FEDERAL RADIATION COUNCIL GUIDELINES FOR RADIATION EXPOSURE OF THE POPULATION-AT-LARGE -- PROTECTION OR DISASTER?

by

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We wish to apprise you that, in our opinion, the most crucial pressing problem facing everyone concerned with any and all burgeoning atomic energy activities is to secure the earliest possible revision downward, by at least a factor of tenfold, of the allowable radiation dosage to the population from peaceful atomic energy activities. The Federal Radiation Council allowable dose of whole body ionizing radiation is 0.17 Rads per year. We shall present to you hard evidence that leads us to recommend that this be reduced now to 0.017 Rads or even less. And we shall present to you the estimated disastrous consequences to the health of the public if this recommendation receives less than immediate, serious attention.

The Federal Radiation Council Guidelines

There has been ample reason for skepticism concerning the FRC guides for many years.[1] In essence, this is the case because a valid scientific justification for the allowable dose of 0.17 Rads of total body exposure to ionizing radiation has never been presented. The general vague statement is usually repeated that the risk to the population so exposed is believed to be small compared with the benefits to be derived from the orderly development of atomic energy for peaceful purposes.

Dr. Brian MacMahon, Professor of Epidemiology at Harvard, writing as recently as early 1969, stated,

"While a great deal more is known now than was known 20 years ago, it must be admitted that we still do not have most of the data that would be required for an informed judgment on the maximum limits of exposure advisable for individuals or populations".[2]

This is vastly different from the bland reassurances of The Federal Radiation Council Guidelines. We find ourselves in general agreement with Professor MacMahon, except that we go further and feel the already-documented evidence amply justifies a drastic revision downwards -- and now.[3, 4]

There is an even more hazardous situation associated with the vagueness of the justification for FRC Guidelines. This hazard has become apparent to us through extensive contact with people in radiation surveillance work, in the atomic energy industry, and in atomic energy laboratories. Widely prevalent is the notion that the existing standards have a wide margin of safety built in. Many such individuals refuse to believe that any responsible body would ever set a guideline dosage into the Federal Statutes without a wide margin of safety.

How is it possible that our current Federal Radiation Council Guidelines may have falsely lulled us into complacency? Let us trace the evidence, and restrict our considerations to two major effects of radiation upon humans, namely, cancer and leukemia - in this generation - that is effects upon those humans actually receiving the radiation. Any conclusion we draw concerning the hazard of the current radiation guidelines can only be amplified and buttressed by consideration of the additional burden of human misery associated with genetic defects, fetal deaths, and neo-natal deaths.[3] The case against perpetuation of the existing FRC Guidelines is overwhelmingly strong just on the basis of the cancer-leukemia risk, without even considering the potentially much larger problem of effects upon future generations.

How Did the Complacency Arise?

First of all, there once existed a very great paucity of data concerning the dose versus effect relationship between radiation and cancer or leukemia induction in man. Steadily, however, during these past 20 years, parts of the story have come to light from a combination of several extremely important sources:

(a) Study of survivors of Hiroshima-Nagasaki by the Atomic Bomb Casualty Commission.

(b) Study of patients treated with radiation for non-malignant diseases earlier in life and then developing cancer or leukemia.

(c) Study of children who commonly received irradiation to the neck area in one unfortunate era of American Medicine.

(d) Study of the occurrence of lung cancer in uranium miners in the USA.

(e) Study of cancer and leukemia in children whose mothers had received irradiation (diagnostic) during the pregnancy.

As the early results started to come forth from the Atomic Bomb Casualty Commission, it was noted that leukemia might be appearing more frequently in those persons irradiated in Hiroshima and Nagasaki. Attention became centered upon leukemia as a sort of "special" response to ionizing radiation and not much thought was given to other forms of cancer. From the ABCC studies[5] and from wholly independent observations[2], it is now clear, and we believe no one disputes the estimate that, at least for total doses of 100 Rads or more, the leukemia risk may be expressed as follows:

1 to 2 cases of leukemia per 10^6 exposed persons, where each of them has received 1 Rad of total body exposure. This does not require 1 Rad per year; rather, we are talking about the above rate of disease occurrence with a total integrated exposure of 1 Rad. Furthermore, this incidence of 1 to 2 cases per 10^6 people per year persists for many years, once the latency period* is over, ultimately declining somewhat, at least for chronic leukemia[5].

An incidence rate of 1 or 2 cases per million people per year sounds like a small number, especially when this number is viewed in isolation. Indeed, many have hastened to add that spontaneously, without any man-made radiation, leukemia occurs with a frequency of 60 cases per million per year, which makes it a relatively rare disease. So, 1 or 2 cases per year sounds small by itself, and sounds even smaller viewed against a spontaneous rate of 60 per million persons per year. And, as a result, with the early atomic bomb survivor data only showing leukemia, a widespread complacency set in concerning long-term effects of ionizing radiation, a complacency extending to high circles.

For two very major reasons, this error in thinking has turned out to be a mistake of the first order of magnitude.

(1) Leukemia happens to show a shorter latency period than most other forms of cancer. Therefore, the reason it appeared early to be the only malignancy in the Hiroshima-Nagasaki survivors was simply that not enough time had elapsed for the other forms of cancer to manifest themselves.

(2) The proper way to look at the incidence rate of 1-2 per 10^6 persons per year from radiation and the 60 per 10^6 persons per year spontaneously is not in isolation from each other, but in relation to each other. Thus, viewed in this light, 1 Rad of ionizing radiation increases the leukemia incidence between 1.6 and 3.3% . Or, we can state that the doubling dose for leukemia (namely, that amount of radiation which will double the spontaneous rate) is between 30 and 60 Rads. (Doubling a spontaneous rate of 60 cases per million each year means producing an additional 60 cases per million per year).

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* It is a known fact, from many observations, that leukemia or cancer is not an immediate response to radiation. There is a period of years (different for different forms of cancer) before the clinical disease is manifest. This period is called the latency period.

What About Other Forms of Cancer?

It now becomes an issue of paramount importance to know whether other forms of cancer behave similarly in response to ionizing radiation. Are other forms of cancer describable by a fractional increase in occurrence rate per Rad, and if so, how do the fractions compare with those for leukemia? We need no longer speculate about such matters because hard, incontrovertible data are available for human cancers induced by radiation. These data represent facts, not opinion. Estimates are available for several forms of cancer from worldwide data, US data, and from the studies by the Atomic Bomb Casualty Commission of survivors of Hiroshima and Nagasaki. Let us consider a variety of forms of human cancers.

(a) Thyroid Cancer

The Japanese data, primarily based upon adults, show an approximate doubling dose of 100 Rads for development of thyroid cancer, or approximately a 1% increase in incidence rate of thyroid cancer in the population per Rad of exposure of the population.[5]

We can arrive at the risk for younger people in the USA from two items of data.

(a) Pochin gives the figure of 1 case of thyroid cancer per 10^6 persons per Rad.[6]

(b) Carroll et al reported that the spontaneous incidence rate for thyroid cancer is $\sim$ 5-10 cases per 10^6 persons per year in the age range of 10-20 years.[7]

Combining these two items of information, it is estimated that between 5 and 10 Rads is the doubling dose for thyroid cancer in young people in the US. This means a 10 to 20% increase in risk of thyroid cancer in the youthful population per year per Rad of exposure. Thus, considering the youthful group (USA) and the adults (Japan), the range is between 1% and 20% increase in thyroid cancer per year per Rad of exposure.

(b) Lung Cancer

Estimates are available from several sources for radiation-induction of lung cancer. The ABCC studies in Japan indicate an approximate doubling of lung cancer incidence rate for 100 Rads of exposure, or a 1% increase in risk of lung cancer in the population for an exposure of 1 Rad.[5] The experiences of the uranium miners in the USA are complicated by two factors: (a) the dosimetry is poorly known, and (b) many of the workers are still in the latency period.[8] What estimates have been made for the uranium miners suggest the doubling dose for lung cancer to be between 250 and 500 Rads. If the correction for latency is estimated as two-fold, the final estimate would be 125-250 Rads as the doubling dose.[8]

Miller has questioned the Japanese data because of non-specificity of the histology of the cancer cells.[9] On the other hand, the similarity of the ratio of lung cancer to leukemia in the Japanese as compared to the British patients studied by Court-Brown and Doll suggests the Japanese data to be quite reasonable.[10] As a compromise estimate, we shall average the Japanese and USA data, to obtain 175 Rads as the estimate for the doubling dose for lung cancer, or a 0.6% increase in the annual incidence rate of lung cancer in the population per Rad of exposure.

(c) Breast Cancer

Breast cancer has been found to be radiation-induced in the Japanese studies.[5] The estimated doubling dose is approximately 100 Rads for breast cancer, or, again, a 1% increase in incidence rate per year of breast cancer in the population per Rad of exposure.

(d) Other forms of cancer

From some important studies on humans receiving therapeutic radiation for the arthritis-like disorder known as rheumatoid spondylitis, Court-Brown and Doll[10] have studied the subsequent occurrence of many forms of cancer in organs heavily exposed, incidental to irradiation of the primary disease in the spine. We don't know that all the heavily exposed regions received equivalent doses, but it appears reasonable to estimate that the various heavily exposed regions were within a factor of 2 on either side of the median value for the group. If we use Court-Brown and Doll's value for bronchiogenic cancer of the lung as a reference value, (and for this form of cancer we have used 175 Rads above as an estimated doubling dose), we can then estimate the doubling dose for radiation for several additional cancers. Uncertainty of precise dose comparisons make these numbers uncertain by a factor of two or thereabouts either on the low or high side. We shall, therefore, not only show the estimated doubling doses for all these additional cancers, but also a range to take this dose uncertainty into consideration. Thus, we have for the following additional cancers:

Site of Cancer	Doubling Dose (Rads)		% Increase in Incidence Rate per Rad	
	Mean	Range	Mean	Range
Pharynx	40 Rads	(20-80)	2.5%	(1.2-5.0)
Stomach	230 Rads	(115-460)	0.4%	(0.2-0.8)
Pancreas	125 Rads	(60-250)	0.8%	(0.4-1.6)
Bone*	40 Rads	(20-80)	2.5%	(1.2-5.0)
Lymphatic plus other hematopoeitic organs	70 Rads	(35-140)	1.4%	(0.7-2.8)
Carcinomatosis of miscellaneous origin	60 Rads	(30-120)	1.7%	(0.9-3.4)

(* Bone may possibly have received higher irradiation dose than other sites. If this were true, the estimated doubling dose is too low for bone.)

Now we are in a position to summarize the radiation-induced cancers for all sites, utilizing all the data available.

Best Estimates of Doubling Dose of Radiation for Human Cancers and the Increase in Incidence Rate per Rad of Exposure

Organ Site	Doubling Dose	% Increase in Incidence Rate per Rad
Leukemia	30-60 Rads	1.6 - 3.3%
Thyroid Cancer		
(adults)	100 Rads	1%
(young persons)	(5-10 Rads)	(10-20%)
Lung Cancer	~ 175 Rads	0.6%
Breast Cancer	~ 100 Rads	1%
Stomach Cancer	~ 230 Rads	0.4%
Pancreas Cancer	~ 125 Rads	0.8%
Bone Cancer	~ 40 Rads	2.5%
Lymphatic + other Hematopoetic organs	~ 70 Rads	1.4%
Carcinomatosis of miscellaneous origin	~ 60 Rads	1.7%

For such an array of widely divergent organ systems, already including hard data for nearly all the major forms of human cancers, it is amazing indeed that there is such a small range for the estimated doubling dose. Correspondingly, there is a very small range in the estimated increase in incidence rate per Rad for these widely differing organ sites in which cancers arise.

The only number that is different, and that one indicates an even higher susceptibility to radiation-induction of cancer, is for thyroid cancer induction in youthful persons (under 20 years of age). As we shall see below, this is not at all surprising or inconsistent, for the data presented below suggest a very high sensitivity of embryos in-utero to irradiation, causing subsequent leukemia and cancer during early childhood.

Furthermore, in some of these studies, aside from leukemia, the persons at risk were most probably still in the latency period when studied, so that full expression of the disease has not yet been reached. This would mean than an even smaller radiation dose is required to double the incidence rate, or expressed otherwise, the percent increase in incidence rate per Rad of exposure is even higher than that tabulated above. We know, from extensive other data, that bone cancer and skin cancer have definitely been produced by radiation. With further observation and study, the ABCC data will provide firm estimates of the doubling dose for the induction of cancer by radiation at the few remaining other major organ sites. At present the only malignant disease reputedly not induced by radiation is chronic lymphatic leukemia. And even this may be in doubt, since malignant lymphoma, a highly related cancerous disorder, is radiation-induced, both from the data of Court-Brown and Doll[10] and from Japanese data.[11]

In Utero-Radiation and Subsequent Development of Childhood Leukemia and Cancer

Stewart and co-workers originally[12] and MacMahon[13 14] and Stewart and Kneale[15] recently have presented evidence that implicates in-utero radiation of embryos (carried out for diagnostic purposes in the mother) with the development of subsequent leukemia plus other cancers in the first ten years of life of the child. The general estimate of the amount of radiation delivered in such diagnostic procedures is 2 to 3 Rads to the developing fetus. From the Stewart and Kneale data, we have, for the following forms of cancer, the estimates of the increase in numbers of cancers for several organ sites:

Type of Cancer	Radiation Induced Increase				
Leukemia	50%	increase	over	spontaneous	incidence
Lymphosarcoma	50%	"	"	"	"
Cerebral Tumors	50%	"	"	"	"
Neuroblastoma	50%	"	"	"	"
Wilms' Tumor	60%	"	"	"	"
Other cancers	50%	"	"	"	"

From the MacMahon data, we have the following highly similar estimates:

Leukemia	50%	"	"	"	"
Central Nervous System Tumors	60%	"	"	"	"
Other cancers	40%	"	"	"	"

If we now take the central values from both the MacMahon evidence and the Stewart-Kneale evidence, we have as a best estimate, 50% increase in incidence rate for all forms of cancer plus leukemia, associated with diagnostic irradiation of the infant in-utero, and the numbers are closely similar for US practise and British practise. So, for 2-3 Rads to the infant in-utero, a 50% increase in incidence rate of various cancers leads to an estimate of 4 to 6 Rads as the doubling dose for childhood leukemia plus cancer due to diagnostic irradiation in-utero. Let us underestimate the risk, and use the higher number, 6 Rads, as the doubling dose for in-utero induction of subsequent leukemia plus other childhood cancers. This means a 17% increase in the incidence rate of such leukemias plus cancers per Rad of in-utero exposure of the infant.

It is not at all surprising that infants in-utero should appear most sensitive to irradiation, children next in sensitivity, and adults third (but by no means low). This is precisely the order in which these groups stand in terms of the fraction of their cells undergoing cell division at any time--and much evidence suggests these are the cells most susceptible to cancer induction.[16]

General Laws of Cancer Induction By Radiation

In view of the widely diverse forms of human cancers plus leukemias showing such striking similarity in their risk of radiation induction, it does not appear at all rash to propose some fundamental laws of cancer induction by radiation in humans:

Law I "All forms of cancer, in all probability, can be increased by ionizing radiation, and the correct way to describe the phenomenon is either in terms of the dose required to double the spontaneous incidence rate of each cancer or, alternatively, as the increase in incidence rate of such cancers per Rad of exposure".

Law II "All forms of cancer show closely similar doubling doses and closely similar increases in incidence rate per Rad".

Law III "Youthful subjects require less radiation to increase the incidence rate by a specified fraction than do adults".

Based upon these laws and the extensive data already in hand and described above, the following assignments appear reasonable for all forms of cancer.

For Adults	~100 Rads as the doubling dose ~ 1% increase in incidence rate per year per Rad of exposure
For Youthful Subjects (<20 years of age)	Between 5 and 100 Rads as the doubling dose Between 1 and 20% increase in incidence rate per year per Rad of exposure
For Infants in-Utero	~ 6 Rads as the doubling dose ~17% increase in incidence rate per year per Rad of exposure

For the radiation of infants in-utero, Stewart and Kneale[15] clearly stated the outlines of these general laws. For adults, Court-Brown and Doll[10] clearly stated the outlines of these general laws.

With all the additional data available plus the data of Stewart and Kneale, MacMahon, and Court-Brown and Doll, we consider the enunciation of these general fundamental laws as having a better experimental base than many laws of physics, chemistry, or biology had when first proposed. Furthermore, we would estimate that the absolute numbers, if anything, probably underestimate the risk. For purposes of setting radiation tolerance guidelines, one might even be advised to use lower doubling doses than those estimated above.

The Implications of these Laws for the Population Exposure Associated with Atoms-for-Peace Programs

The statutory allowable dose to the population-at-large in the USA is 0.17 Rads per year from peaceful uses of atomic energy in all forms. If everyone in the population were to receive 0.17 Rads per year from birth to age 30 years, the integrated exposure (above background) would be 5 Rads per person. If the risk for all forms of cancer plus leukemia is an increase of 1% in incidence rate per Rad, we have 5 x 1 = 5% increase in incidence rate for all forms of cancer plus leukemia per year.

For a population of 2×10^8 persons in the USA $\frac{1}{2}$ can roughly be estimated to be over 30 years of age. In this group, irradiated from birth, the latency period might, on the average, be expected to be over by ~35 years of age.

The spontaneous cancer incidence is ~$280/10^5$ persons per year.

5% x 280 = 14.0 Therefore, 14 additional cancer cases per 10^5 persons per year due to irradiation.

Thus, 14,000 additional cancer cases per year in the USA, considering only those over 30 years of age.

If we estimate that latency plus lower accumulated dosage provides a smaller number of additional cases in the under 30-year age group, it would by no means be an overestimate to add

2,000 additional cases for the under 30-year age group. (Especially is this true when we see the data above concerning the greater sensitivity of this group to radiation-induced cancer).

There should be added some contribution of additional cases each year to take into account the fact that 0.13 Rads will have been received by each infant in-utero. (0.17 Rads/year x 40/52 years). It is hard to know whether this in-utero radiation carries an increased cancer risk for the whole lifetime or not. The additional contribution for the in-utero radiation (at a period when the effectiveness per Rad is very high) could be between a few hundred and several thousand additional cancer cases per year. We shall not attempt to guess the additional contribution due to in-utero irradiation.

Therefore, 14,000 + 2,000 = 16,000 additional cancer plus leukemia cases per year in the USA if everyone received the Federal Radiation Council statutory allowable doses of radiation. This would, for the several reasons outlined, appear to be a minimum value. 16,000 cases is equivalent to the mortality rate from one recent high year of the Vietnam war! It would appear that this is rather a high price to consider as being compatible with the benefits to be derived from the orderly development of atomic energy.

And we must add to these estimates the comment that we have used only the hard data in hand based upon cancer and leukemia induced in humans by radiation. We have said nothing of the additional possible burden of loss of life and misery from genetic disorders in future generations, fetal deaths, and neo-natal deaths.[3] Furthermore, we have not used the vast array of experimental animal data which indicate that not only does cancer mortality increase from irradiation, but that many, if not all, causes of death increase -- and in about the same proportion as does cancer mortality.

What Must Be Done

In the absence of any direct evidence in man that factors will operate to reduce these estimated cases of cancer plus leukemia, it would appear that the only sensible thing to do right now is to reduce drastically the Federal Radiation Council dose allowable to the population-at-large - by at least a factor of 10. The new figure should be below 0.017 Rads for peaceful uses of atomic energy. We are well aware that this suggestion recommends that man-made radiation exposure be limited to a small fraction (0.1 or less) of natural background sources.

Are There Any Counter-Arguments?

A number of counter-arguments may be raised against this proposal by some advocates of the peaceful uses of the atom. Before demonstrating to you the lack of validity of every one of these arguments in turn, we must emphasize that this is not a proposal against peaceful uses of the atom. Rather, it is a proposal for the use of common sense discretion in atomic energy development, weighted always in favor of the health and welfare of the people of the USA.

Argument 1. "Atomic energy projects thus far have not delivered 0.17 Rads to everyone in the population"

That is perfectly true! But the nuclear power industry is only now getting going, and 0.17 Rads per year is on the Federal Statute Books as allowable. Additionally, Plowshare proposals and industrial uses of radiation sources will surely add some increment to the population dosage.

Argument 2. "We don't plan to deliver the allowable 0.17 Rads per year to everyone in the population-at-large from peaceful uses of atomic energy".

We should certainly hope not! But, if it be true that such doses are unnecessary in the peaceful development of atomic energy, and if it be true that we can develop atomic energy for electric power and other uses with a much lower delivery of radiation to humans, that is indeed excellent news. Surely there can be no objection to immediate codification of this welcome news into law so that no one can possibly be confused by a high allowable standard and the concomitant promise that we will stay well below that figure.

We have alluded previously to our experience indicating that misinformation concerning potential hazard is widespread, with numerous responsible people in atomic energy development laboring under the impression that the current standards have a wide margin of safety built in. Just recently an eminent authority in nuclear safety, Professor Merrill Eisenbud, expressed his opinion that, "The standards contain enormous built-in conservatism" and "that 50-100 millirads per year (1/3 to 1/2 FRC Guideline values) will produce no harm".[17] We would indeed be relieved of our concern if Professor Eisenbud would replace his opinion with some hard evidence to refute the facts presented here today.

Industry urgently needs a real standard that can be expected to hold up over time, since a later revision downward can lead to excruciatingly costly retrofits in a developed industrial application of nuclear energy. It is far better to lower the guidelines for radiation exposure now and do our engineering accordingly. We believe engineering talent can direct its effort to essentially absolute containment of radioactivity at every step in any useful atomic energy development.

If we are fortunate enough later to find that some unknown effect operates to protect against the hazards we have demonstrated here, it will be easy enough to raise the guidelines for radiation exposure then. In this way we can avoid irreversible injury to our environment and to a whole generation of humans while we find out the true facts.

Argument 3. "We live in 'a sea of radioactivity' and man has for time immemorial been exposed to ionizing radiation. Why worry about adding a little?"

This argument presumes that natural radiation does no harm! As we can demonstrate readily by elementary arithmetic, natural radiation, in all likelihood, does just about as much harm as we would expect from all the evidence we have laid before you.

Let us apply our factor of a 1% increase in cancer incidence rate per Rad. A reasonable value for average radiation due to natural causes is approximately 0.1 Rad per year. At 30 years of age, the average man has received 30 x 0.1 = 3.0 Rads of radiation from natural sources. (It is higher in some locations, and we shall consider that in a few moments).

Now 3 x 1 = 3, so we expect a 3% increase in the spontaneous cancer rate due to natural radiation. We doubt very, very much that many persons informed in this field would be prepared to argue that 3% of "spontaneous" cancer plus leukemia is not due to natural radiation. So, this argument concerning the sea of radioactivity falls of its own weight.

Argument 4. "But possibly there is a "threshold" dose of radiation below which no harm accrues to man. Aren't you, therefore, unduly pessimistic about our standards?"

There are two crucial answers to this question.

1. Before the work of Stewart, Kneale, and MacMahon all the data concerning cancer plus leukemia induction in man was for total doses of 100 Rads or more. But their data for irradiation of infants in-utero are for 2 or 3 Rads. And, even more importantly, their data indicate that each Rad may be even 10 times more effective in inducing cancer at these extremely low total doses than is each Rad at the high doses. So the threshold concept has suffered some rather severe reverses!

2. We and others are doing experiments on human cells actively to determine the effect per Rad at various total doses to see if threshold type effects ever exist for man. But to use a hope that such thresholds may exist in setting guidelines for the exposure of our population now would seem like absolute folly.

Argument 5. "But isn't it true that delivering radiation slowly over a period of years, as would be the case for peaceful applications of atomic energy, may be less harmful with respect to cancer induction than the same dose delivered rapidly?"

It is perfectly true that, for some biological effects, the ability of the body to repair damage from previous radiation makes the effect of slow, protracted radiation less than for the same dose delivered rapidly. No evidence exists for such an effect on cancer or leukemia induction by radiation in man. Furthermore, the uranium miners received their irradiation slowly over a period of years, and it appears that any protection this provides, if there is any, is not enough to appreciably alter any of our major conclusions.

Further, it may take 10 or 20 years to ascertain whether such protraction of radiation lessens cancer induction in man. This only militates in favor of reducing the allowable dosage standards rather than against reducing them. Why, during such an interval of 10-20 years, should we take the high risk, at the expense of the people of the USA, of producing extensive irreversible injury?

Argument 6. "But isn't it true that some children have received large dosages of radiation to their thyroid gland from radio-iodine from fallout, as in St. George, Utah, and have failed to show a high incidence of thyroid cancer?"

Let us look very closely at this issue. Tamplin has presented evidence, never refuted, that high levels of radio-iodine were indeed deposited in the St. George area during the Nevada tests above ground during 1952-55.[18] If children in that area consumed 1 liter of milk each day from cows grazing upon contaminated pastureland, he calculated that the radio-iodine dosage to their thyroid glands would have been approximately 120 Rads. Now there are several points to consider:

(a) There are some 2,000 children in St. George, Utah.

(b) When these children were examined, years after the possible exposure, some of the children in St. George were those who had moved there since the exposure, so the true number who might have been exposed is less than 2,000.

(c) Some of the children probably didn't drink 1 liter of milk per day.

(d) Some of the cows were not grazing on contaminated pastureland. They were eating uncontaminated stored feed.

But, for the sake of argument, let us assume all 2,000 children were in St. George, and did drink 1 liter per day of radio-iodine-contaminated milk, and did receive 120 Rads to their thyroid glands. How much cancer should have been expected?

Again, by simple arithmetic, we can use the mid-figure for increased incidence of thyroid cancer in children per Rad as 15% of the spontaneous rate. If the spontaneous rate is $\sim$ 10 cases per million per year, our expectation would be, for St. George

$$\left(\frac{2{,}000}{10^6}\right)\left(\frac{15}{100}\right)\left(10\right)\left(120\right) = 0.36 \text{ cases per year.}$$

Thus, every three years, 1 case of thyroid cancer would be expected. With this expectation, one could go 6 or 10 years and not see that one case. Further, the points mentioned above in (b) through (d) would have reduced even this small expectation! So the data from St. George, Utah don't prove at all that radio-iodine exposure doesn't produce cancer in children. The St. George Studies just prove if an inadequate study is done, an inadequate result is obtained.

Argument 7. "But isn't it true that living in Denver at high altitude exposes people to more cosmic radiation and that as a result their annual "natural" radiation dose is 1.5 to 2.0 times what it is at sea-level?"

The answer is, "Yes".

"Then why don't they have a higher cancer incidence than people at sea-level?"

This particular argument is brought out and burnished brightly at regular intervals.

The answer is that the excessive radiation due to cosmic rays probably produced precisely as much extra cancer in Denver as our calculations would indicate. Let us make those extremely simple calculations.

First, to compare Denver with a sea-level region, we would have to know that the medical reporting of disease categories were just as good both in Denver and the sea-level community.

Second, we would want to be sure that the people at risk in Denver had lived there all their lives, and the people at sea-level had lived there all their lives.

Third, we would want to be sure that all other factors, aside from radiation, were identical in Denver and the sea-level community.

We don't know all these points, but let us suppose we were satisfied on all three. Let us say, to exaggerate the case, that Denver residents get 0.2 Rads per year versus 0.1 Rads per year at sea-level. In 30 years, the average Denver resident would accumulate 6 Rads; the average sea-level resident would accumulate 3 Rads.

Using our increase in cancer incidence rate of 1% per Rad, we would estimate,

for Denver, a 6% increase in the cancer incidence rate;

for Sea-Level, a 3% increase in the cancer incidence rate.

So, if we set all other "spontaneous" causes of cancer at 100%, we would say, Denver residents should experience 100 + 6 = 106

Sea-Level residents should experience 100 + 3 = 103.

No expert in the field of Vital Statistics would be prepared to contest that Denver residents might be experiencing a 3% increase in cancer incidence rate due to cosmic radiation compared with otherwise equivalent people at sea-level.

Argument 8. "But aren't medical x-rays also capable of producing cancer along the lines of your argument?"

Absolutely! There is no justification whatever for non-essential x-rays in the course of medical practise. Every physician should acquaint himself with the facts described above and he should be convinced that the risk to his patient is greater by not having a particular x-ray taken than by having it taken. There is ample evidence of a concerted campaign within the medical profession to reduce the radiation exposure through diagnostic x-rays.

Argument 9. "Why do you criticize the guidelines for radiation exposure from the development of nuclear energy for electricity generation and say nothing of the hazard to the public from fossil-fuel electricity generating plants?"

Our answer is that we don't condone homicide with knives any more than homicide with guns.

We are in the field of atomic energy and we believe our knowledge enables us to speak to the issue of atomic energy. Therefore, we are presenting the evidence upon which a reasonable set of guidelines for radiation exposure from the peaceful atom can be based. We are not against nuclear generation of electricity. We have great confidence that our engineers have the talent to design reactors, reprocessing plants for spent nuclear fuel, transport systems, and waste storage facilities in such a manner that any release of radioactivity that might conceivably expose humans be kept so low as to preclude harm.

If fossil-fuel plants are causing disease in our population, this issue should be evaluated as soon as possible, and the fossil-fuel generating plants should be redesigned to remove effluents that are producing harm.

The general argument that making either nuclear plants or fossil-fuel plants safe will increase the cost of electricity does not impress us. Probably a dollar per month added to electricity cost per family would allow super-clean plants either of fossil-fuel or atomic variety. We submit it is much better to pay a little more for electricity than to die prematurely of cancer or leukemia.

Argument 10. "Experts have estimated that the dosage levels we are discussing in the existing Federal Radiation Council Guidelines might only shorten the average lifespan of humans some weeks or months. Isn't this worthwhile compared to the benefits?"

Absolutely not! First, even the average life-shortening may be greater than estimated. Let us assume, however, that the experts are right. The real answer is that this argument is totally immoral. Let us assume it is true that the average life expectancy is reduced only by several weeks. But how, we must ask, does this average reduction come about? It arises because many of the victims of premature cancer (those 16,000+ cases per year we referred to previously) lose 10, 20, 30, 40, or 50 years of their potential life span. While 16,000 cases is a large number, when it is diluted into the couple of hundred million people in the country, the resulting average reduction of life span due to radiation-induced cancer comes out only several weeks. This monstrous hoax should stop recurring.

Some Closing Remarks to Senators Muskie, Gravel, Randolph and their Committee Colleagues

We believe the real area where the problem of safeguarding the public health rests is in the primary biological standards of allowable radiation exposure. We do not think the current standards are at all acceptable.

With respect to calculating how much radiation the public might receive from nuclear power reactors, underground Plowshare events, we have, in our own laboratory, (supported by the Atomic Energy Commission) developed, under Dr. Tamplin's and Dr. Ng's guidance, a handbook, "Prediction of the Maximum Dosage to Man from the Fallout of Nuclear Devices", which enables anyone to calculate the radiation dose possible to any organ of the body from each and every radionuclide producible.[19] Wherever the data are inadequate, the worst possible case is assumed, in order to err always on the side of public protection. We constantly are updating this Handbook and are providing it to workers in the atomic energy field nationally and, where requested, worldwide. We welcome anyone concerned to visit our laboratory to learn, in detail, how to use this Handbook for their needs in public protection work in the radiation field. Thus, in the area of estimating possible dosage to humans, there exists, sponsored by the Atomic Energy Commission and required for its work, a highly advanced ability for anyone who wishes to avail himself of it. *

At the same time we, both members of an Atomic Energy Commission supported laboratory, should like to speak out on two issues of major importance.

First, any release of radioactivity associated with Plowshare or other programs to regions where humans or other members of our ecosystem can possibly be exposed should be documented by a truly independent agency and made immediately available to public sources for independent review. It may well turn out that attention to injury to other members of the ecosystem may be of greater long-range relevance to man than the immediate attention to man with extensive neglect of the ecosystem which supports his life.

The U. S. Public Health Service is, in principle, such an independent agency, but in practise the overly long delay in release of their measurements for public review is unacceptable. Furthermore, in the vicinity of the Nevada Test Site the AEC can exercise control over their reporting practises. This is also unacceptable. All measurements of radioactivity releases, radionuclide by radionuclide, to any unrestricted area must be made available for public scrutiny on an immediate and, therefore, timely basis. It is doubtful that public credibility can be maintained under existing circumstances.

It is difficult to believe such requirements can really in any way compromise the National Security. If measurements of radioactivity releases to unrestricted areas can possibly benefit an unfriendly power, it would indeed be a paradox that such measurements are possible for a hypothetical unfriendly power while being withheld where they may impinge upon the public health and safety of citizens of the USA.

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* Additionally, in the Supplementary Section of this testimony is an extensive recent bibliography of contributions from our Laboratory bearing directly upon documentation related to possible dose from underground nuclear explosives of the Plowshare Program. We believe this Committee will find that a large body of evidence is being developed already on this subject.

Second, we are speaking out in the strongest terms against the current guidelines for radiation exposure to the population-at-large. We are urging the Atomic Energy Commission itself to join us in seeking early downward revision of the Federal Radiation Council Guidelines.

When the AEC in 1963 requested our laboratory to undertake long range, systematic studies of the effects of Man-Made Radiation upon man, we told AEC Chairman Seaborg and (then) Commissioner Haworth that the results of our studies could very well suggest restrictions upon on-going or proposed AEC projects. We said further that we intended fully to disclose publicly any evidence developed, favorable or unfavorable to the AEC. Both commissioners assured us they were perfectly happy about this prospect -- all they wanted was for us to be sure to provide the truth.

Today, we have presented your Committee with much evidence indicating that current radiation exposure guidelines are indeed dangerous--much too high. It would indeed be naive for us to believe that our recommendations will be received with enthusiasm in all quarters. To the best of our ability we have endeavored to present the truth. Our calculations, our evidence may, upon critical examination by others, prove wrong in minor respects. We doubt they will prove wrong in any major respect. The sharp cutting edge of scientific criticism, with all the evidence placed squarely in the open forum, will demonstrate any fallacies, will show where additional evidence is needed, and where errors have been made.

We intend to continue to provide critical appraisal of questions of atomic energy safety in such a manner that the evidence can be examined by the scientific and public community at large. We do not subscribe to the concern that the public might, thereby, become unduly or prematurely alarmed. If a real controversy concerning the evidence exists, the public very well ought to be alarmed, and ought to demand that we pace our technical progress in such a way always that unanswered questions are decided in favor of the health and welfare of the public.

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Supplement to the testimony of

John W. Gofman and Arthur R. Tamplin

In the preceding text we indicated that in our own Laboratory, sponsored by the Atomic Energy Commission, an advanced ability for prediction of estimated dosage from nuclear events is available. Included here is a non-exhaustive, but recent, bibliography of direct documentation studies of the distribution of radioactivity from Plowshare nuclear explosions and related studies from our own Laboratory. We believe that this Committee will find useful in its deliberation an overview of the kinds of efforts already completed, or in progress, related to the subject of Committee inquiry.

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