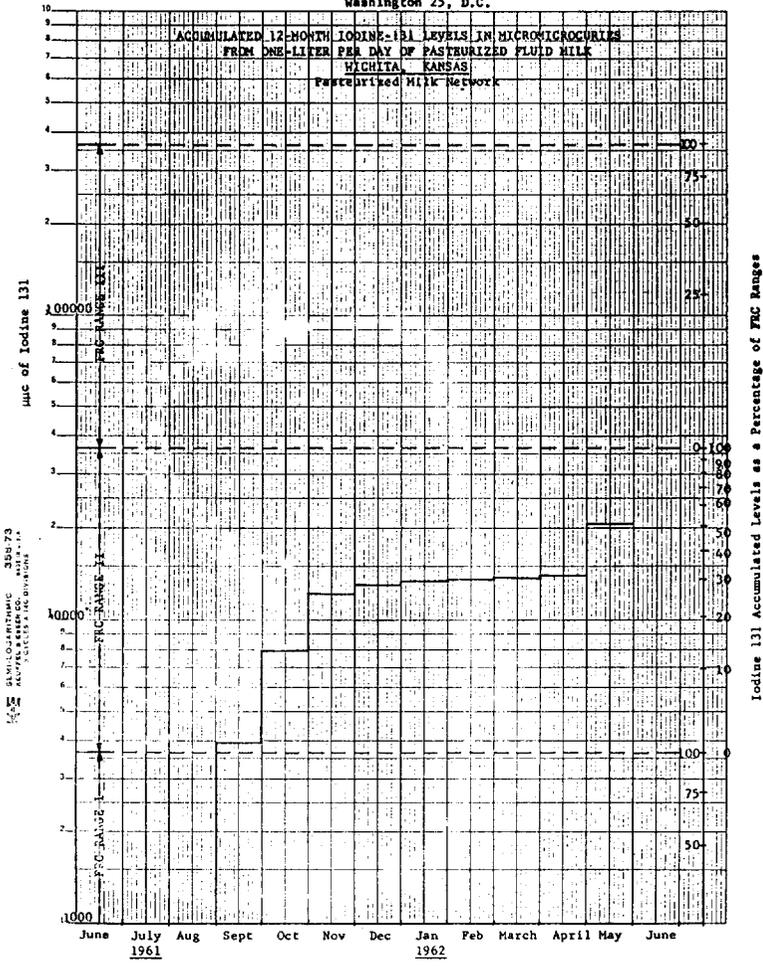
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Iodine 131 Accumulated Levels as a Percentage of REC Ranges

H<sub>2</sub>E SEMI-LOGARITHMIC REC RANGES IN  $\mu\text{c}$  PER LITER OF MILK

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Iodine 131 Accumulated Levels as a Percentage of FPC Ranges

Representative PRICE. I understand you are going to be on one of our panels, because you could have some of that material ready to present in an open hearing.

Dr. CHADWICK. I will be glad to do that, sir.

Chairman HOLIFIELD. I would like to ask a question.

Assuming that you would detect a level in range III of radioactivity in milk, say, in July, August, or some other month, how many months would you allow this to go before you exercised controls to keep it from going above the annual RPG?

Dr. CHADWICK. That is a very difficult question, as I am sure you are aware. It would have to depend upon two things. Three things, really. What had been happening in the immediate past: In other words, was there a prolonged period of no detectable iodine as was the situation last fall. Secondly, what would be the projections of what was going to happen in the future. In other words, was the situation one which appeared to be temporary. Did it look as if this was one intrusion and there was not going to be any more, or did it look like a situation in which there would be more iodine.

Finally, it would depend upon what measures were available as countermeasures. This is a subject that I plan to discuss in a little more detail in my testimony on Thursday. In other words, what are the kinds of decisions involved in the situation where you apply environmental controls versus the situation where you have source control as your major tool.

Chairman HOLIFIELD. Maybe my question could be phrased in a different way, then.

If at any time there did seem to be a definite burden of radiation to the point where it would be damaging to human beings, it would be the policy of the Public Health Service to make this information known to the public and to take such control measures as the law allows.

Dr. CHADWICK. Yes, sir, it would, in general. I think, though, if one looks back at the concepts underlying radiation protection standards, as described in the Federal Radiation Council, it is pointed out that anything you do in terms of radiation protection standards, any of the decisions involve some kind of balance between the risk from the radiation that you are attempting to control versus the impact of the measures that you would have to take to control it.

So I think the decision as to what one would do in a situation that you describe is not really entirely a health decision. Because the impact of any measures that might be taken include not only health impact but they include other factors.

So I think the decision that is made would have to reflect the balance of all of these factors.

Chairman HOLIFIELD. In other words, the decision would have to be made at that time as to whether this was a burden that you would have to live with in relation to the advantages that you would obtain from the use of milk, or whether drastic measures would be taken to prevent the use of milk.

You would have to come to some type of a recommendation. I do not see it would be within the power of the Public Health Service to do anything but recommend.

Dr. CHADWICK. Yes, sir.

Chairman HOLIFIELD. In any event, you would make this information known to the public?

Dr. CHADWICK. Yes, sir.

Chairman HOLIFIELD. And the area that it would affect first would be the infants or the young children because of the need of calcium for bone structure or the iodine uptake, and therefore, it might be entirely feasible that children below a certain age might be temporarily taken off milk and the older population could use the milk without deleterious effects, relatively speaking?

Dr. CHADWICK. Indeed, this is the suggestion that has been made by the British Medical Research Council, that under certain conditions in which expected annual accumulation of iodine 131 would reach a certain level, the British Medical Research Council has recommended that infants in this age group be placed on some kind of canned or powdered milk.

Chairman HOLIFIELD. There was one incident at Windscale in England where they had the reactor excursion accident in which the pasturage was contaminated to the point where they absolutely took everyone off milk for a time period, is that not true?

Dr. CHADWICK. Yes. They actually dumped milk and disposed of it.

Chairman HOLIFIELD. Until the radiation went down?

Dr. CHADWICK. Of course, it is quite clear that that milk could have been held. In other words, it could have been put into some kind of processing such that radioiodine would have decayed out of the milk.

I think they simply went to great lengths to take effective and complete action in the situation.

Chairman HOLIFIELD. They exercised supercaution, you might say?

Dr. CHADWICK. I think you are quite right.

Mr. RAMEY. How does your range III for iodine 131 for the general population compare? Is there any comparable figure for employees in the radiation industry as a maximum permissible intake?

Dr. CHADWICK. There are really three factors that would make the amount that one would permit radiation workers to take, greater than the general population.

First of all, there is the fact that the limitation of the intake of radioiodine is based upon the concentration of the radioiodine in the very small infant's thyroid, which is a factor of 10 below the size of the adult thyroid. So, given the same given intake, the infant would receive 10 times the dose simply because of the fact that the energy would be released in a gland of one-tenth the size.

Secondly, the general population is restricted to a lower value than radiation workers. In general, this has been a factor of the order of 10. Finally, there is an additional factor here in the case of radioiodine. The thyroid gland in adults has been shown to be a relatively radioresistant organ.

In the case of children, the evidence would suggest that the thyroid is not a relatively radioresistant organ. That is a sort of double negative there. In other words, there is not that factor of radioresistance in the thyroid of the infant or child as compared to the adult.

So whereas the thyroid gland in radiation protection standards for radiation workers is permitted a greater dose than the general run of

other organs in the body—actually, by a factor of 2—this factor is not permitted in the case of a child because the child's thyroid does not have this radioresistance. At least the evidence would suggest that it does not.

Mr. RAMEY. This factor of 10 applies in a great deal of your radionuclides and other radioactive hazards. Where you begin to approach nearer to where you might have damage as against a sort of danger signal used by your general population maximum permissible dose or level in your radiation guides.

Dr. CHADWICK. We have accounted here for two factors of 10 and then an additional factor of the order of 2.

Representative PRICE. Are there any further questions?

If not, the committee will recess until 2 o'clock this afternoon.

The first witness will be Dr. Wright Langham.

Dr. Chadwick, the committee appreciates your fine presentation and the valuable information which you have supplied for this hearing.

Dr. CHADWICK. Thank you, sir.

(Whereupon, at 12:20 p.m., the subcommittee recessed, to reconvene at 2 p.m., the same day.)

#### AFTERNOON SESSION

Representative PRICE. The committee will be in order.

This is a continuation of hearings on radiation standards including fallout. The committee will finish hearing witnesses on worldwide fallout since 1959 and then hear the panel discussion on predictions.

The first witness this afternoon will be Dr. Wright H. Langham of the Los Alamos Scientific Laboratory. Dr. Langham.

#### STATEMENT OF WRIGHT H. LANGHAM,<sup>1</sup> LOS ALAMOS SCIENTIFIC LABORATORY

Dr. LANGHAM. Mr. Chairman, members of the subcommittee, I have submitted two documents to Mr. McAlpine regarding the testimony that I will present orally and briefly. Those two documents are a full statement of my testimony, and a recent paper published by Dr. Gustafson of the Argonne National Laboratory, dealing with the subject of short-range fallout from the 1961 tests of the U.S.S.R.

The last two subcommittee hearings on this particular subject have produced volumes of information regarding the details of the method of fallout, the probable effects of fallout, and the various factors and ramifications that enter into this rather complex subject. At present nothing can be added to the basic concepts.

<sup>1</sup>Dr. Wright H. Langham has been associated with the atomic energy developmental program for over 18 years. The first 2 years were spent at the metallurgical laboratory of the University of Chicago and at Los Alamos developing micromethods for the analysis of trace impurities in plutonium.

In late 1944, his interests were turned to problems of toxicology, biophysics, and radiobiology. He became the group leader of the Biomedical Research Group of the Los Alamos Scientific Laboratory in 1946 and still holds that position. His major interests have been in the fields of physiology and toxicology of plutonium, tritium, and other radioactive materials; effects of massive doses of radiation on animals; relative biological effectiveness of radiations of different types and different energies; potential hazards of worldwide radioactive fallout from nuclear weapon tests; use of radioisotopes in biology and medicine; and radiation problems associated with space conquest.

He is a member of the International Subcommittee on Internal Hazards of Radiation; the National Committee for Radiation Protection; the National Academy of Sciences-National Research Council Study Group on Radiation Problems of the NASA Apollo Program, the Radiation Research Society, Health Physics Society, and the Federation of American Societies for Experimental Biology.

Representative PRICE. Without objection, your statement will be carried in full, and the document you mentioned will be carried in the record.

Dr. LANGHAM. Thank you.

(The documents referred to follow:)

**GAMMA RAY DOSE FROM SHORT-LIVED FISSION PRODUCTS FROM NUCLEAR-WEAPON TESTS**

Philip F. Gustafson, Division of Biological and Medical Research, Argonne National Laboratory, Argonne, Ill.

The  $\gamma$ -ray dose from short-lived fission products deposited on the ground may constitute the major source of whole-body radiation during the testing of nuclear weapons in the atmosphere and for some months thereafter. The magnitude of this dose relative to that from ground-deposited  $\text{Cs}^{137}$  depends critically upon the time that it takes nuclear debris to travel from the site of detonation to the point of deposition. The transport time in turn is dependent upon the size of the detonation, the altitude and latitude at which it occurs, and the time of year of its injection into the atmosphere.

Nuclear debris from a small (kiloton range) surface burst is confined within the troposphere and hence is completely deposited within a few months. As a result the amount of short-lived radioactivity relative to that from  $\text{Cs}^{137}$  is large, although the absolute magnitude of the concentration is small. In the case of a high-altitude burst (30 kilometers or higher), regardless of size, many months and even years may elapse before an appreciable fraction of the debris reaches the ground. The decay of much of the short-lived component before deposition leads to a lower dose relative to  $\text{Cs}^{137}$ . There is also a latitude effect, in that debris injected into the low polar stratosphere (a portion also being present initially in the adjacent troposphere) will be deposited somewhat more rapidly than that from an equivalent injection into the low equatorial stratosphere.

The rate of removal of nuclear debris from the stratosphere is not constant, but undergoes seasonal variations, being greatest during the spring months in the hemisphere in question and least during the autumn and winter. The corresponding variation in the concentration of  $\text{Cs}^{137}$ , for example, in surface air is illustrated in figure 1. The repetitive cycle of maximums and minimums is of meteorological origin as shown by its occurrence during 1959 to 1961 in the absence of nuclear testing. This phenomenon is believed to result from the subsidence of the airmass over the winter pole with a subsequent influx of stratospheric debris into the lower atmosphere during the spring. The strong influence of the polar stratosphere explains in large part the more rapid removal of debris injected in polar regions. The variation in removal rate from one month to the next does not preclude a reasonably constant annual removal rate. A measure of the annual removal rate or mean stratospheric residence time may be obtained by comparing successive maximums or minimums as shown in figure 1.

Three nuclear test situations will be considered regarding the gamma ray dose due to short-lived fission products: (1) Injection into the low polar stratosphere, (2) injection into the low equatorial stratosphere, (3) high-altitude detonation or injection. Small detonations, whose debris is contained within the troposphere, will not be considered because of the relatively small amount of radioactivity produced therein.

The following radionuclides have been considered in computing the  $\gamma$ -dose from fission products on the ground:  $\text{Zr}^{90}$ - $\text{Nb}^{90}$ ,  $\text{Ru}^{103}$ ,  $\text{Ru}^{106}$ ,  $\text{Ce}^{141}$ ,  $\text{Ce}^{144}$ - $\text{Pr}^{144}$ ,  $\text{Ba}^{140}$ - $\text{La}^{140}$ , and  $\text{Cs}^{137}$ .  $\text{I}^{131}$  has been omitted because of its short half-life.  $\text{Sb}^{125}$  becomes of some relative importance 2 years after a test; however, the accuracy of measurement of this nuclide in soil has not been sufficient to warrant its consideration at this time. The concentration of the various nuclides in soil has been determined by means of gamma ray spectrometry of soil cores. Monthly increments in deposition have been determined in part by direct analysis of soil and in part by analyses of precipitation and air samples.

All sampling referred to herein was conducted at the Argonne National Laboratory site; hence the dose values derived from these data pertain rigorously only to this location. Due to the similarity in deposition observed at other sites having comparable precipitation and located nearby in latitude, the dose values may be presumed to have considerably wider applicability.

As illustrations of the three test situations, Hardtack I (April-July 1958) was chosen for the low equatorial stratospheric injection case, Soviet October 1958 for low polar stratospheric injection, and the Orange and Teak shots ( $\approx 100,000$  feet over Johnston Island in August 1958) for the high-altitude case. The choice of these series and shots is not arbitrary, since the production of  $W^{181}$ ,  $^{186}$  in Hardtack I and  $Rh^{102}$  in the Orange shot provided tracers for these events. Activity ratios between appropriate nuclides have been used to determine the Soviet portion of the remaining debris.

Modifications of Dunning's method for obtaining the infinite plane dose from surface deposition were used to calculate the air gamma ray dose rate. The modifications take into account the actual distribution in depth, determined experimentally, of each of the various fission products in soil. The attenuation and dose buildup factors based upon the vertical distribution in soil are included in the dose equations which are given in appendix I for each isotope. In essence, the dose rate so calculated is no longer the usual infinite plane dose, but is analogous to that obtained by applying corrections for weathering and terrain roughness to the infinite plane values. Further reduction in the actual dose to an individual may arise due to shielding by dwellings and other structures. Shielding factors currently in use range from 0.2 to 0.7 times the open field dose.

During late 1958 and throughout 1959, soil measurements at Argonne indicated the deposition of 40 millicuries per square mile<sup>2</sup> of  $Cs^{137}$  arising from the Soviet October 1958 tests. Furthermore it was shown from concurrent air and precipitation studies that almost all of the Soviet debris came down within 1 year after the series ended. Assuming that this quantity of  $Cs^{137}$  came from 12.5 megaton of fission, 3.2 millicuries per square mile<sup>2</sup> of  $Cs^{137}$  was produced per megaton of fission and was deposited within 1 year. The open-field dose from this deposition during the first year amounted to approximately 0.1 milliroentgen. The dose from short-lived nuclides during this interval was 3.83 milliroentgen as shown in table I. The corresponding integral doses for 30-year (genetic dose) and 70-year (lifetime dose) intervals are also shown in table I. The mean stratospheric residence time of this debris was 8 to 10 months as derived from  $Cs^{137}$  concentration in surface air according to the method illustrated in figure 1. The ratio of short-lived fission product dose to that from  $Cs^{137}$  for 30- and 70-year intervals has been calculated as a function of mean stratospheric residence time and is shown in graphical form in figure 2. The ratio of dose from short-lived emitters to that from  $Cs^{137}$  for the Soviet October 1958 tests is shown in tabular form in table II for the 30- and 70-year intervals. The mean residence time corresponding to these values as obtained from figure 2 is indicated in parentheses.

For Hardtack I, the assumption has been made that 1.6 millicuries per square mile<sup>2</sup> of  $Cs^{137}$  per megaton of fission will be deposited at Argonne instead of 3.2 millicuries per square mile<sup>2</sup> per megaton as the debris is presumed to divide equally between Northern and Southern Hemispheres. In addition the longer mean stratospheric residence time deduced from the  $W^{181}$  data (15 to 18 months) means that 1.6 millicuries per square mile<sup>2</sup> per megaton will be an upper limit for  $Cs^{137}$ , because a portion of the nuclide will decay before reaching the ground. Approximately half of the total Hardtack  $Cs^{137}$  reached the ground during the first year after the series, hence the dose from this nuclide pertaining to the deposition of 0.8 millicuries per square mile<sup>2</sup> in 1 year has been computed (table I). The corresponding dose from short-lived fission products was obtained using the dose ratio found upon computing the various dose contributions from the observed deposition of Hardtack debris. The 30- and 70-year integral doses for  $Cs^{137}$  and short-lived components are also indicated in table I. The dose ratios are indicated in table II with corresponding values of mean residence time as derived from figure 2 shown in parentheses as before. The reasonably good agreement between observed mean stratospheric residence time and those found from figure 2 is somewhat surprising when one realizes that a constant rate of deposition is implicit in the data plotted in figure 2.

Experimental data on the third case—namely, that from Orange and Teak—are somewhat sparse. The most striking feature is that debris from this source, as indicated by  $Rh^{102}$ , did not appear in detectible quantity at ground level until a year after detonation (in September 1959  $Rh^{102}$  was first noted in surface air at Argonne). Hence there is no dose contribution during the first year, and the dose from short-lived fission products is severely reduced due to decay. Again an equal partition between hemispheres was assumed. The 30- and 70-year integral doses computed for these shots are shown in table I, and dose ratios are indicated in table II.

The ratio of short-lived dose to  $Cs^{137}$  dose as well as the assumed deposition of  $Cs^{137}$  in terms of millicuries per square mile per megaton may be used to evaluate the possible radiological implications of the Soviet 1961 polar tests and those being conducted by the United States in the equatorial Pacific.

Only for the Soviet 1961 tests are sufficient data available to compare with the situation observed in 1958-59. The simplest approach is to assume a direct correspondence between events in 1958-59 and those occurring, and to occur, in 1961-62. This is not a bad first approximation, since both series were conducted north of the Arctic Circle during the autumn. On two occasions in 1961, however, very large detonations were involved, 25 megatons in one case and 57 megatons in the other, which resulted in sizable portions of the debris being carried initially to greater altitude than was the case in 1958. Proceeding with a direct comparison, and taking the figure of 25 megatons as the fission yield of the 1961 series, one arrives at the dose from  $Cs^{137}$  and from short-lived activity as indicated in table III. As of mid-May 1962 the integral dose from September 1961 from Soviet debris, including  $Cs^{137}$ , as measured at Argonne is less than 50 percent of that observed during the corresponding period in 1958-59 due to Soviet tests. The difference in deposition is perhaps illustrated more clearly by comparing monthly deposition of  $Cs^{137}$  as shown in table IV, where the present values are roughly one-half those attributed to 12.5 megatons in 1958-59.

The most ready explanation for this difference is that an appreciable fraction of the total yield is being held at high altitude or otherwise has not yet been deposited. That holdup at high altitude is occurring was shown by a series of balloon flights made during early April 1962 at Thule, Greenland, by a team composed of Argonne and Weather Bureau personnel in which a gamma ray spectrometer was flown to altitudes of 100,000 feet. The results show considerable debris above 75,000 feet, with the maximum concentration between 60,000 and 70,000 feet. Thus the behavior of a portion at least of the Soviet 1961 activity may more closely resemble that from a high-altitude detonation than from an injection into the low polar stratosphere. The rate of deposition should then be slower, and the total dose will be reduced below that tabulated in table III.

In summary, the dose from short-lived fission products relative to that from  $Cs^{137}$  is greatest in the case of polar, low stratospheric injection. The deposition of  $Cs^{137}$  per megaton of fission is also greatest in this case. The dose from short-lived nuclides is somewhat less, relative to the  $Cs^{137}$  dose, in the case of equatorial low stratospheric injection; the  $Cs^{137}$  deposition per square mile per megaton of fission is also less (by a factor of 2), but is more widespread. High-altitude detonations—presumably independent of latitude—result in an appreciable reduction in the dose from short-lived emitters, the bulk of which may not survive the fairly long residence in the stratosphere. In addition decay of longer-lived components may also become appreciable, and likewise result in a reduced dose per megaton of fission. (This work was performed under the auspices of the U.S. Atomic Energy Commission.)

TABLE I.—Integral gamma ray dose for 1-, 30-, and 70-year intervals

[In milliroentgens]

Time interval	Gamma ray dose per megaton of fission					
	Soviet, October 1958		Hardtack I		Orange and Teak	
	Cs <sup>137</sup>	Short-lived activity	Cs <sup>137</sup>	Short-lived activity	Cs <sup>137</sup>	Short-lived activity
0 to 1 year.....	0.1	3.83	0.025	0.62	0	0
0 to 30 years.....	2.08	4.80	.95	1.24	.52	.06
0 to 70 years.....	3.22	4.80	1.47	1.24	.80	.06

TABLE II.—Ratio of gamma ray dose from short-lived fission products to that from Cs<sup>137</sup>

Time interval	Test series		
	Soviet, October 1958	Hardtack I	Orange and Teak
0 to 30 years.....	2.31	1.31	0.12
0 to 70 years.....	1.49	.85	.08

TABLE III.—Integral gamma ray dose for 1-, 30-, and 70-year intervals from 25 megatons of fission from Soviet 1961 tests assuming same deposition pattern as in 1958-59

[In milliroentgens]

Time interval	Gamma ray dose		
	Cs <sup>137</sup>	Short-lived activity	Natural radiation
0 to 1 year.....	2.5	96.0	100
0 to 30 years.....	52.0	120.0	3,000
0 to 70 years.....	80.5	120.0	7,000

TABLE IV.—Cumulative ground deposition of Cs<sup>137</sup>

[Millicuries per square mile]

Month	Soviet October 1958, Cs <sup>137</sup>	Month	Soviet 1961 Cs <sup>137</sup>
1958—October.....	0.08	1961—September.....	0.10
November.....	.50	October.....	.20
December.....	.68	November.....	.50
1959—January.....	1.35	December.....	1.53
February.....	4.41	1962—January.....	2.60
March.....	12.70	February.....	3.60
April.....	26.97	March.....	8.06
May.....	38.35	April.....	10.11
		May (to May 15).....	14.51

APPENDIX I.—Factors used to compute air dose in  $\mu\text{r}/\text{hour}$  from deposition of radioactivity expressed in  $\text{mc}/\text{mi}^2$

Isotope	Factor ( $\mu\text{r}/\text{hour}/\text{mc}/\text{mi}^2$ )	Isotope	Factor ( $\mu\text{r}/\text{hour}/\text{mc}/\text{mi}^2$ )
Cs <sup>137</sup> .....	$3.4 \times 10^{-3}$	Ce <sup>141</sup> .....	$0.35 \times 10^{-3}$
Zr <sup>95</sup> .....	$4.0 \times 10^{-3}$	Ce <sup>144</sup> —Pr <sup>144</sup> .....	$0.17 \times 10^{-3}$
Nb <sup>95</sup> .....	$4.2 \times 10^{-3}$	Ba <sup>140</sup> .....	$1.0 \times 10^{-3}$
Ru <sup>103</sup> .....	$2.75 \times 10^{-3}$	La <sup>140</sup> .....	$16.0 \times 10^{-3}$
Ru <sup>106</sup> .....	$1.3 \times 10^{-3}$		

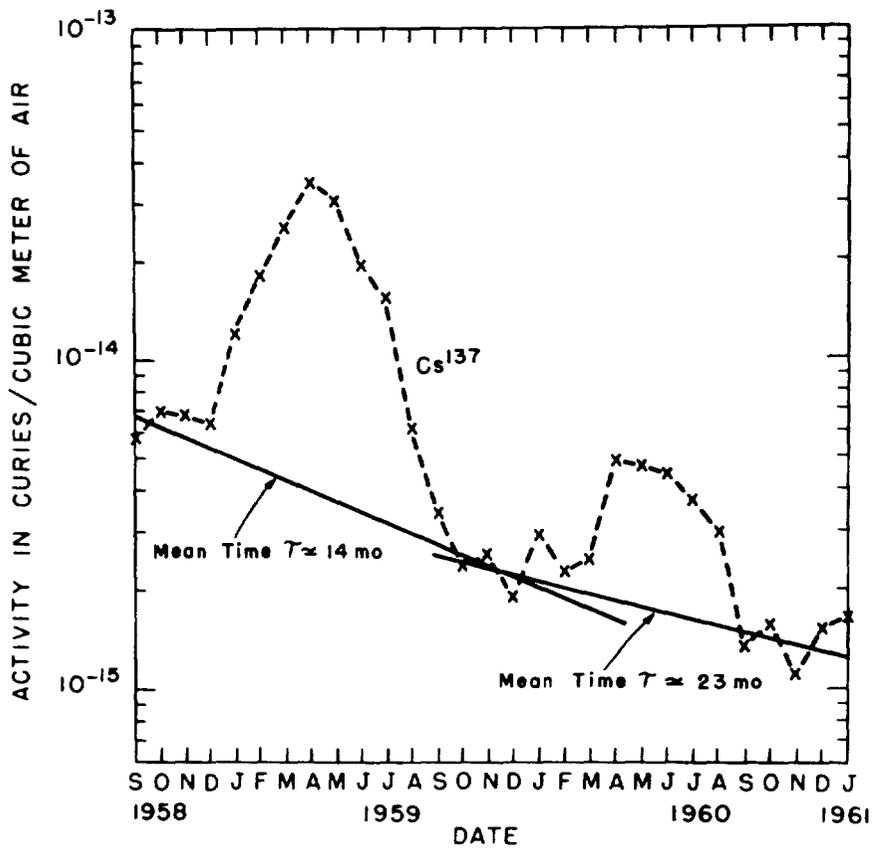


FIGURE 1.— $\text{Cs}^{137}$  in surface air at Argonne National Laboratory and the determination of mean stratospheric residence time.

## RADIATION EXPOSURE TO PEOPLE FROM NUCLEAR WEAPON TESTS THROUGH 1961

By W. H. Langham and E. C. Anderson, Los Alamos Scientific Laboratory,  
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## INTRODUCTION

Past subcommittee hearings (1957, 1959) on the subject of radioactive fallout from nuclear weapon testing have produced voluminous reports (1, 2) covering all aspects of fallout phenomena, exposure of the population, and possible biological effects. Little can be added at the present time to the basic concepts set forth in the previous hearings. Collection of additional data during the test moratorium from November 1958 to September 1961, however, has afforded basis for more quantitative definition of some of the physical and biological parameters. Better quantitative definition of the following parameters has resulted in refinement and improved accuracy of average population exposure estimates: (a) Fallout rate and integral surface deposition level as a function of point of stratospheric injection; (b) dependence of dietary level on differential and integral fallout; and (c) dietary and metabolic factors. More refined estimates of population exposure from various components of fallout have been made by a number of investigators and agencies, notably Dunning (3), Kulp and Schulert (4), Gustafson (5, 6), Anderson et al. (7), Public Health Service (8), Defense Atomic Support Agency (9, 10), the Federal Radiation Council (11), the United Nations (12), and the Prediction Panel of the present hearings (13).

Since the 1959 hearings, one additional factor has influenced the estimation of exposure of people from fallout: i.e., the resumption of tests by both the U.S.S.R. and the United States. The purpose of this rather brief presentation is not to present details of the refined dose calculations but rather to summarize the present estimates of population exposure level from long-range fallout, taking into consideration the 1961 U.S.S.R. test series and the additional quantitative data collected since the previous hearings.

## COMPONENTS OF FALLOUT EXPOSURE

Radiation exposure from long-range fallout (independent of local fallout which is of primary concern in event of war) is composed of several components, each of which will be discussed briefly prior to summarizing the population dose contributed by each. Depending on the component, exposure may be either internal (i.e., from radionuclides taken into the body through food chains) or external (from deposition of gamma-emitting isotopes in the environment), or both. As pointed out in previous hearings, the relative contribution of each component to the integral dose is dependent on a variety of factors, including radiological half-life of particular radioisotopes, biological uptake and turnover rates, fallout rate of each injection, and in some cases even on the age of the individual exposed. These and other factors produce such degrees of complication that any detailed review of their significance in the dose estimations is impractical for the purpose of these hearings.

*Strontium 89 and strontium 90*

Because of the chemical similarity of strontium and calcium, isotopes of the former element are taken into the body and deposited in the skeleton. Since both  $\text{Sr}^{89}$  and  $\text{Sr}^{90}$  emit beta particles only, they produce no genetic hazard, and their somatic hazard is confined entirely to the bone and bone marrow. Animal experiments have proved unequivocally that enough  $\text{Sr}^{89}$  and  $\text{Sr}^{90}$  deposited in the skeleton will produce bone cancer and other skeletal pathology. The amounts of these isotopes required to produce bone disease in man are not definitely known. Because of the short half-life of  $\text{Sr}^{89}$  (51 days), it contributes to the bone dose only during the first year of fallout and does not accumulate in the ecological cycle. Strontium 90, with its 28-year radiological half-life and its 30-year biological turnover time, can integrate in the soil and in the bone and contribute significantly to skeletal radiation throughout one's entire life. For this reason, it is a major component of fallout exposure. Because the rate of growth of the skeleton is dependent on age (up to 20 years), the present concentration of  $\text{Sr}^{90}$  in the bones of the population is likewise dependent on age. The quantitative explanation of the age-dependence of  $\text{Sr}^{90}$  concentration was given by Langham and Anderson (14) and has since been refined and proved experimentally by Kulp et al. (4, 15, 16, 17, 18). The age

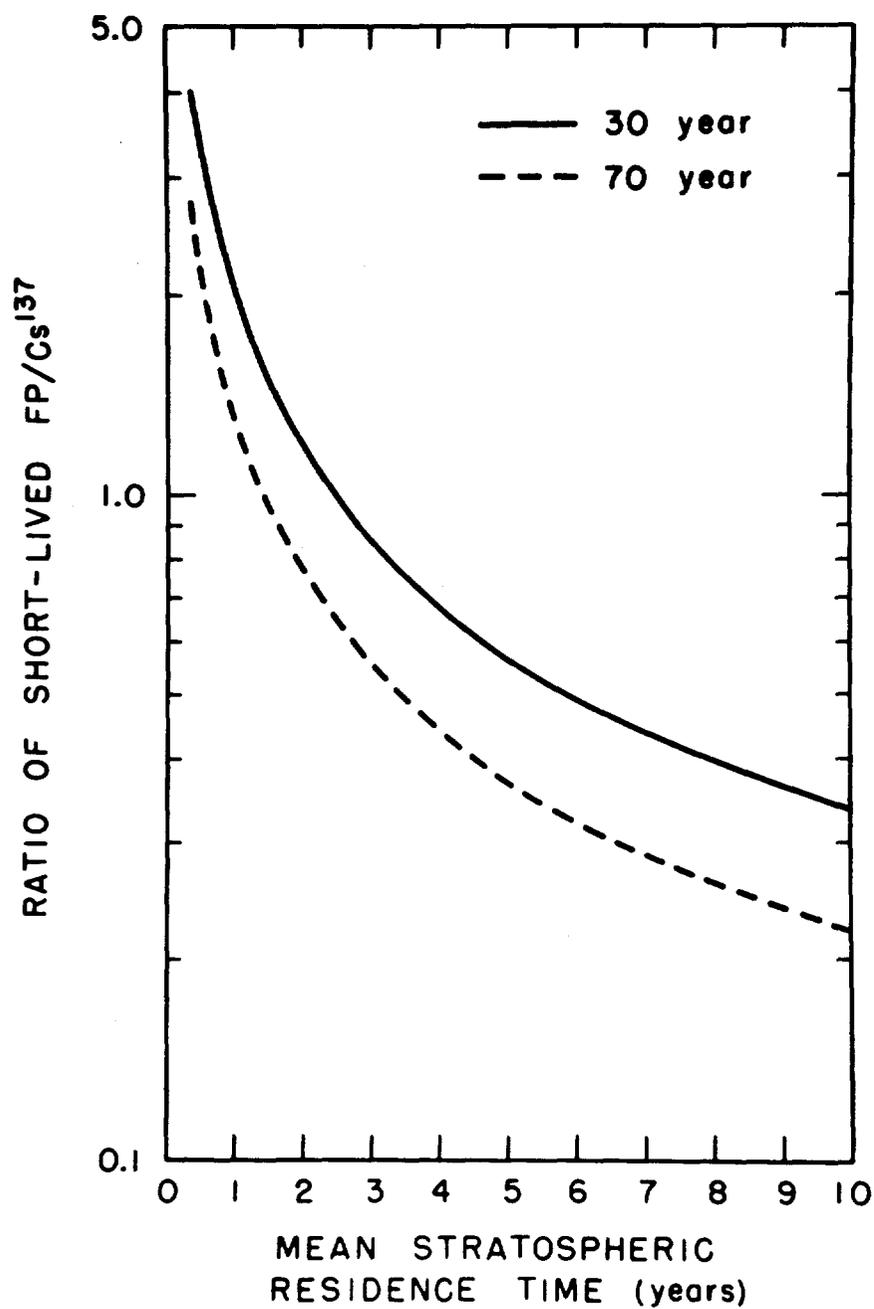


FIGURE 2.—Ratio of dose from short-lived fission products to that from  $\text{Cs}^{137}$  as a function of mean stratospheric residence time.

factor complicates derivation and interpretation of exposure values. Any specific set of values does not necessarily represent actual risk to the present population, because the population is composed of all ages and is continuously changing in relation to the selected time interval.

Concentration of  $\text{Sr}^{90}$  in the skeletal calcium is also dependent on its concentration in the calcium of the diet. Comar (19) has estimated that the concentration in skeletal calcium laid down in the first year of life is about one-half that in the diet. The average  $\text{Sr}^{90}$  concentration in bone calcium laid down after the first year or so of life is only 0.25 of that in the calcium of the diet. The  $\text{Sr}^{90}$  concentration in dietary calcium is dependent on its absorption by the leaves of plants (and, therefore, on fallout rate) and on root uptake from the soil (dependent on integral surface deposition level). The most important factor in  $\text{Sr}^{90}$  dose evaluation established since the 1959 hearings is the quantitative dependence of dietary  $\text{Sr}^{90}$  concentration on fallout rate and integral surface deposition level. The concentration of  $\text{Sr}^{90}$  in pc/g of dietary calcium ( $Q_d$ ) is given by the expression

$$Q_d = 0.6A + 0.15B,$$

in which  $A$  is the annual rate of  $\text{Sr}^{90}$  deposition in millicuries per square mile per year, and  $B$  is the cumulated deposition in millicuries per square mile.

Introduction of this refinement into exposure calculations is largely responsible for the fact that the present estimates of population exposure dose from  $\text{Sr}^{90}$  are no greater than the estimates given at the 1959 hearings, even though an additional 25 megatons of fission was added to the environment during the U.S.S.R. 1961 tests.

Another observation since the 1959 hearings which tends to mitigate average  $\text{Sr}^{90}$  population exposure estimates is worthy of mention. It now appears that the accumulated  $\text{Sr}^{90}$  soil deposit may be undergoing leaching and/or weathering, decreasing its availability to plant roots at a rate of about 5 percent per year. This observation is highly significant in that it means that the  $B$  term in the previous expression for dietary  $\text{Sr}^{90}$  is decreasing at a rate of 7.5 percent per year instead of 2.5 percent per year from radioactive decay alone. In other words, the surface deposition component of  $\text{Sr}^{90}$  dose is decreasing with a half time of about 9 years instead of 28. However, because this factor is not sufficiently established quantitatively, it will not be introduced into the present exposure dose estimations.

#### *Cesium 137*

Cesium 137 has a long radiological half-life (28 years), providing a long integration time in the soil, it emits both beta and gamma rays, and creates both a potential external and an internal hazard, both somatically and genetically.

*Internally deposited cesium.*—Cesium is chemically very similar to potassium, a required constituent in plants and animals. Cesium 137, therefore, tends to follow potassium ecologically and metabolically as  $\text{Sr}^{90}$  follows calcium. In the body,  $\text{Cs}^{137}$  tends to deposit in muscle where it has a retention half time of about 140 days, very short compared to that of  $\text{Sr}^{90}$ . This short biological turnover time results in rather rapid establishment of equilibrium between body  $\text{Cs}^{137}$  and  $\text{Cs}^{137}$  in the diet with no significant dependence on age. Since  $\text{Cs}^{137}$  emits gamma rays and the gonads are surrounded by muscle, it creates a potential genetic hazard. Penetration of bone by gamma rays and deposition of small amounts of  $\text{Cs}^{137}$  in bone result also in a potential somatic hazard to the bone and bone marrow.

Since the 1959 hearings, data from an extensive and intensive 6-year study of  $\text{Cs}^{137}$  levels in the U.S. diet and in the population have been summarized (7). Two significant conclusions were drawn from these data: (a) The  $\text{Cs}^{137}$  levels in the U.S. diet and in the population are predominantly dependent on fallout rate and consequently on the rate of weapons testing and not on the integral surface deposition level, and (b) the population average genetic, bone, and bone marrow exposure doses from weapon tests through 1961 are a factor of 2 to 3 lower than predicted at the 1959 hearings, even though the U.S.S.R. has since injected an estimated 25 megatons of fission into the environment.

*External cesium 137 deposition.*—Because of its gamma ray emission,  $\text{Cs}^{137}$  deposited in the environment produces external exposure of the gonads, bone, and bone marrow. Such exposure is dependent on the integral surface deposition level and is calculated from the infinite plane dose at 3 feet above the surface, mitigated by a variety of ill-defined factors, including surface removal (leaching, weathering, or runoff), shielding (by terrain, buildings, and portions of the body

itself), and a 2.5 percent per year radiological decay rate. The same factors also enter into the estimation of external gamma exposure from fallout of short-lived fission products. Assignment of numerical values to the above modifying factors can be done only on the basis of very broad and highly uncertain assumptions. Since the last hearings, however, there is considerably more agreement as to the assumed values. Some authorities now accept the following factors: Terrain shielding, 0.8; structural shielding, 0.5; body absorption, 0.7; and loss by weathering, 0.7; making an overall mitigating factor of  $\sim 0.2$  when converting plane dose to population exposure dose. Gustafson (6) has estimated that the effective external air dose from deposited  $\text{Cs}^{137}$  in 0.03 milliroentgens per year per milliecurie per square mile. This is the infinite plane dose, corrected for weathering and terrain but not for body absorption and shielding by buildings. His values both for  $\text{Cs}^{137}$  and short-lived fission products, multiplied by an additional factor of 0.35 ( $0.7 \times 0.5$ ) to give population exposure dose, are used in the present report.

#### *External short-lived fission products*

Surface deposition of relatively short-lived gamma-emitting fission products constitutes another component of population exposure from fallout. A list of the principal isotopes with their respective radiological half-lives is given in table 1. Because these isotopes emit penetrating gamma rays, they produce wholebody exposure and constitute both a potential genetic and a somatic hazard. Present knowledge of this particular component of fallout exposure is considerably greater than during the 1959 hearings, largely through the efforts of Gustafson, Martell, Machta, and others. Estimation of population exposure from short-lived fission products is essentially the same as for external  $\text{Cs}^{137}$ . All of the assumed mitigating factors (leaching, weathering, shielding, etc.) apply. One additional factor is highly important. Because of the relatively short half-lives of the principal isotopes, the population exposure dose is critically dependent on the time it takes the nuclear debris to travel from the site of detonation to the point of deposition. For this reason, the exposure dose varies widely depending on whether injection is into the low polar stratosphere, the low equatorial stratosphere, or at high altitude. Quantitative treatment of the differences produced by these different methods of injection is given in Gustafson's most recent report (6), which is being inserted into the record of the present hearings.

TABLE 1.—Significant short-lived gamma-emitting isotopes in fallout

Isotope	Half-life (days)	Isotope	Half-life (days)
Zirconium 95	65	Cerium 141	33
Niobium 95	35	Cerium 144/praseodymium 144	285
Ruthenium 103	40	Barium 140/lanthanum 140	14
Ruthenium 106	369		

#### *Carbon 14*

Capture of escaping bomb neutrons in atmospheric nitrogen produces  $\text{C}^{14}$ , which emits weak beta rays and has a radiological half-life of 5,700 years. Carbon, however, is the basic element of all living matter, and the  $\text{C}^{14}$  is taken into the body through the biological cycle and equally deposited throughout, resulting in whole-body radiation and both a potential genetic and a somatic hazard. About  $2 \times 10^{26}$  atoms of  $\text{C}^{14}$  are produced per megaton of total weapon yield; however, about 95 percent of that produced becomes unavailable to the biosphere through diffusion into the ocean reservoir with a half-time rather uncertainly estimated as  $\sim 20$  years. Most of the population dose is delivered prior to establishment of equilibrium with the ocean reservoir and consequently to the first generation after a weapon test. The 5 percent remaining in biospheric equilibrium can, however, continue to contribute to the population exposure for a mean time of about 8,000 years. This has caused some concern over genetic consequences. The integrated genetic dose should, however, be compared with the average natural background dose integrated over the same period of time. In these considerations, only the integral dose prior to establishment of equilibrium is considered.

*Iodine 131*

Since the 1957 fallout hearings,  $I^{131}$  has become increasingly recognized as a rather significant component of population exposure from fallout. Lewis (20), in the 1959 hearings, called attention to the potential hazard to children of the  $I^{131}$  component of fallout exposure. Although  $I^{131}$  has a radiological half-life of only 8 days, it finds its way readily into milk and from milk into the human body, where it concentrates almost exclusively in the thyroid gland. Because of the short half-life, radiation exposure occurs only during tests and for short periods thereafter, and the concentration in the thyroid is critically dependent on the time it takes to travel from point of detonation to site of deposition. Rapid localization in the small thyroid gland ( $\sim 2$  grams in the infant to  $\sim 18$  grams in the adult), however, can result in rather high radiation doses. The fact that the infant with its very small thyroid consumes largely a milk diet makes exposure of the infant population a potential problem. Since the 1957 hearings, considerable data have been collected on the concentration of  $I^{131}$  in the thyroids of the population in relation to frequency and location of nuclear weapon detonations. The milk surveillance program of the Public Health Service has contributed materially to present knowledge of this component of population exposure. Their evaluation of the problem (8) is presented as a part of the program of the present hearings.

## POPULATION EXPOSURE FROM FALLOUT

Estimates of U.S. population 70-year exposures contributed by the various components of fallout from all tests prior to the moratorium (November 1958) and from the U.S.S.R. 1961 series are shown in table 2. These values were chosen from various references or derived from various concepts which, to the authors, seemed reasonable. No strong argument can be made that these estimates are more accurate than similar ones made by others. The following qualifying statements are necessary before trying to draw any general conclusions from the estimates: (a) The estimates are averages for that age group receiving the maximum 70-year integral exposure (usually the 0- to 2-year age group); (b) the averages apply generally to the U.S. population in the 30- to 60-inch rainfall region and perhaps generally to north temperate population belt; (c) estimates for the 1961 U.S.S.R. tests are based on the very uncertain assumptions that 25 megatons of fission were injected into the stratosphere and that it was deposited in exactly the same manner as their 1958 tests. This latter assumption is not being borne out by recent experimental observations (6). For this reason, estimates of the U.S.S.R. 1961 contribution to population exposure, especially with regard to external dose from short-lived fission products, may be too high.

TABLE 2.—Maximized contribution of the various components of fallout to the U.S. average 70-year population dose\*

Component	Due to all tests prior to moratorium (mrad)	Due to U.S.S.R. 1961 tests (mrad)	Total (mrad)
External (whole body):			
Short-lived fission products.....	1 57	1 42	99
Cesium 137.....	1 46	1 28	74
Internal (whole body):			
Cesium 137.....	2 11	2 6	17
Carbon 14.....	3 11	3 8	19
Skeletal deposition (structural bone):			
Strontium 90.....	4 250	4 200	450
Strontium 89.....	3 8	3 6	14
Iodine 131 (thyroid).....	200-400	140	340-540

<sup>1</sup> From data of Gustafson (6), using building shielding factor of 0.5 and body shielding factor of 0.7.

<sup>2</sup> From Anderson et al. (7).

<sup>3</sup> Estimated from factors proposed by Prediction Panel, these hearings.

<sup>4</sup> Authors' estimates, based on data of Kulp and Schulert (4) and fallout models of Machta (21).

<sup>5</sup> Values of Lewis (20).

<sup>6</sup> Public Health Service report (8), these hearings.

\*GENERAL NOTE.—In all calculations, the data of Dunning (3) were used for fission and fusion yields.

As brought out in past hearings, other qualifications and reservations, such as the uncertainties of extrapolating data far beyond the point of observation, lack of statistically established confidence limits, uncertainties in the use of general assumptions where specific data are lacking (e.g., choice of shielding and weathering factors), and the question of distribution of individual values about the mean, should be recognized also.

With these reservations in mind, the data in table 2 may be used to estimate the total population average 30-year genetic, 70-year bone and bone marrow doses, and the  $I^{131}$  thyroid exposure from all weapon tests through 1961. Table 3 presents such estimates in relation to natural background exposure. These data show that the presently estimated U.S. average 70-year bone and bone marrow doses from all tests through 1961 (including the recent U.S.S.R. series) are approximately the same as those estimated during the 1959 hearings for all tests through 1958. This discrepancy is readily explained. The 1959 predictions were based on the assumption that  $Sr^{90}$  in the diet at that time was totally dependent on the integral surface deposition level. This assumption led to overprediction of the 70-year doses by approximately a factor of 2. This overprediction is approximately equal to the predicted increase in dose as a result of the U.S.S.R. 1961 tests. The 30-year genetically significant dose from tests through 1958 was estimated during the 1959 hearings as 50 mrad.

TABLE 3.—Maximized significant tissue doses to U.S. population from all tests through 1961 in relation to natural background exposure

Source of exposure	70-year bone dose (millirads)	70-year bone marrow dose (millirads)	30-year gonad dose (millirads)	70-year thyroid dose (millirads)
Natural background.....	10,000	7,000	3,000	7,000
Weapon tests.....	<sup>1</sup> 673	<sup>2</sup> 381	<sup>3</sup> 175	<sup>4</sup> 649
Percent of background.....	6.7	5.4	5.8	9.3

<sup>1</sup> Sum of whole-body external, whole-body internal,  $Sr^{90}$  and  $Sr^{137}$  exposures (from table 2).

<sup>2</sup> Sum of external and internal whole-body exposures and  $1/2.7 \times Sr^{90}$  and  $Sr^{99}$  doses.

<sup>3</sup> Sum of short-lived fission product dose, internal  $Cs^{137}$  dose, and 30-year integrals of  $Ci^{14}$  and external  $Cs^{137}$  doses.

<sup>4</sup> Sum of  $I^{131}$ , external whole-body, and internal whole-body doses.

The present estimate from tests through 1961 is higher by a factor of about 3. As shown by the data in table 2, this large predicted increase is not due entirely to the U.S.S.R. 1961 tests. Predictions made at the 1959 hearings assumed most of the genetic dose would come from internal and external  $Cs^{137}$  and failed to give much weight to the contribution from short-lived fission products. Their prediction, therefore, was a factor of approximately 2 too low. That, plus the predicted U.S.S.R. 1961 contribution, accounts for the factor of 3 increase over the dose predicted in 1959.

One other observation to be made from the data in table 3 is the rather high average exposure to the thyroid. Although thyroid exposure was recognized as a significant potential hazard during the last hearings, it seems to be more significant now as a result of the rapid fallout rate of fission products injected into the lower polar stratosphere. It should be emphasized again, however, that the dose estimates given in table 3 are not age-weighted average exposures for the present U.S. population. They are maximum doses applicable to a hypothetical population that received the maximum possible dose from all components of fallout exposure from all tests. It is impossible, for example, for a child who would have had to be born in the spring of 1961 to receive the maximum 70-year  $Sr^{90}$  dose to also receive short-lived fission product and  $I^{131}$  exposure from tests prior to the 1958 moratorium.

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Dr. LANGHAM. The basic concepts of this problem have not changed since the previous hearings. All that can be added which is new are the results of the collection of additional data which allow us to define some of the parameters better and to make calculations that I think are considerably more accurate.

The second thing that has changed the picture since the previous hearing is the resumption of weapons tests both by the U.S.S.R. and the United States. I will not elaborate particularly on what these improvements in data are in the interest of trying to get us back on schedule, but rather I will refresh your memory to say that the radiation effects of worldwide fallout will be due to a number of components. These I am sure are familiar to most of you. The first, of course, is strontium 90—strontium 89—those substances which because of their chemical similarity to calcium deposit in bone produce skeletal irradiation exposure. The next component of worldwide fallout is

cesium 137, an isotope similar to natural body potassium. It concentrates in muscle and can therefore produce internal whole body irradiation. It also emits a gamma ray, therefore its accumulation on the ground will provide whole body external radiation.

Another component is that of the external radiation from the short-lived fission products excluding iodine in this case which constitutes a special topic. The short-lived isotopes you have all been familiar with are zirconium niobium, ruthenium, cerium, barium, and lanthanum. These are gamma emitters and produce whole body irradiation when deposited on the ground. Carbon 14 is another component of fallout, carbon being an element that is the basis of all living matter, naturally will accumulate in the body and deliver whole body irradiation.

We have also an internal emitter of special significance—iodine 131—a very short-lived isotope which has the peculiar property of concentrating almost entirely in a single organ of the body, that being the thyroid gland. These, then, are the components of radiation exposure from fallout. It is my job before this panel to estimate the population exposure from these various components as a result of weapons tests through 1961. The population exposures are usually estimated on the basis of the 70-year integral dose if we are dealing with such effects as leukemia, bone cancer, life shortening. They are usually integrated over 30 years if they are dealing with the genetic aspect of the radiation problem. There have been a number of competent predictions of the radiation exposures from these various constituents. One just having been released by the Federal Radiation Council. I can make no claims that my predictions are any more to be desired or any more accurate than predictions made by others. There is an element of uncertainty in the prediction regardless of the person who is making it.

Let us then look at the contribution in terms of weapons tests to date from each of these components, considering all weapons tests prior to the moratorium in one case, and the contribution that might be anticipated from the Russian tests in 1961, keeping in mind that such predictions for the Russian tests must be predicted on two rather tenuous assumptions:

One, that the Russians detonated the equivalent of 25 megatons of fission energy release, something that I know will be denied by the Russians.

The other assumption is that this material will fall out in essentially the same way as did the material which they injected in the fall of 1958. You have already heard Dr. Machta testify that this is not being the case. For that reason any prediction which is made with regard to the short-lived activities, especially, will probably be in error on the high side because it seems that the Russian debris is not coming down as fast or as concentrated as one would assume on the basis of their 1958 tests.

If we then consider these various parameters of fallout exposure, taking first the short-lived fission products, this being an estimate now, my own, based on Dr. Gustafson's work we would predict that 57 millirads (70-year integral dose) would have been received as a maximum to the population from the short-lived activities of all past weapons tests prior to the moratorium. The Russian tests, had they come down in the same pattern as anticipated, would be about 42, indicating that expected short-lived fission product exposure from the Rus-

sian debris will not quite equal the exposure received from all past weapons tests. Relative exposure from cesium 137, the external portion of it, is predicted as 46 millirads from all weapons tests prior to the 1958 moratorium, and 28 from the Russian debris. Internal whole body exposure from cesium and carbon 14, from all tests prior to 1958, would be about 22, while the total from these two sources as a result of the Russian tests would be about 15.

Radiation of the bone marrow from strontium 89 and strontium 90 has been the primary concern in every hearing that has preceded this one. Estimates of the bone marrow doses were made on the basis of Dr. Kulp's data on bone analyses using a 7090 computer program at Los Alamos. The estimates indicate that the average doses to those persons receiving the maximum would be about 250 millirads from strontium 90 and 8 from strontium 89 from all tests prior to the 1961 Russian tests.

The Russian test in 1961 might be expected to almost double these numbers making a total of about 460 rads from strontium 90 and strontium 89 from all weapons tests to date, excluding what is now being detonated near Christmas Island by the United States.

The iodine 131 thyroid dose—prior to the 1961 Russian test—to a large segment of the children living in the population at that particular time was estimated by Lewis as 200 to 400 millirads.

The present Public Health Service estimate of iodine 131 exposure from the U.S.S.R. tests is of the order of 140 millirads.

Let us take these separate numbers and add them up in the proper way to give exposure from all weapons tests to those critical organs or tissues which have been of principal concern. Let us compare that with the only benchmark worth comparing it with and that is natural background.

The 70-year accumulated bone dose from all weapons tests to date according to our calculations would be about 670 millirads. The 70-year dose to the bone marrow would be about 380 millirads. The 30-year genetic dose according to our calculations would be about 175.

The 70-year thyroid dose to children would be of the order of 650.

Now let us qualify these numbers to put them in perspective. First, the predicted 70-year bone dose is about 6.7 percent of natural background. The marrow dose is about 5.4 percent of natural background. The 30-year gonad exposure is about 5.8 percent of natural background. The thyroid dose to those children who had received the maximum would all have occurred within the first year or two and would be about 8 or 9 percent of what they would have received from a 70-year natural background exposure.

Secondly, it is necessary to keep in mind that the estimated doses are the maximum doses that will be averaged by the most susceptible population. In other words, they are the average doses to that particular segment of the population born at the right time to receive the maximum exposure to the particular tissues, neither does it mean that some person or persons might not receive considerably more or considerably less. The way the doses have been calculated they apply to a hypothetical population whose thyroid, bone marrow, and bone were born at different times. They were born at that time which would allow them to accumulate the maximum exposure. That is why we say it is a maximum average. You will find these numbers are

in some cases higher than those given by the Federal Radiation Council, though they are not very much higher.

If I made the same adjustments with regard to population weighting, I think we would find in most cases the numbers would be the midpoint of their spread or perhaps near their lower limit. Let us compare these numbers with the Federal Radiation Council numbers. I give 670 millirad as the 70-year bone dose. The Federal Radiation Council said 400 to 900. The bone marrow dose I gave was 380. They gave 150 to 350. If I had adjusted my data in the same way they did, or had applied it to a population that was born all at the same time, I would have come out with about 270 as compared with their 250 to 350.

The genetic dose is off perhaps more than the others. I had 175, they said 60 to 130. This could conceivably be due to the fact that Dr. Gustafson's fallout numbers gave a little higher value than that of the Federal Radiation Council for the contribution from weapon tests prior to 1959.

I would think the disagreement between 175 and 60 to 130 is not bad. Let us look at these numbers with regard to the numbers that have been predicted before this panel on past occasions.

I have served on both of those prediction panels, and I know the circumstances under which those predictions were made. We can say at the present time, despite the fact that the Russians have injected 25 megatons of fission into the stratosphere that the radiation exposures estimated at the present time are just about equal to what the panel predicted in 1959 if no more tests were conducted. This difference or this fact that the situation seems to have gotten no worse even though 25 additional megatons have been injected into the polar stratosphere can easily be explained on the basis of the understanding we now have, of the relative contribution of direct fallout—the rate factor—and the soil uptake factor—integral surface deposition—to the strontium burden.

In other words, our predictions have improved to such an extent that we now see we were predicting approximately a factor of 2 too high in 1959.

This shows, as is usually the case when one is predicting from a point of lack of knowledge, he is very apt to be conservative. We were being conservative. I think we are still being conservative because in these numbers which I have given you are a number of apparent factors, at least one, which I have not put in because I don't think it is sufficiently well established to include, and that is the possibility that strontium 90 is becoming unavailable in the soil at the rate of about 5 percent per year. This was mentioned by Dr. Comar. This is not in our present calculation. But if we hold another panel in a couple of years maybe that will be certain enough we will be able to insert it.

I may say jokingly, if we can keep our slide rules and our pencils working in the right direction, it may be able at that time to say the situation is no worse even though there have been more tests. I am saying that in a facetious manner. But the situation insofar as I can see is no worse at the present time than we were predicting it would be prior to the Russian test.

Now I cannot say anything about the present U.S. testing. It is pretty obvious that it is less potentially dangerous to test in the equa-

torial region than it is in the polar regions. If we knew how much fission would be detonated in the U.S. Christmas Island nuclear test series I think the prediction panel this afternoon could give you a reasonable number as to what the potential risk might be.

But since we do not know those numbers, there is no reason why we should be expected to predict the dose commitment. I would say that these estimates and those given by the Federal Radiation Council might possibly be accurate to a factor of 2. It does not concern me in the slightest that these numbers may be off by a factor of 2. I think we are dealing with something that is so relatively insignificant in the general scheme of things that a factor of 2 will make no difference. Besides, I wish we could introduce into the test philosophy something that has been effectively interjected into the philosophy regarding the peaceful uses of atomic energy.

Representative PRICE. Doctor, Mr. Ramey has a question to ask at this point.

Mr. RAMEY. He might finish.

Dr. LANGHAM. I am just about finished.

That interjection is the concept of potential risk versus the potential gain. I for one would say that if there is any remote hope that the further testing of nuclear weapons is contributing to the defense of this country then the risk we are dealing with is certainly worth taking. This is the only question that concerns me. That is, that in three congressional hearings we have predicted or tried to predict the risk involved. I am surprised to see that our predictions of that risk have held up reasonably well through these three hearings. The question in my mind is, Who is evaluating the potential gain? Is it absolutely necessary to the defense of this country that we continue to test weapons? If it is, then we have no choice but to test.

Thank you.

Mr. RAMEY. On your comment of being off by a factor of 2, doesn't concern you, would you mind elaborating on that a little bit. If a person is off by a factor of 2 on his bank account, say, or if he is writing a staff report and misses by a factor of 2 he is usually somewhat embarrassed about it.

Representative HOSMER. It depends on whether the bank account is a million dollars or a dollar.

Dr. LANGHAM. I was going to say if one was drawing a dollar a year and his salary was doubled he would not feel very concerned about his raise, would he?

Mr. RAMEY. I take it what you are saying is that these factors are so conservative on the extent of fallout and on the measures of the amount of risk if your figures were off by 100 percent you would still not have a level that would really cause damage or hurt the population, is that right?

Dr. LANGHAM. That is right. I would add one other thing.

I really believe if they are off, the odds again are going to be off on the conservative side. So I think in the first place we are apt to be over on the conservative side. In the second place, if we are off a factor of 2 insofar as the general health of the American people is concerned, I don't think it is a matter of concern, certainly compared to many other things that we accept in everyday living.

Representative PRICE. Mr. Holifield, do you have any questions?

Chairman HOLIFIELD. I think as usual you have made a very fine contribution, Dr. Langham. I think your emphasis on the figures we are dealing with cannot be overemphasized. We are dealing in millions of curies and millirad measurements which are so small in comparison to the amounts which are considered to be dangerous by the consensus of scientific opinion that this should bring some solace and some comfort to the people who have not been correctly informed and who are emotionally upset by these figures that are given. I think this is the importance of your testimony which is as I understand the consensus of scientific testimony in general on this subject.

As far as you know, there is no appreciable degree of scientific people that are in opposition to your conclusion that you presented today.

Dr. LANGHAM. There can be very little objection to the dose calculations, because it is rather amazing the uniformity one gets throughout the scientific community in the estimation of these doses. Just as I was pointing out the difference between the numbers I came up with and the Federal Radiation Council, these were completely independent of each other and they are in very acceptable limits of each other. The real controversy comes over arguing about the effect of this small dose, and this can be argued from the moralistic point of view, from the pacifistic point of view, it can be argued from so many points of view. Very frequently the pacifistic point of view have by far the most vocal spokesmen. The result is that the public is confused and the press is confused on this question of what effect it will have.

I remember a certain Nobel Prize winner who has been very prominent in this particular aspects of things with whom I debated on a panel once in which his key statement was, "I am a scientist, and as a scientist I feel as obligated to object to fallout if it harmed one single individual in the population as if it harmed a hundred thousand," to which my only comment is, "Yes, I am a scientist, too, and I feel obligated to protect the democratic principles of one person just as much as I do to protect the democratic rights of 180 or 190 million." It depends strictly on what one is setting as a sense of values. I happen to enjoy the right of appearing before a committee of my Government and saying exactly what I think, and to me this is worth a few strontium units in my milk.

Representative HOSMER. The line you ended your testimony with, in one sense did you mean that, about the people who are evaluating the dangers of testing, or the test dangers? The last line of your testimony.

Dr. LANGHAM. If you can remember the last line of my testimony you are better than I am.

Representative HOSMER. The fact that your worry was not so much about the dangers of fallout as it was the people who were evaluating other dangers.

Dr. LANGHAM. It is now established if there is no threshold to radiation damage then we must look upon it as a probability of risk. This being the case we must weigh the potential gain as against the potential risk. We can evaluate the risk and I think we can evaluate it perhaps to a factor of 2. Can we evaluate to a factor of 2 the importance of further weapons tests to the defense of this country?

Representative HOSMER. Were you complaining about the long extension of the moratorium on testing or what? Is that what you were implying?

Dr. LANGHAM. No. I would just like to know, are we gaining significantly by holding additional tests or is further weapons testing essential to the defense of this country? If it is, there is no question but what we should do it.

Representative HOSMER. I guess somebody evaluated it and found it was worth while.

Dr. LANGHAM. Undoubtedly they must have.

Chairman HOLIFIELD. I am sure that the President and his advisers looked into this matter very carefully. I was present at some of the conferences that took place. I have also been present in executive hearings where evaluations of the debris from the Russian tests were analyzed and the meaning was conveyed to the members of this committee which indicated in some instances a sophistication which did not exist in the 1958 test. The problem of defending our Nation, of course, is involved in the President's decision. The President has expressed himself more than once that he would like to see testing stopped, that he would walk the last mile to obtain a cessation of testing and establishment of a disarmament—a real disarmament in the world—but lacking the progress in these fields due to what many of us who have watched the negotiations believe to be the recalcitrance of the Russian Soviets and their absolute refusal to allow anything that approached a guaranteed inspection system, and in the face of the tests which indicate capability of improvement in military capability to attack this free constitutional government which we believe in, the President and his advisers have made this decision that it is necessary. It has not been made idly.

It has been made after a great many months of soul searching and the best scientific advice available. So I can assure you as one member of this committee that the resumption of tests was decided to be necessary. It was a reluctant and long-delayed decision. But it was made on the basis that the security of our Nation was involved in making that decision.

Dr. LANGHAM. This was not said in the way of criticism at all. It was said to imply that as far as I can see with the risk this small, and a potential importance so great, that the President had no alternative.

Representative PRICE. Dr. Langham, on page 4 of your complete statement, you state that animal experiments have proved unequivocally that enough strontium in the skeleton will prove bone cancer and other skeletal pathology. You also state that the amount to do this in man is not known. What is presently being done in this area to give us this information and how much longer will it be to complete this work.

Dr. LANGHAM. There are any number of animal experiments under way involving the tumorigenic properties of strontium 89 and 90 and radiations of other types. We may know eventually how much of this material it takes to produce a bone malignancy in a rat or mouse or other laboratory animal. We may never know how much it takes to

produce it in a human. We certainly hope we don't. All we can do is extrapolate from animal data to human data and on the basis of this draw some conclusion as to what might be an expected limit and then introduce a safety factor.

I would say that this information is coming out all the time. It is in the same state as the information on our fallout predictions. It gets better and better and perhaps in a few more years this number will be able to be pinned down or at least a value put on it that has a degree of confidence considerably greater than the present time. But we may never know how much it takes to produce bone pathology in a human specifically.

Mr. RAMEY. Would you elaborate a little more on the hazard of cesium? You have made a study of this.

Dr. LANGHAM. Yes. We spent 6 years studying the cesium problem, and it is our opinion now we were betting on the wrong isotope. It turned out to be not very spectacular. The levels of cesium in the population and in the diet is almost entirely dependent upon the rate process which means during periods of weapon tests cesium activity will be high. When weapon tests cease the activity will drop very fast, dropping with perhaps a half time of 10 months or comparable to the fallout rate.

Mr. RAMEY. Is that because it falls on the leaves of crops?

Dr. LANGHAM. Yes; it is getting into the plant only by the contamination of the foliage.

Representative PRICE. Thank you very much, Dr. Langham.

I understand that you will appear on the panel later this afternoon. We appreciate your fine paper today.

Dr. LANGHAM. Thank you.

Representative PRICE. The next witness will be Dr. James G. Terrill of the U.S. Public Health Service.

**STATEMENT OF JAMES G. TERRILL, JR.,<sup>1</sup> DEPUTY CHIEF, DIVISION OF RADIOLOGICAL HEALTH, PUBLIC HEALTH SERVICE, U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE, WASHINGTON, D.C.**

Mr. TERRILL. Thank you.

Representative PRICE. Your full statement will appear in the record. I understand you intend to summarize your statement.

<sup>1</sup> Mr. Terrill was graduated from the University of Cincinnati in 1937, with a degree in civil engineering. He studied public health engineering at the Massachusetts Institute of Technology Graduate School from 1938 to 1941. Since 1941 he has been active in the Public Health Service. He participated in the first Bikini tests. During the period 1948-51 he studied radiological defense engineering under the sponsorship of the Armed Forces special weapons projects at the U.S. Navy Postgraduate School and the University of California; and received a master of bioradiology degree from the University of California. He has participated in and directed the Public Health Service activities related to the Nevada and Pacific test operations during 1953-57.

Mr. Terrill is a member of the National Committee on Radiation Protection, the Nuclear Standards Board of the American Standards Association, and the Expert Advisory Panel on Radiation of the World Health Organization, and is a diplomate of the American Academy of Sanitary Engineers. He is the Department of Health, Education, and Welfare representative on the Working Group of the Federal Radiation Council and is, at present, Chairman. He is a member of the American Society of Civil Engineers and a member of the Program Area Committee on Radiological Health of the American Public Health Association.

Presently, he is Deputy Chief of the Division of Radiological Health of the Public Health Service.

Mr. Terrill lives at 9223 Quintana Dr., Burning Tree Estates, Bethesda, Md.

Mr. TERRILL. Yes, sir; I intend to summarize in about 10 minutes, a very few pages, the development of our radiation surveillance systems in the Public Health Service, and some of the arrangements we have with other agencies to supplement this.

The monitoring programs of the Public Health Service have been developed as part of a comprehensive effort to assess and reduce human exposure to radiation. The Department of Health, Education, and Welfare has the responsibility of serving as a focus in the Federal Government for radiation surveillance activities directed toward measurement of exposures received by the public.

The current surveillance systems utilize monitoring techniques which make optimal use of available manpower and equipment and are designed to yield radioactivity measurements that can be most readily interpreted in terms of the average exposure dose to individuals and population groups and the possible somatic and genetic effects of this exposure.

The current systems reflect the technical competence in radiation exposure assessment which has been built up within the national public health and scientific community in recent years; the desire of the public to have radiation data readily available; and the necessity of establishing screening systems to make the most effect use of available resources.

Data on radioactivity levels in various environmental media are collected through a system of intradepartmental monitoring programs conducted, to a great extent, in cooperation with State and local agencies. Liaison is maintained between the Public Health Service, the Food and Drug Administration, the Atomic Energy Commission, the Department of Agriculture, and the Department of Defense and their contractors, to assure the continuous interchange of surveillance information. September 8, 1961, soon after the resumption of Soviet weapons testing, the Department of Health, Education, and Welfare, and the Atomic Energy Commission held a meeting to coordinate surveillance activities. It was agreed that the Department of Health, Education, and Welfare would serve as the focus for surveillance and public information related to these activities. Specific arrangements for coordination were made at the policy, public information, and operational levels. Concurrently, arrangements were made for coordination with the Department of State, Department of Commerce (Weather Bureau), and the Department of Defense.

To carry out the Public Health Service responsibilities expeditiously, a Radiation Surveillance Center was established in the Division of Radiological Health early in September 1961 to facilitate the analysis and dissemination of surveillance information. The Center provides immediate assessment of significant changes and trends in environmental radioactivity levels so that changes in monitoring operations can be made and possible countermeasures could be developed or initiated, if required. These data are collated, analyzed, and compiled in the monthly publication, Radiological Health Data. This publication, which is made available to the scientific community in the United States and throughout the world, provides health agencies

and other organizations and individuals working directly with radiation, or in related fields of competency, with basic radiological health data which can be further analyzed and interpreted to meet specific program needs.

The assessment programs and the related research effort of the Public Health Service in radiation surveillance are described in detail in the later sections of this report. Each of the operational programs, while having a specific objective, is in turn related to other programs. These can be briefly summarized as follows:

The radiation surveillance network is the basic alerting system for determining the levels of operation of many other surveillance activities. The network measures gross beta radioactivity of particulates in air and precipitation; sampling is done by the State health departments throughout the United States. Within the Division of Radiological Health, data from this system are used in the general planning of sampling schedules and surveillance activities of other monitoring networks. In addition, the data are made available on a daily basis to other agencies of Government, including the Atomic Energy Commission, the Department of Defense, and the Weather Bureau for use in their respective programs.

This alerting system is particularly important since Soviet weapons testing has become a major factor in radiation exposure from fallout. The first reliable information available to health agencies relative to the possible magnitude of the Soviet fallout is provided by this system. The requirement for continuing operations is thus greater than it is when the U.S. testing programs are the basic source of radioactive fallout, and knowledge concerning the magnitude and duration of the testing program is thus available to the Public Health Service.

The pasteurized milk network measures radioactive iodine, strontium, cesium, and barium in milk sampled at 61 stations representing major metropolitan areas in the United States. In total, the samples collected reflect the milk consumption of about 60 million people. It is believed that radioactivity in milk is presently the best single indicator of the significant elements from fallout which can be quickly measured and translated into exposure data for comparison with the guidelines established by the Federal Radiation Council.

During the weapons testing moratorium, monthly samples were taken at each sampling station for analysis of gamma emitting isotopes—particularly iodine 131, and for radiochemical analysis of strontium 89 and strontium 90. Since weapons testing was resumed, weekly samples are collected when minimum fresh fallout is expected. When the gross beta activity in air or other indicators suggest that appreciable levels of iodine 131 can be expected, the sampling procedures may be stepped up to a semiweekly or a daily basis. The greater number of samples thereby obtained facilitates the comparison of average population exposure with Federal Radiation Council guidelines.

The institutional diet sampling program is being developed so that we can assess more accurately the daily intake of radionuclides by

placing emphasis on the fundamental relationship of radiation exposure of total intake rather than on a specific item in the diet, such as milk. Presently this system is in the developmental stage and includes 21 locations. Data on the dietary intake of radionuclides are, in turn, related to radioactivity levels reported in pasteurized milk.

Supportive programs: In addition to the radiation surveillance network, the pastuerized milk network, and the institutional diet sampling program, which are used initially to evaluate dietary intake, there are several supplemental programs within the Department of Health, Education, and Welfare which serve as a basis for study of the vectors—air, water, and foods—by which radioactive materials reach man. These programs are the Consumers Union study, which will be described to you by Mr. Michelson; the national air sampling network, which is operated by the Division of Air Pollution of the Public Health Service; the national water quality network, which is operated by the Division of Air Pollution of the Public Health Service; the national water quality network, which is operated by the Division of Water Supply and Pollution Control; and the drinking water analysis program, which is operated principally by the Division of Environmental Engineering and Food Protection. They carry out the field activities associated with these efforts with their staff and with the State and local health, air, water pollution, and waterworks authorities concerned.

The Consumers Union activity is financed by a direct contract with the Division of Radiological Health, but the other networks merely look to this Division for laboratory support.

An exception within the Department is the Food and Drug Administration activity which is carried out entirely by that agency.

In addition to measuring the levels of radioactivity in environmental media, an effort is also being made to determine, through research and biological surveillance, the levels of strontium 90 and other radionuclides in the human body. This particular activity is an extension of the work of Kulp and others which has become a Public Health Service activity through an understanding with the Atomic Energy Commission. Samples of human bones are being collected and will be correlated on the basis of age, sex, height, and data and place of death. These data should be very useful in developing standards for environmental radioactivity and in making projections of intake and exposure.

As surveillance data reveals significant amounts of iodine 131 in the environment, special studies have been and will be made to determine the levels of iodine activity in man for the purposes of assessing human exposure to this isotope and planning, and if necessary, initiating counter measures. This information will also be useful in developing environmental protection standards for radioactive iodine.

These operational activities are supported by three regional laboratories, a laboratory quality control system, and research and investigative programs which are described in more detail in the body of this

report. These include, for example, development of improved methods of sampling and more rapid methods for determination of strontium 90. Investigations are also being made of the factors contributing to the occurrence of high levels of radionuclides in market milk. It is hoped that the research leading to the establishment of indicator foods and the compilation of basic food consumption data will enable us to obtain more accurate estimates of the total daily intake of radioactive materials within the most important population groups.

Some of the more significant findings of these symptoms have been described by Dr. Chadwick, as indicated by the schedule. On the basis of past experience, these hearings generally, as well as your comments and questions on this presentation, will be valuable to us in planning future activities.

Representative PRICE. Thank you, Mr. Terrill, for your fine statement. We appreciate having it.

On the first page of your summary statement you state that liaison is maintained between the various pertinent Federal agencies to assure the continuous interchange of surveillance information. Will you tell the committee how this is organized and how communications are affected?

Mr. TERRILL. Sir, the basic system on which we are operating at the present time dates back to a meeting on September 6 shortly after the Soviet weapons testing began. It was agreed at the policy level between the Atomic Energy Commission and the Department that Mr. Dwight Ink, Assistant General Manager, would serve as the policy coordinator for AEC, and that Mr. Jones, Assistant Secretary for Health and Medical Affairs of our Department, would handle policy matters from that standpoint. Operationally, Dr. Woodruff, of AEC, and I were designated to maintain liaison. On the day-to-day basis our respective radiation surveillance centers are expected to keep each of us up to date as things come in.

Representative PRICE. You state that sampling is done by the State health departments. What technical staffing do these departments have and how well equipped is the instrumentation and machines?

Mr. TERRILL. With regard to these particular sampling programs, the States are given air samplers. They are also given standards that they can use to measure the radioactivity on the filter pads. We in turn check the readings from the filter pads and thus maintain uniformity throughout the country. Some of the States, I might say, are probably just as well equipped as we are to carry out all the measurements. Other States have very little in the way of equipment and personnel. We try to maintain a uniform system within the surveillance system regardless of the capability of the individual States.

With regard to the milk, it is simply a matter of State representatives picking up the samples from collecting stations which meet the basic criteria which have been established for the network. They may and in many cases make additional samplings but these are not shipped to our laboratories and analyzed.

Representative PRICE. Dr. Chadwick stated this morning, and you state in your paper, that milk is the best single indicator of significant elements from fallout and can be quickly measured. How soon after taking the milk sample can it be completely analyzed?

Mr. TERRILL. At the present time it takes about 6 weeks to 2 months depending upon the levels of strontium 90. The limiting factor in our laboratory system from a time standpoint is the method that we use to measure strontium 90 at the present time.

Representative PRICE. What legal authority, if any, does the Public Service have to stop the consumption of milk in the event that they find excessive amounts of radioactivity from fallout?

Mr. TERRILL. We have not come to that. We hope we don't get to that particular point in any of our activities. The way this undoubtedly would be done, if it should become necessary, is through advising the States. The action would have to be taken by the State health departments or the State agricultural departments which may have jurisdiction in some specific case. As far as interstate shipment of milk is concerned I believe, and I would be willing to stand corrected, that the Food and Drug Administration would have to act if this type of action became necessary.

Representative PRICE. You mention the institutional diet sampling program on pages 1-4 of your statement. Would you tell the committee how this will be carried out?

Mr. TERRILL. This, sir, is an attempt to get a direct measurement of the total intake in a representative group that might be affected by these radionuclides. Logistically we have the problem of either trying to measure all of the foods for radioactivity or trying to pick representative diets from a population group that might be most affected in a significant way. We have chosen as a developmental project to take our samples from institutions which are feeding teenage boys as being a representative way in which to do this. The analyses, again, of these food samples are made at our surveillance laboratories.

Representative PRICE. You talked about developing improved methods of sampling and a more rapid method for the determination of strontium 90. Is this type of work being done in collaboration with other Federal agencies?

Mr. TERRILL. Yes, sir.

Representative PRICE. Which agencies?

Mr. TERRILL. All of our work at the laboratory level without any particular effort on our part is a matter of collaboration between the AEC, Department of Defense, and others. I would say that the most active group in this field in other agencies at the present time is the Health and Safety Laboratory of AEC. But I am certain there are many other contractors in the atomic energy research program who are contributing instrumentation and ideas and that probably the Health and Safety Laboratory merely serves as a focus for their effort.

Representative PRICE. Mr. Terrill, if the committee asks you for the recent report of the National Advisory Committee on Radiation and referred to section 202 of the Atomic Energy Act which requires Federal agencies to keep the Joint Committee fully and currently informed, would the Public Health Service supply the report?

Mr. TERRILL. Of course I can't speak for the Public Health Service. The Advisory Committee was asked to consider the current levels of radioactivity that we were finding during the Soviet tests in the light of the Federal Radiation Council guidance and in the light of the legal and public responsibilities that the Public Health Service might have. They have developed such a report, and I understand that its issuance is under consideration within the administration.

Representative PRICE. The issuance to who? It has already been leaked.

Mr. TERRILL. It may have been leaked but I am not familiar with how this was done and I am not familiar precisely with the length of time it might take to have the report published. I understand that everything is not issued when it is leaked.

Representative PRICE. We attend many executive sessions on the other committees of Congress, not so much on this one, and I am sure that the leaks do not come from the committee. But by the time we get to our office we read the full account of the incident in the newspaper.

Representative HOSMER. Possibly the gentleman behind the witness could elucidate for us.

Representative PRICE. But that is neither here nor there. Does the report as far as you know give pertinent attention to the surveillance program and countermeasures?

Mr. TERRILL. I would say the three basic things that it is concerned with are surveillance, assessment and possible countermeasures and some of the consequences of countermeasures. These things are not exactly a one-way street. As Wright Langham pointed out, with regard to the weapons testing as a whole, it is not as simple as stopping U.S. weapon testing when you are considering the national interest and the lack of control over testing by other nations.

Representative PRICE. Mr. Ramey, do you have any question?

Mr. RAMEY. On page 11-5 of your statement you mention the St. Louis study. Are reports available on the first two phases of the study?

Mr. TERRILL. Reports on this study are available. If you wish us to supply you with those I am certain they can be supplied.

Representative PRICE. They should be supplied for the record.

Mr. TERRILL. Yes, sir.

(Reports of the St. Louis area study are on file with the Joint Committee.)

Mr. RAMEY. Have any significant findings come out of those reports?

Mr. TERRILL. I would prefer, sir, to supply a summary to the committee. I may just give some offhand remark that would not stand up on further reflection.

Representative PRICE. Do you want to make any comment on that St. Louis report?

Mr. TERRILL. I believe it would be in the best interests of the committee if I didn't confuse the issue but provided the report and a statement of the significant findings.

Representative PRICE. Thank you.

Mr. Terrill is on the Panel and I doubt he will have the information before the Panel, but before the hearings are concluded.

Mr. TERRILL. You can rely on it.

Representative PRICE. Thank you very much, Mr. Terrill. We appreciate having your fine statement and valuable contribution to the hearing.

Mr. TERRILL. Thank you all.

(Mr. Terrill's statement and supporting data follows:)