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NUCLEAR ENERGY PROGRAMS AND THE PUBLIC HEALTH

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It is an unfortunate fact that a great conflict is now going on between those who wish to preserve an habitable earth and those who worry that this effort will interfere with "needed" technological progress. The current controversy over nuclear reactors for generation of electricity is a major case in point. As a result of our work on the issue of radiation hazards for humans[1-25], we have necessarily become involved in consideration of the nuclear electricity problem, and by now have a position in this matter. It is our purpose here to describe the basis for our position concerning nuclear reactors for electric power generation.

I. The Radiation Hazards Problem

We have expressed our criticism of the entire basis for setting so-called acceptable doses of radiation both for the population-at-large and for occupational workers in atomic energy industry. When standards are set, there are two possible bases:

(a) Some dose of radiation is known to be safe. In such a case, it would be proper to consider exposures below that level as harmless.

(b) No dose of radiation is known to be safe. In such a case, setting a "standard" for exposure means that a value judgment has been made. Such a value judgment means that a benefit versus risk calculation has been performed, and the determination has been made that the risks of exposure of persons to radiation are more than compensated by the benefits to be received by those exposed.

*This work was performed under the auspices of the U.S. Atomic Energy Commission.

We can state, without fear of contradiction, that no dose of radiation is known to be safe. Furthermore, it has become abundantly clear that no one in any aspect of atomic energy work has ever even approached a benefit versus risk calculation, other than to state that the benefits outweigh the risks. Recently we have estimated that the risks to man of ionizing radiation are much higher than had been thought by the public, by radiation experts, and by standard-setting bodies. But what has disturbed us most of all is that widespread throughout the nuclear energy community is the idea that exposure of humans to 170 millirads (the FRC guideline for allowable average exposure of the population) is without appreciable harm to humans. Congressman Holifield told us he had been assured this was the case. Jordan, an expert on atomic reactors, and recently appointed to the Atomic Safety and Licensing Board Panel, has even stated in May, 1970 that exposure to occupational guidelines (5000 millirads per year) is well below the point where harm may accrue to the individual concerned(26). Jordan's comments will come as a shock to every responsible biologist in the world, for it reflects a total ignorance of the hazards problem. Others have stated that 170 millirads has not been proved to cause harm.

Underlying all such assertions, no one of which is relevant and no one of which is scientifically documented, are one or more of the following:

(1) Some safe threshold level of radiation exists. This is not accepted by any standard-setting body.

(2) Slow delivery of radiation will protect against cancer or leukemia from radiation. No standard setting-body accepts this.

(3) No effect has been "observed" at 170 millirads of exposure of humans. There is a colossal difference between no effect and no effect observed, when indeed no appropriate experiment has even been done to try to observe effects at this dose.

Since none of these three assertions provide standard-setting bodies or the public with any reassurances concerning absence of hazard at 170 millirads per year, all responsible authorities agree that we must, for public health purposes, use the following conservative approaches to estimate the hazards of ionizing radiation to man.

(1) Cancer or leukemia risk per rad is available for moderate or high doses for human adults. The usual conservative approach (not the most conservative) uses a linear relationship between dose and effect at all doses. Incidentally there are extensive experimental animal and human data which are best fitted by this relationship down to very low doses.

(2) No difference in cancer-leukemia risk is assumed whether a particular dose is accumulated instantaneously or spread over time.

(3) Genetic effects are assumed to be linearly related to dose.

(4) Genetically-determined diseases are assumed to be maintained in the population through mutations, whatever be the cause of such mutations.

The Cancer-Leukemia Risk — Effects Upon This Generation

Evaluation of this risk has been approached in the worst possible fashion in the atomic energy field. No field of human toxicology has applied the archaic approach used by standard-setting bodies in the radiation field. For food additives we reject a substance, by law, for human use if cancer is demonstrated at any dose in any species. This is why a ban was recently placed upon cyclamates, a correct and courageous public health decision. For over 15-20 years it has

been known for several animal species that cancer of essentially every type can be induced by radiation. The evidence also suggested 5% or greater increase in incidence rate of a variety of cancers per rad of exposure, that is a 5% or greater increase in the spontaneous incidence rate of such cancers per rad of exposure. In a responsible society, understanding the simplest elements of public health practice, it would have been assumed that all human forms of cancer plus leukemia would be inducible by ionizing radiation and a conservative expectation of at least a 5% increase over spontaneous incidence rate per rad of accumulated exposure would have been utilized in hazards evaluation.

Had this been done, we would have proceeded, along responsible public health lines, as follows, in evaluating the hazard of FRC Guideline radiation.

At 30 years of age, an average person would accumulate $30 \times 0.17 \cong 5$ Rads of radiation. At earlier ages, a lesser dosage would be accumulated, but as we shall see below the sensitivity to cancer induction is grossly higher. At older ages, a higher dose would have been accumulated. We do not know that the carcinogenic effect of accumulated radiation lasts indefinitely. For chronic leukemia, the effect appears in Hiroshima Survivors to die off; for other leukemias and cancers the effect seems to persist over very many years. Thus, taking the accumulated radiation dose by 30 years is a reasonable approximation.

Now for 5 Rads, and 5% effect per rad, it would be estimated, from experimental animal data, that $5 \times 5 = 25\%$ increase in cancer (+leukemias) incidence would occur.

Spontaneous cancer incidence in USA $\cong$ 320,000 per year

25% of 320,000 = 80,000 extra cancers per year would have been expected for an average population exposure of 170 millirads per year. AEC Commissioner Theos Thompson has introduced the irrelevancy that nuclear reactors are not

currently giving an average dose of 170 millirads, and that hence the numbers quoted are wrong. His statements are irrelevant simply because we are not at this point discussing nuclear reactors or any other specific atomic energy program, present or future. We are discussing a Federal Regulation which allows an average exposure of 170 millirads to the US population. There should be no comfort whatever for the public in anyone's assertion that a particular nuclear program will deliver a small fraction of that allowed exposure. This issue is totally separate. The first step is to ascertain the hazard per rad of exposure. Indeed this is the only way we can ever get to a benefit versus risk calculation to decide which nuclear programs, if any, we as a society think are worthwhile.

Now, we have shown above that from evidence long available for experimental animals plus the minimal elements of sound public health principles, the cancer + leukemia risk alone (leaving out genetic and other effects) should have led to an expectancy of 80,000 extra cancers + leukemias annually from 170 millirad average exposure for the entire US population. And, based upon the principles stated, the expectancy would be proportionately higher or lower for doses above and below 170 millirads, respectively.

But radiation standard-setting bodies, undoubtedly with total sincerity and devotion, demonstrated and still demonstrate an appalling lack of understanding of the sound public health principles. Thus, instead of accepting the experimental animal data, the sanguine demand was made that, until human cases of cancer plus leukemia were proved directly to have been produced by radiation, they would refuse to consider human cancer or leukemia inducible by radiation. No more irresponsible position could conceivably be imagined. Yet these are the evident facts of what has occurred and still occurs today. One must contemplate how

rapidly the earth would become uninhabitable for humans and other species if this Neanderthal concept prevailed with respect to each potential environmental pollutant. For if the demand for human corpses is made we would have to resort to Nazi-type experimentation on humans or use the accidental approach of waiting for some human population samples to be inadvertently exposed before we can design any standards. The illogic of such an approach, to say nothing of the inhumanity, is self-evident. It is important that the reader not derive the impression that any individuals are being criticized or that any impugnment of motives of standard-setting bodies is even to be considered. The sound public health principles were simply not understood by them, and a change is imperative if society is to survive environmental ravage by pollutants.

In the case of radiation-induction of cancer and leukemia, we have, unfortunately, acquired data for human exposure from a variety of sources, so the experimental animal evidence can be supplemented by human data. The crucial point is we should not have waited for human data to set standards sound with respect to protection of the public health. We have human data from the following major sources:

(a) The irradiated survivors of Hiroshima-Nagasaki.

(b) The irradiated British Subjects treated for a form of spine arthritis by X-Rays.

(c) Children in the USA irradiated in infancy in the neck area.

(d) Tuberculous patients radiated by fluoroscopy in the course of treatment of tuberculosis.

(e) Infants irradiated in-utero incidental to diagnostic x-ray studies in the mother.

By now, most of the forms of human cancer plus leukemia have been proved to be radiation-inducible in one or another of these studies. In the most recent publication of Stewart and Kneale, a doubling of the future incidence of cancer plus leukemia was found for 1/3 of a rad delivered during the first 13 weeks of pregnancy. So, direct human data are available down to extremely low total doses. Furthermore, Stewart and Kneale's data indicate a linear fit is best for the cancer-leukemia risk versus dose in the region from 1/3 rad to a few rads, completely consistent with human and experimental animal data in higher dose ranges.

Even though a few of the rarer forms of human cancer have not yet been proved inducible by radiation, simply because of small sample statistics, no significant alteration in conclusions concerning humans would be made from the following generalizations derived from the data already available.

TABLE I

How Radiation Increases Occurrence Rate of Various Cancers and Leukemias (Adults)*

Type of Cancer	Percent Increase in Occurrence Rate for Each Accumulated Rad	Number of Rads of Radiation Required to Double Spontaneous Cancer Occurrence Rate
Leukemia	2.2%	45 rads
Thyroid	1.0%	100 "
Lung	1.4%	70 "
Breast	3.3%	30 "
Stomach	1.1%	90 "
Pancreas	1.7%	60 "
Bone	1.1%	90 "
(Lymphatic + other (blood-forming organs)	2.2%	45 "
Colon	1.1%	90 "
Miscellaneous cancers	2.2%	45 "

*Cancers vary as to the latent period between the receiving of radiation and the clinical observation of the cancer. Many of the forms of cancer shown in the table have long latency periods. As a result, the true increase in cancer

due to radiation will be even higher than shown in the table, for the full effect has not yet been seen in some of the human groups exposed to radiation. Therefore, we have concluded that the true average doubling dose for all forms of cancer produced by radiation will not be larger than 50 rads, and consequently for each rad of radiation there is not less than a 2% increase over the spontaneous occurrence rate for each form of cancer.

TABLE II

Generalizations Concerning Radiation Carcinogenesis

For Adults	50 rads to double the spontaneous cancer and leukemia incidence. 2% increase in incidence rate per rad of exposure.
For Children	Between 5 and 10 rads to double spontaneous incidence. 10 to 20% increase in incidence rate per rad of exposure.
For Infants in utero	Between 1/3 and 1-1/2 rads to double spontaneous incidence. 60 to 300% increase in incidence rate per rad of exposure.

So we have a 2% increase in spontaneous cancer incidence per rad in adults; 10-20% increase per rad for children. The estimate of ~5% increase per rad in experimental animals would not have misled us.

If we use the adult value of 2% per rad and the 30-year accumulation of 5 rads for average population exposure, we would estimate 5 X 2 = 10% increase over the spontaneous cancer + leukemia incidence rate. And 10% of 320,000 gives 32,000 extra cancer plus leukemia cases. This is the origin of our estimate of the consequences of average exposure at the FRC Guideline. It cannot be overstressed that statements concerning "We don't plan such exposure," are totally extraneous to the evaluation of risk of this allowable dose. We can only say average exposure at the Guideline should indeed shock anyone concerned about human health and welfare. And they should be tremendously disturbed by the existence of such a shocking codified Federal Guideline.

We can note that the use of the adult human data leads to 32,000 extra cancers + leukemias compared with 80,000 derived from experimental animal data. Since the human data do not credit exposure at earlier ages as more carcinogenic, which we know they are, the 32,000 figure is highly conservative, and should, in all probability, be an underestimate.

Genetic Consequences of Radiation - Effects on Future Generations

At any point in time it is a fundamental truth that our biological knowledge is primitive. Thus what we don't know should concern us far more than what we do know. The standards (FRC) for Guideline exposure of the population at large were set before 1960. Since then an explosion in our knowledge of genetic and chromosomal disease in humans has occurred. We now know that such major human diseases as coronary heart attacks, diabetes mellitus, rheumatoid arthritis, and schizophrenia are in part genetically determined, more than one gene being involved in these diseases in contrast to such rare genetic disorders as hemophilia, where one gene is involved[27]. Many geneticists and other medical authorities believe that further evidence will indicate all human disease to have a genetic component. Since coronary heart disease is so large a fraction of adult deaths, we can already effectively consider the bulk of human disease to be genetically determined.

For diseases that are genetically determined, the responsible approach of geneticists is to consider that such diseases are maintained in the population through mutations of genes. Further, it is considered by authorities that after some unknown number of generations, a fractional increase in mutation frequency will finally lead to the same fractional increase in the incidence rate of the corresponding disease. Thus, doubling of mutation rate for a

specific gene would double the ultimate incidence rate of a disease determined by such a mutant gene. It is even possible, for chromosomally-determined genetic disease, to get the full expression of disease in one generation.

Estimates vary as to how much radiation is required to double the mutation frequency for the average gene in humans. Responsible authorities have suggested the "doubling" dose to be between 10 and 100 rads. Let us explore the implications of this range of values.

At FRC Guideline exposure for the average person in the U.S., we have estimated above 5 rads accumulated by 30 years of age, which is usually considered the average time for reproduction.

If 10 rads is the doubling dose, then 5 rads corresponds to a 50% increase in mutation frequency. If 100 rads is the doubling dose, then 5 rads corresponds to a 5% increase in mutation frequency.

If we use the highly likely prospect that all human disease has a genetic component, we can state 5 rads by 30 years would lead ultimately to a 5% to 50% increase in overall death rates. Since 3,000,000 people would die annually in the USA (for a population of 3×10^8), this corresponds to between 150,000 and 1,500,000 extra deaths per year. These are fantastic numbers compared with the already very high number, 32,000 extra deaths per year, for cancer plus leukemia.

And we have only spoken of genetic diseases that lead to death. Additionally we must expect similar increases in socially and individual maiming diseases such as schizophrenia, a disease already proved to be a multigene disease. This additional toll can be enormous.

Lederberg has recently suggested $10 billion yearly as the genetic cost of population exposure averaging FRC Guideline radiation[28].

What Do We Do About Atomic Energy Programs

The known magnitude of the hazards of ionizing radiation at FRC Guideline to humans are grossly higher than had been estimated. The uncertainties concerning precisely how huge the genetic effect may be should concern us far more, since very reasonable estimates above suggest that FRC Guideline average exposure to the U.S. population can be a virtual prescription for human genocide.

All atomic energy programs, including nuclear electricity generation, have proceeded until now under the false illusion that FRC Guideline exposure corresponds to no harmful effect or to a very small effect. In view of the grave error involved in assessing hazard, prudence would suggest a moratorium on all such nuclear programs that can lead to human radiation. We must re-think the future of all these programs. Many may be needed by society. If they are, society at large must understand clearly the knowns and unknowns in the risk side of the equation before accepting the programs. Otherwise, blindly proceeding as we have been, with a possibly genocidal set of radiation standards, can prove to be the final, irreversible step taken by man.

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