ENVIRONMENTAL COALITION ON NUCLEAR POWER

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May 2, 1981

Dear Mr. Secretary:

Enclosed are my brief comments on the proposed rule changes in 10CFR51 and Appendix H

Yours sincerely

[signature]

L-4-1, H.51

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The accident at the Three Mile Island Nuclear Power Plant, which began on March 28, 1979, focused an unusual amount of attention on the workings of the Nuclear Regulatory Commission (NRC), among other things. Two separate review commissions were set up to investigate certain of the events which led up to that accident. Neither of the review commissions gave the NRC "high marks" for its performance before and during the accident, which has still not been terminated. One commission found

> With its present organization, staff, and attitudes, the NRC is unable to fulfill its responsibility for providing an acceptable level of safety for nuclear power plants.[1]

The second major commission observed

> In our opinion the Commission is incapable, in its present configuration, of managing a comprehensive national safety program for existing nuclear power plants and those scheduled to come on line in the next few years adequate to ensure the public health and safety.[2]

and

> However, the work done by the Special Inquiry Group over the past 7 months has led us to conclude that unless fundamental changes such as those outlined above are made in the way commercial nuclear reactors are built, operated, and regulated in this country, similar accidents-perhaps with the potentially serious consequences to public health and safety that were only narrowly averted at Three Mile Island--are likely to occur.[3]

Such findings and conclusions should cause the taxpayers of this nation, whose tax dollars the nuclear program is deeply dependent upon, to have serious concerns about the NRC, its staff, and their attitudes, absent prompt and readily observable changes. These changes have not materialized. In fact, the Chairman of the NRC's Special Inquiry Group was recently quoted as having observed that the NRC was "expediting the things that made us uncomfortable."[4] It is this same NRC Staff which has proposed a narrative and certain rule changes to 10 CFR 51.

The narrative has certain pre-established criteria which must be met as determined by, among other things, the applicable judicial decisions. The purpose of the narrative is both to satisfy the National Environmental Policy Act of 1969, as amended (NEPA), and to preclude any open discussion of fuel cycle impacts in future reactor licensing proceedings. NEPA has been interpreted by the courts to be "an environmental full disclosure law"[5]. A different court required that "the test of

compliance with 102 of NEPA , then, is one of good faith objectivity, rather than subjective impartiality"[6]. Additionally, the time period for which "environmental effects" are "to be considered are those...for the full detoxification period."[7] This is by no means an exhaustive list, but it shows that reviewing courts have set high standards for agencies for compliance with NEPA.

The NRC Staff is fully as objective in its S-3 narrative as the Roman Catholic Church was, centuries ago, in its persecution of Gallileo. If these proposed rule-changes become finalized as proposed, the NRC will dogmatize into "regulations" a vast quantity of scientific and technical information, frequently incomplete and inadequate; the NRC will have succeeded where the Church failed. The proposed regulations would define as "true" misleading, deceptive, and erroneous information for the rubber stamp of the NRC's own Inquisition--its licensing and appeal boards. The resulting "true" rules would be too cumbersome and difficult to correct, as will ultimately be necessary. One would hope that only the best, most factual information, with stated uncertainties would appear in the narrative; such is not the case. In fact, in many instances, values seem to be arbitrarily chosen for the purpose of showing a lower-than-actual environmental impact. Specific examples of errors and/or misconceptions are detailed below.

1. The values given for the ore mined and the U_3O_8 concentration on page 15160(F.R.) of the narrative may have been accurate 20 years ago, but are not accurate now. Worse yet, as time goes by they will be less accurate, since ore grades are dropping.

2. All assumptions concerning any form of disposal of radioactive wastes (F.R., p. 15161-2) in the future must be regarded as speculative. There can be no assurance that there will be enough available petroleum to do the job (see Science, Vol. 211, Feb. 6, 1981, p. 576-79). Furthermore, the inability of governments to control or eliminate monetary inflation should cause a serious questioning of the ability of future peoples to pay for the disposal of today's wastes. This is especially important for radioactive wastes, where for both mill tailings and high-level wastes, some form of heavy construction or earth moving will be required, and the costs of these activities have historically escalated faster than inflation. All expectations and promises of what can be done with these wastes must be ignored. All that counts is what <u>is</u> done with them. In this regard the narrative is totally inadequate and misleading. It should also be noted here that while regulations have been promulated by the NRC

to require a low-level of mill tailings pile reclamation, these regulations were challenged in court the very day they were finalized.[8] Furthermore, none of the referenced discussions of radwaste disposal meet either the "good faith objectivity" or the "full toxic period" tests set by reviewing courts referred to above. Nowhere does the narrative discuss the relationship between the uncertainties about long-term repository or tailings pile cover behavior and the cost-benefit analysis for the facility. Nowhere does the narrative discuss whether or not the narrative meets the judicial requirements, even though one of the decisions mentioned here is also mentioned in the narrative (ref. 7, F.R., p. 15154).

3. The narrative assumes that reactor fuel is irradiated to 33,000 MWD/MT (p. 15164). While this may be occasionally true, it does not appear to be a normal value in practice. The narrative does not discuss the relationship between fuel burn-up and uranium needs for the plant. This amplifies the problems noted above in #1.

4. The refusal of the NRC staff to openly discuss in the narrative the long term effects of the nuclear fuel cycle is nothing more than a ruse to conceal those effects. Of course, such estimates, if were made, the associated assumptions would have to be stated, but so what? It can hardly be said that here the narrative meets any of the judicial criteria mentioned above. To hide behind a statement like "it is impossible to estimate with precision the complete EDC for very long-lived nuclides" (p. 15166) is hypocritical in the extreme. The Staff has frequently used, and still uses, imprecise models to generate information favorable to its precious programs. The Uranium Milling Draft EIS is one such example of the flagrant use of silly models designed to support the preconceived conclusions.

5. Footnote c, p. 15166 of the narrative contains another example of the attitude problem of the staff. Here the staff admits to the use yet again of the highly flawed risk estimators invented for WASH-1400. Contrary to the stated "more recent radiobiological data," the authors of WASH-1400 took conscious efforts to <u>underestimate</u> the effects of ionizing radiation on people. For example, in that report, the two risk estimators (relative and absolute) used in BEIR I were taken, and the one which produced the highest death toll was arbitrarily dropped. The lower one was then renamed as the "upper bound" risk estimator, a misstatement of fact. Then, out of areas where no

human data exists, the staff adopted the misinterpretations of poorly conducted experiments using homogeneous strains of animals. These misinterpretations were used because they made it look like low dose and lo dose-rate irradiations caused fewer cancers than an acute exposure. From these results, which were not evaluated for statistical relevance and which were not shown not to be artifacts of poorly conceived experiments, Dose Rate Effectiveness Factors were invented for the sole purpose of making reactor accidents look less harmful. This became the "Middle" range of risk estimates. The "lower bound" was nothing but a resurrection of the long-discredited "threshhold theory" of injury, a theory which never has had a theoretical or a genuine experimental basis. All of the risk estimators from WASH-1400 should be dropped from the narrative for the sake of scientific honesty.

6. The risk of "genetic effects" from radiation are similarly grossly understated (p. 15167). The narrative ignores the well known fact that the overwhelming most frequent mutations are "mild", in that they do not directly cause death. Yet they do cause misery and ill health. Why does not the narrative mention this commitment to an increased level of ill-health?

7. The conclusions concerning the radiation effects of the nuclear fuel cycle on P. 15167 represent an extreme case of over "Rasmussenizing". A large number of mathematical manipulations are presented and discussed. Yet, as in WASH-1400, there are no confidence limits stated. They have been stripped away at every stage, never to be properly used. Furthermore, the use of adulterated risk estimators (above) only adds to the problem. But worse yet, such risk estimators do not reflect the inherent bases of uncertainties in the original data, and in each subsequent mathematical manipulation.

8. The narrative ignores completely the entire issue of human variability. Outside the field of program oriented research that has characterized radiation research, it is well known that humans are virtually infinitely variable. Organs have varying sizes, locations, functions, orientations, and even

numbers.[9] The ICRP has created what it calls a "standard man", yet that organization does not appear to have the integrity to reveal to what extent of the population their "man" is wholly applicable. Only among the program-support radiation researchers does human variability remain largely unknown.

9. I have attached a copy of a monograph I recently received. I find it quite troubling, because if the author is correct in his findings, the NRC has again grossly underestimated radiation effects. I have endeavored to check the references in this document, but the critical reference, to the Russian journal Radiobiology (trans.), is unavailable in Pennsylvania. I would hope that the staff would undertake a truly objective review of this problem, rather than its normal criticism-for-the-purpose-of-dismissal.

I would also hope that these comments would get an objective review by the Staff.

Yours sincerely,

Chauncey Kepford

Chauncey Kepford

References

1. "Report of the President's Commission on The Accident At Three Mile Island" Oct., 1979, p. 56.

2. "Three Mile Island: A Report to the Commissioners and the Public." Mitchell Rogovin, Director, March, 1980, p. 89.

3. Ref. 2, p. 90

4. "Three Mile Island, Part II" the New Yorker Magazine, April 13, 1981, p. 109

5. E.D.F. v. Corps of Engineers, 325 F. Supp. 749 (1971) 759.

6. E.D.F. v. Corps of Engineers, 470 F.2d 289, 296 (8th Cir., 1972)

7. NRDC v. Vt. Yankee 547 F.2d, n. 12 (D.C. Cir., 1976).

8. Petition to Review, Kerr-McGee Corp. v. NRC, Docket No. 80-2043, 10th Cir., filed Oct. 3, 1980.

9. "Biochemical Individuality" Roger Williams. John Wiley and Son, Pub., 1956.

The Danger to Human Life from the

Emissions of Carbon-14

from the

Light Water Reactor Fuel Cycle

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Prior to 1975, neither the nuclear industry or the United States government realized that the levels of carbon-14 leaking from the nuclear fuel cycle were endangering the public. For almost two decades this isotope was released under the assumption it was harmless relative to the far greater amounts produced naturally in the upper regions of the atmosphere or by the testing of nuclear weapons within the atmosphere. Though both the latter two sources were known to result in the mutation of large numbers of human beings[1], and inspite of the fact that the Joint Committee on Atomic Energy had been warned about the inherent danger of carbon-14 emissions as far back as 1957[2], it wasn't until the USEPA published an announcement of the "discovery" of the danger from USLWR fuel cycle emissions[3] that the United States government admitted this danger existed. Since the discovery that carbon-14 emissions from the USLWR fuel cycle will mutate thousands of people, absolutely nothing has been done to stop it from leaking (see below).

Carbon-14 is formed in light water reactors when stable carbon-12 undergoes two successive neutron captures. It is formed under the intense neutron irradiation present in the fuel bundles and along the primary coolant surface boundary layer of reactors (which are composed of high-carbon steel). The amount formed depends on a large number of variables such as the intensity of the neutron flux, the amount of certain isotopes present in the coolant (e.g., N-14 and O-17), the amount of coolant present, and the mass, shape and location of all the internal components of the reactor[4]. The carbon-14 which is formed then begins to separate from the alloy within which it is contained and is released into the off-gas system principally as carbon dioxide but also with some quantities as carbon monoxide and in the form of various hydrocarbons[5].

From here it is released to the environment via the various leaks in the off-gas system[6] with the main leak occurring at the steam jet air ejectors. Whatever carbon-14 leftover in the spent fuel bundles and other internal reactor components which are reprocessed to obtain recyclable uranium and/or plutonium will be released through a similar off-gas system at the reprocessing center or temporarily stored as waste in a repository for spent fuel bundles[7]. Whatever quantity of carbon-14 is stored as waste in a repository will eventually be discharged (vented) into the biosphere[8]. It is estimated that virtually all of the carbon-14 discharged from the reprocessing and waste storage portions of the LWR fuel cycle will go in the form

of carbon dioxide gas with possible trace quantities of carbon monoxide and hydrocarbons present.

All known methods of carbon-14 separation or removal from this carbon dioxide gas waste stream have been officially labeled as "highly impractical", "not technically feasible", "speculative", "unfavorable", "technically infeasible and...unsatisfactory", and "technically less feasible (than a system which is) not technically feasible"[9]. Thus, there is no indication that carbon-14 effluents from the LWR fuel cycle will ever be stopped. Rather, once it is created by man, it is a matter of time until it is released directly into the biosphere in the readily absorbed form of carbon dioxide gas.

Because of its extremely long half-life (5,770 years) and the need for such an isotope to go through eight half-lives before it decays to an "acceptably" safe level, carbon-14 represents potential dose committments for at least 46,000 years[10]. Because it so closely resembles stable carbon-12, the foundation for all life as we know it, its potential for migration through the biosphere is unequaled by any other radioisotope or element. It travels equally easy to all parts of the human body and is not barred by the placental barrier (but rather, is selectively biomagnified to) the fetus or developing embryo[11]. Carbon-14 may therefore be passed on at mutagenic levels for generations within the human body, either by concentrating in womens' wombs or by becoming part of our DNA[12].

The first published evidence linking man-made carbon-14 to human genetic damage was in 1958 by Dr. Linus Pauling[13]. Pauling, utilizing information published by Professor James F. Crow[14], the National Academy of Sciences[15], and Willard F. Libby (the then chairman of the Atomic Energy Commission)[16], demonstrated that the vast majority of the approximately one million human genetic mutants[17] (which the AEC and other above mentioned sources had stated would result from thirty years of atmospheric testing at the 1956 testing rate with a population of two billion children)[18] were due to the biomagnification and absorbtion of this man-made carbon-14 from the biosphere. Though atmospheric testing has not yet been carried out for thirty years since 1956, it is now known that the AEC assumption that the testing rate of 1956 would not be exceeded was incorrect. Subsequently, taking into account the different amounts of carbon-14 produced by atomic and hydrogen bombs (a ratio of about 1 to 7, respectively)[19], the testing programs of the United states, the USSR, and Great Britain released enough carbon-14 by the end of 1962 to produce 721,600 human

mutations[20]. Since that time, a considerable amount of testing has been done within the atmosphere by France and the People's Republic of China. Additionally, the U.S., U.S.S.R., and British figures do not include tests which are still classified for obvious reasons. These levels for human mutations were all based on the 1957 estimates by Crow, the National Academy of Science, and others as to the genetic damage wrought by the exposure of the parents of two billion children to one tenth a roentgen of fallout[21].

In order to better understand the hazards posed by exposure to carbon-14, it is necessary to understand more of the nature of carbon cycles in the biosphere. The carbon-14 produced naturally is produced in the upper atmosphere (bombardment of nitrogen-14 by cosmic rays and its resultant transmutation into carbon-14)[22]. The quantity produced in this manner is estimated to be between 30,000 and 40,000 curies per year with a total equilibrium established at 220 million curies[23]. Of this amount, approximately 87.8% is inorganic matter in the ocean, 6.7% is organic matter in the ocean, 3.88% is terrestial living matter and humus, and 1.69% is atmospheric carbon dioxide[24]. Thus, only about 4½% of the total[25] is located where it might expose mankind. This means the danger from natural sources of carbon-14 is actually coming from the much lower figure of **ten** million curies; a considerable amount of radioactivity representing about 1 millirem per year per person or about 1% of the total background radiation dose[26]. It can logically only be assumed that this radioactivity represents a significant portion of the normal rate of human mutations [27]. Soviet scientists, on the otherhand, postulate that this amount of carbon-14 represents 25% of the normal rate of mutation (see below).

Carbon-14 production by atmospheric testing of nuclear weapons has been estimated (1971) to lie at 6.2 million curies[28]. Of this amount virtually all is taken to the stratosphere by the heat and air currents which typify the mushroom clouds and is eventually distributed all over the globe. A disproportionately large percentage of it is likely to come down in the polar regions due to the lowered elevation of the stratosphere in these regions. Generally, the cycling behavior of bomb produced carbon-14 is similar to that of naturally produced carbon-14 except for one important difference. Pauling has estimated that two thirds of the carbon-14 generated by atmospheric testing forms HCO_3^-, thus falling into the ocean where it is in a form and place generally considered not hazardous to man[29]. Therefore, of the remaining 2+ million curies only 4½ (again, Pauling's estimate) or 93,000 curies is readily avail-

able to expose mankind.

As for nuclear energy, the last official estimate for USLWR fuel cycle releases of carbon-14 by the year 2000 was 600,000 curies[30]. This figure was based on a projected rate of growth almost twice as great as that which is now evident[31]. Thus, a conservative projection is that it may take America until the year 2020 to reach this level. However, the worldwide LWR fuel cycle carbon-14 emissions are projected at 706,000 curies by the year 2000[32]. Regardless of just how much is produced or when it is produced it is obvious how close these projected levels are to the quantity which is readily available from natural sources; and how much higher it is than the quantity which is readily available from atmospheric testing of nuclear weapons. It may also prove interesting to note that worldwide emissions from the LWR fuel cycle should match and start to exceed the natural rate of production of carbon-14 by the year 1995[33]. Thus, a new equilibrium for the total level of carbon-14 in the biosphere is presently being established (and along with it, a new equilibrium in the normal rate of mutation). It is again important to note that Soviet scientists postulate that 25 % of the normal rate of mutation is due to the background levels of carbon-14 in the biosphere (see below).

Unlike the carbon-14 produced by other sources, the carbon-14 emissions of the LWR fuel cycle will be readily available to expose mankind in its entirety. Of special interest in the cycling behavior of this carbon-14 is the important role played by the organic matter in the soil which serves as the major sink for LWR fuel cycle emissions[34]. Whereas the greatest percentage of carbon-14 from natural sources or from atmospheric testing of nuclear weapons is going to land in the ocean sink, this natural cycle is broken from the very start in the case of nuclear power by the location of nuclear fuel cycle facilities on the land masses of Earth. Thus, the crops grown around LWR fuel cycle facilities will contain significantly higher levels of carbon-14 due to their proximity to the source.

The plants themselves will absorb $^{14}CO_2$ through their leaves during the process of photosynthesis and distribute it throughout the plant. Additionally, they will absorb ^{14}C containing matter through their root systems. Thus, the plants themselves will constitute a major sink for LWR fuel cycle emissions of carbon-14. Furthermore, the biomagnification of carbon-14 into mankind via his foodchain may well make mankind himself a significant bio-sink for the LWR fuel

cycle emissions of carbon-14.

Yet what is this alleged hazard from carbon-14? Is it not too small a dosage to individual human beings to be concerned about? The answer is no. There is no dose of radiation so small that is not genetically harmful[35]. Furthermore, the number of human mutations induced (and therefore introduced into the human gene pool) is considered to be directly proportional to the radiation dose absorbed by the gonads[36]. It is therefore possible to make crude numerical estimates of the hazards, provided information is available on the average dose to the gonads during the reproductive period[37].

In 1975, the USEPA published a report[38] which estimated the level of genetic human mutations that would be produced in the century following the release of 600,000 curies of carbon-14 (by the year 2000). The USEPA concluded that this release would , in that time frame, cause the DNA of 12,000 human beings to receive a high enough radiation dose to cause them to have "severe" genetic damage. Basing the effects of radiological damage on the published figures of the National Academy of Science 1972 BEIR report[39], the USEPA concluded this radiation induced damage would consist of 12,000 cases of:

> "cancers (including leukimia), and serious genetic effects (these include congenital abnormalities leading to serious disability, and increases in diseases that are specifically genetic, such as certain forms of mental defects, dwarfism, diabetes, schizophrenia, epilepsy, and anemia)." 40

On the subject of the milder mutations, the USEPA had this to say:

> "The genetically related component of diseases such as heart diseases, ulcers, and cancer as well as more general increases in the level of ill-health are omitted from estimates of genetic effects, as are effects on growth, development and life span, because of the wide range of uncertainty in existing estimates of their importance, coupled with a judgement that their total impact is probably not greater than that of those health effects that have been quantitatively considered." 41

Yet Professor James F. Crow, Dr. Bentley Glass, Dr. H.J.Muller, and many other leading scientists have amply demonstrated over two decades ago[42] that the total effect of the less severe mutants is at least equal to, and probably far greater than the effects from the more severe mutations. This is primarily due to the greater probability that a minor mutation will be passed on as it is far more viable than the more severe mutations. Thus, it more than makes up for its lower level of severity by affecting far more people[43].

It should be borne in mind that effects such as the EPA has described ([illegible] in heart disease, ulcers, cancer, ill-health, as well as effects [illegible] retard growth, development, and life span) merit far more atten-

tion than a brief mention in an EPA report which is soon to be forgotten on a dusty library shelf and apparently covered-up by the nuclear industry and its government regulating agencies. These are the kinds of effects which, if ignored and allowed to spread throughout a species, can cause the elimination of that species for they reduce its viability. Perhaps one of the biggest underestimates the USEPA has ever made is contained in the sentence which followed their above mentioned statements, which says:

> "To the extent that other somatic and genetic effects are important, the present estimates of the impact of radioactive effluents on health are not conservative..."44

The fact that the USEPA chose not to quantify the above effects further demonstrates the folly with which mankind embarks upon the development of a form of energy he neither controls or understands. For since the EPA has elected not to quantify the number of less severe mutations caused by LWR fuel cycle emissions of carbon-14, individual human beings will themselves serve to quantify these effects for the USEPA by becoming the victims of nuclear power themselves. Yet these mutant victims will undoubtedly have no way of proving, or even knowing if they are indeed the mutant victims which the Federal government has, in its wisdom, chosen to ignor. Thus, the nuclear industry continues to experiment at will upon live human beings with mutagenic substances that maim and kill.

Though we cannot precisely quantify these less severely mutated people as well as we can the more severely mutated ones, we do know that the total number of less severely mutated human beings are sufferring from the incorporation into their DNA of a much more viable mutant gene. Thus, the total number of the less severely mutated people will greatly exceed the number of more severely mutated people. Thus, 12,000 severely mutated people plus far over 12,000 less severely mutated people equals far over 24,000 human mutants within the first century of release of 600,000 curies of carbon-14 from the LWR fuel cycle.

Since carbon-14 is an isotope whose half-life is longer than one century, a true estimate of the human mutants produced by its emission from the LWR fuel cycle must take into account its effects over the time span in which it will be mutagenically dangerous. As stated earlier, this period is eight half-lives, and each half-life is 57.3 centuries long. Thus, in order to account for the human mutants which will be produced in the first half-life of the emission of 600,000 curies of carbon-14 from the LWR fuel cycle, we would take the number of mutants produced in the first century and multiply that by the average amount of carbon-14

which will be present in that first half-life (the average between 1 and ½ = 3/4), and then multiply their product by the number of centuries in that half-life (57.7). Therefore:

far over 24,000 human mutants
x 3/4
far over 18,000 human mutants
x 57.7 centuries
far over 1,038,600 human mutants in the first half-life

The number produced afterwards by the remaining half-lives would be equal to:

far over 24,000 human mutants
x 3/8 + 3/16 + 3/32 + 3/64 + 3/128 + 3/256 + 3/512
the product
x 57.7 centuries
human mutants in next seven half-lives.

This expression can also be stated (by adding up the fractions as a decimal):

far over 24,000 human mutants
x 0.7441406
17,859.37440
x 57.7 centuries
far over 1,030,485 (approximately) human mutants

Thus, the total number of human mutants produced over the hazardous life following the release of 600,000 curies of carbon-14 from its radiological effects is:

far over 1,038,600 human mutants
+ far over 1,030,485 human mutants
far over 2,069,085 human mutants

At this point it should be noted that we have not included mutations from anything other than the direct irradiation of the genes in the DNA molecule from 600,000 curies of carbon-14. There are two other vital factors to take into account when discussing the total mutagenicity of carbon-14. The first is mutations produced by the transmutation effect of carbon-14. The second is recessive mutations.

The USEPA did not see fit to consider either of the above two factors. However, in 1979, the Department of Energy published a report which for the first time ever for a US government agency, addressed the subject of health effects from carbon-14's transmutation effect[45]. Yet this consideration amounted to little more than a weak attempt to sweep the whole issue under the rug. Specifically, in an incredibly irrational analysis, the USDOE wrongly concluded:

"since there is no experimental evidence for a transmutation effect that is many times larger than the radiation effect..."

they therefore did not deem it preferable to

"consider the possibility of carbon-14 transmutation effects."[46]

Yet this effect has been known since at least the time of Pauling's original article on the hazards of bomb produced carbon-14 (then called the Szilard-Chalmers effect)[47]. This transmutation effect occurs whenever the carbon-14 isotope

emits its beta particle (which can strike any locus of DNA causing the heretofore described radiological damage to the human genetic code). Yet once this beta particle has been emitted by carbon-14, the neutron in its nucleus which emitted the beta particle is instantly transformed by the loss of this negative charge (along with the loss of the beta's mass and spin characteristics and the loss of one or more neutrinos and some energy emitted as a photon) into a proton. Thus, we are no longer dealing with the carbon-14 isotope which contains six protons and eight neutrons, but with an isotope containing seven protons and seven neutrons; that is, nitrogen-14. Everytime a carbon-14 atom is transmuted into this nitrogen-14 atom within the DNA molecule it causes a chemical mutation for the chain which controls the DNA code is itself changed, and thus, mutated.

Yet quantifying the increased amount of these mutations due to the transmutation effect is complicated. The beta particle emitted by the carbon-14 atom has sufficient energy to travel across the length of the germ cell to strike any locus of a chromosome in that germ cell (but not enough to penetrate into a germ cell next to it). This means that radiological damage can occur not just from those carbon-14 atoms located in the DNA chain itself, but from the carbon-14 atoms in the interstitial fluids throughout the germ cell[48]. On the otherhand, the odds of a beta particle being emitted from anywhere in the DNA chain or even the interstitial fluid of that particular germ cell and striking a locus on a chromosome within that germ cell is very small indeed. This is because the size of the beta particle and even that of its target chromosomes (which are at least quadrillions of times larger) is still extremely tiny when compared to that of the distances the beta particle must travel and all the different directions in which it might travel (sort of like hitting Pluto from a light year away with a pea shooter). Though Lee, et al, have argued that the ionization potential of the beta particle (its negative charge) will compensate for the small size and tremendous distances involved[49], the American scientific community does not accept his results (see below).

In order to quantify how many mutations are produced by direct irradiation and how many are produced by the transmutation effect, scientists have done two basic types of experiments with both plants and insects. In the first type, the plant or animal would be exposed to the direct irradiation and transmutation effects of carbon-14 through internal injections. Meantime, controls would be exposed to external irradiation by a high energy gamma emitter, such as cobalt-60. Lee, et al., for example, did this with Drosophila and then tried to correct his

results by mathematically accounting for the increased ionization potential of the hot particles. However, the scientific community both in America and abroad have declined to accept his results as valid. These are the results that the USDOE accepted as valid in arriving at their conclusion mentioned previously.

Another type of experiment involves the incorporation of carbon-14 into plant cells and observing the different quantities of chromosomal aberrations induced by varying the position of the carbon-14 in the chemical utilized for the cellular injections (i.e., thymidine-2-C^{14} and thymidine-methyl-C^{14}, such as in McQuade and Friedkin's experiments with onion root tips)[50]. McQuade and Friedkin found that when the carbon-14 isotope was in the methyl position, the number of onion root tip cells with chromosomal aberrations doubled: from 5.48 percent to 10.29 percent (control cells in water had shown 0.54 percent aberrations). Yet many different experiments have produced widely differring results. For example, Kuzin, et al., whose experiments were similar to Lee, et al., noted that internal injection of carbon-14 produced 9-25 times as many aberrant cells as external gamma radiation. In the words of R.Kirsch and M. Zelle:

> "The results of various workers have not been consistent. Some have claimed that all effects are accounted for by beta-irradiation. The most clear-cut results are probably those of McQuade and Friedkin, who reported that thymidine-methyl-^{14}C induced twice the rate of chromosomal aberrations in the onion root tips as did thymidine-2-^{14}C implying, since no difference would be expected for beta-radiation produced effects, that transmutation effects were important when ^{14}C was in the methyl position." 5.

From this data it would appear that any conservative estimate of the number of human mutations produced by carbon-14 in the biosphere must include the transmutation effects of carbon-14. Any data produced which is claimed by its authors to be an authoritative statement of the health effects of carbon-14 which does not account for the transmutation effect at least to the degree that McQuade and Friedkin have shown to be true for onion root tip cells can only be termed a "charade". Such data is not conservative and therefore purposely subverts its intended purpose of protecting the public. No conservative arguement can ever be made that this data should not be assumed to hold true for more complicated life forms simply because they are more complicated. For such complicated life forms obviously have a great deal more parts which can go wrong if their genetic code is chemically or radiologically altered.Therefore, in light of the above words of Kirsch and Zelle, a conservative judgement of the health effects of carbon-14 must assume that the transmutation effect will at least double the total

number of human mutations produced by the release of carbon-14 into the biosphere. Thus, the figure of far over 2,084,122 human mutants becomes the figure of far over 4,178,244 human mutants.

There are however several disturbing problems with the research of McQuade and Friedkin. In fact, these problems greatly affect the credibility of all the experimental research done to date on the transmutation effect of carbon-14. Golenetskii, Suskov, and Stepanok have addressed this issue most candidly and accurately when they said:

> "Attempts at an experimental evaluation of the relative genetic effectiveness (RGE) of the transmutation of ^{14}C contained in DNA in comparison with the external influence of X ray or gamma radiation ($RGE_{tc/r}$) have been few and give extremely contradictory results — from 1 to 20 (1,5). Most of them were obtained by comparing the rate of appearance of a definite type of biochemical, lethal, or visible mutations of a characteristic, and in (5) according to the number of chromosome aberrations in the decay of ^{14}C contained in DNA and in the case of external irradiation of the organism with gamma quanta at the same dose. Such an approach is not entirely correct for a number of reasons. First of all, the spectra of induced mutations in the two cases may differ substantially, with a corresponding difference in the frequencies of appearance of the observed characteristic. Furthermore, an external influence of weakly ionizing radiation is characterized by a dependence of the effect on the stage of mitosis, the biological affiliation of the object of the investigation, the degree of saturation of the tissue with oxygen, the dose rate and conditions of irradiation, the state of the system of dark repair, etc.(6-8). Finally, the use of X rays or gamma radiations as the standard for the RGE is unfortunate in view of the low value of their LET. The latter leads to the fact that the RGE of radiations with a large LET and other mechanisms of interaction with matter proves to depend on the size and composition of the investigated biological object, its habitat at the moment of irradiation, and the presence of reflecting materials. Evidently, this may explain the substantial dispersion of the experimental values of the RGE of fast neutrons for various biological objects, which, according to the data of different authors, range from three (chromosome aberrations in mouse spermatogonia) to 45 (induction of prophage in E. coli) and even 100 (chromosome aberrations in onion root cells) (8). A simultaneous consideration of all the enumerated factors is frequently complicated or simply impossible. From this the dispersion of the experimental values of $RGE_{tc/r}$ noted above becomes understandable."[52]

In their work, Golenetskii, Suskov, and Stepanok have compared the RGE of the transmutation of carbon-14 with the transmutation of neutrons. Their calculations show:

$$RGE_{tc/tn} = 4.44/0.054 = 82.5 \quad [53]$$

Additionally, they compared the relative genetic effect of the transmutation of carbon-14 with that of radiations such as gamma and X ray. Their calculations show:

for microobjects
$$RGE_{tc/r} = 4.4 \times (70-137) = 310-600$$

for macroobjects
$$RGE_{tc/r} = 85.2 \times (5-8) = 426-680$$

as the [illegible] for chromosome aberrations. They then take the average value of -- [illegible] = 500 -- as the lower limit for chromosome mutations, regardless of the biological affiliation and size of the object under investigation.[54]

They further note:

> "The RGE $_{tc/r}$ with respect to gene mutations, as was indicated above, should be several times higher (a minimum of 10 times) than with respect to chromosome muatations, and evidently may depend substantially on the biological affiliation of the object of investigation. Thus, in the case of irradiation of mice with fast neutrons, the RGE $_{fn/r}$ with respect to certain visible mutations reaches 30 (20), which is 5-10 times higher than RGE $_{fn/r}$ = 3-6 for chromosome mutations in spermatogonia and dominant lethals in the smae objects (16, 17, 18). Considering all possible types of mutations, the total RGE $_{fn/r}$ should be even higher. This is all the more correct for thermal neutrons. Thus, there will be no great error in the estimation of the lower limit of the possible values of the total RGE $_{tc/r}$ according to gene mutations as of the order of 500 x (5-10) = 2500-5000, or on the average, 4000.
>
> If the values obtained for RGE $_{tc/r}$ are correct (and the triviality of the calculations and considerations cited provokes no doubts of their correctness) and are confirmed experimentally, then the biological significance of radiocarbon ^{14}C is presented in a new light. In particular, its role as one of the basic natural mutagens and, correspondingly, factors of variability during the evolution of life on earth, becomes evident." 55

Finally, calculations are presented to estimate the amount of spontaneous mutation on Earth which the authors believe to be caused by carbon-14. They note that their calculations show a possible range of from 24 to 98 percent of the total amount of spontaneous mutation on Earth. They further note that "according to the estimate of Academician N.P.Dubinin, the contribution of this factor to spontaneous mutagenesis is of the order of 25% (21)." 56 In the light of this research, one can see that the potential for harm to the human race from leakage of carbon-14 from the LWR fuel cycle to the biosphere is far greater than has ever been indicated by any US government agency or any official in the nuclear industry.

If the above research of the Russian scientists is correct (and there is no scientific evidence - experimental or otherwise - which in any way proves them wrong) then the true number of human mutations wrought by the leakage of 600,000 curies of C-14 into the biosphere by the LWR fuel cycle is increased by a factor of 4000. This figure does not include recessive mutations. Thus, if 2,069,085 human beings are mutated by the radiological effect of the above release of carbon-14 into the biosphere, then the transmutation effect of this carbon-14 will increase the total to approximately 8,276,340,000 human mutants. Again, this figure does not include recessive mutations.

Even if one rejects the projections over the first eight half-lives made by this author, the number of mutations still remains staggering. Taking the BEIR [illegible] estimate of 12,000 severely mutated humans within the first century of release of 600,000 curies of carbon-14 by the LWR fuel cycle and multiplying by the data of the Russian scientists shows:

12,000 severely mutated humans
x 4,000 RCE tc/r
48,000,000 severely mutated human beings

within one century of release of 600,000 curies of C-14 into the biosphere. One would also expect an even larger number of less severe human mutants to occur simultaneously.[57]

The last official estimate made by USEPA concerning health effects from leakage of carbon-14 by the USLWR fuel cycle to the biosphere stated that approximately 3,900 to 5,500 human mutations would occur within a century of the amount of carbon-14 to be released by the year 2000.[58] The lower figure was based upon a growth rate for nuclear power which is in actual existence today.[59] Thus, since the USEPA only considered the radiological effects of carbon-14, the data presented by the Russian scientists shows that the transmutation effect of carbon-14 will increase the total by a factor of 4000. Thus, the carbon-14 to be leaked into the biosphere by the USLWR industry by the year 2000 will cause approximately 15,600,000 human mutants to be born during the 21st Century (not counting recessive mutations or the less severely mutated humans).

As for recessive mutations it is noted that H.J.Muller has calculated the rate of recessive damage to visible damage as 1,000 to one.[60] Just how much of this will eventually be expressed phenotypically in the human race is largely unknown. Yet it is obvious that it will greatly increase the totals.

The only way for recessive genes to be removed from our DNA code is for an individual to receive such a recessive gene from both of his parents.[61] It has been shown that on the average recessive genes will continue to spread throughout the human genetic pool for somewhere on the order of 30-50 generations.[62] Additionally, there is also evidence that inheritance of a single mutant gene usually does harm. This harm includes lowering the general resistance to disease, shortening the life-span, or reducing the fertility of the carrier. While creating additional harm, these effects would also reduce the viability of such genes, and thus, reduce the number of recessive mutations to some extent.[63]

Since the average mutant gene takes 30-50 generations to be removed from the human genetic pool, we can get a rough estimate of the number of recessive mutations which will occur. At the absolute minimum, the creation of a mutant will lead to 30-50 (on the average) recessive carriers if that mutant breeds. It is likely that all of these recessive carriers will suffer some harm, though they will continue to breed and pass along the mutant gene. Yet we do not know how many of them will suffer severe or substantially harmful mutations. We do

know that since the only way the recessive genes can be removed from the gene pool is for someone to inherit it from both parents, that recessive mutations will at least double the number of mutations which are initially passed on. Since there is an absolute minimum average of 30-50 recessive carriers, any number of which are likely to show some form of harmful mutation and furthermore, to breed several children themselves who will carry the mutant gene, then we are obviously discussing a large increase in the number of deleterious mutant genes which can only be removed from the race through individual suffering and misery. Thus, it becomes obvious why H.J.Muller estimated recessive genetic damage at three orders of magnitude above visible damage. It is also obvious that recessive mutations will tend to be a little less severe in the amount of harm they cause to the average progeny of a carrier. However, it is probably an underestimate to say that recessive mutations would increase the total number of human mutants by an order of magnitude.

Conclusion

It has been shown that the release of 600,000 curies of carbon-14 from the LWR fuel cycle will result in the radiological and chemical transmutational mutations of over 8½ billion human beings plus all the additional mutations wrought by inheritance of recessive genes. The latter is likely to increase the total by an order of magnitude to over 80 billion human mutants during the course of the next 46,000 years. It has further been demonstrated that this same emission would result in approximately one hundred million human mutants within one century of its release (not counting recessive mutants). Additionally, it has been shown that USLWR fuel cycle emissions of carbon-14 by the year 2000 will result in 12,000,000 human mutants before the end of the 21st Century (not counting recessive mutations). It has also been noted that worldwide LWR fuel cycle emissions of carbon-14 by the year 2000 will be even larger than the 600,000 curies considered in this report (specifically, worldwide emissions will be 700,000 curies by the year 2000). Operation of the LWR fuel cycle beyond these dates will of course increase the total quantity of human mutants.

From this data it is apparent that operation of the LWR fuel cycle will result in more human mutations than allowed by USNRC regulations. It is hereby concluded that all activities of the LWR fuel cycle which eventually result in the emission of carbon-14 to the biosphere be suspended immediately. It is also recommended that the Atomic Safety Hearings of all licensed and proposed nuclear power plants be reopened immediately to consider the implications of their carbon-

14 emissions as we now understand them. Furthermore, it is most strongly recommended that an immediate investigation be conducted by the National Academy of Science and the National Resource Council, as well as by the Council on Environmental Quality, to determine precisely what danger exists in the emission of carbon-14 into the biosphere from the LWR fuel cycle.

Bibliography

1 Dr. James F. Crow, "Statement of Dr. James F. Crow to the Special Subcommittee on Radiation of the Joint Committee on Atomic Energy", The Nature of Radioactive Fallout and Its Effects On Man, (Washington, D.C.: U.S. Government Printing Office, 1957)pp.1009-1028, Superintendant of Documents # Y4.At7[2] : F19 Pt.2.

2 The Nature of Radioactive Fallout and Its Effects On Man, (Washington, D.C.: U.S. Government Printing Office, 1957).

3 EPA-520/4-77-005 Radiation Protection Activities: 1976, USEPA/Office of Radiation Programs, August, 1977, p/54. see also, Reference #30.

4 NUREG-0016, Revision 1, Calculations of Releases of Radioactive Materials in Gaseous and Liquid Effluents from Boiling Water Reactors (BWR-GALE CODE), USNRC/Effluent Treatment Systems Branch/Division of Site Safety and Environmental Analysis/Office of Nuclear Reactor Regulation, F.P. Cardile and R.R. Bellamy, January, 1979, Section 2.2.22 "Carbon-14 Releases", p.2-53. see also, Reference #6 Section 1 and Section 2.

5 ORP/TAD-76/3 Public Health Considerations of Carbon-14 Discharges From the Light Water-Cooled Nuclear Fuel Cycle, Edited by T.W. Fowler, et al, USEPA/Office of Radiation Programs, (Washington, D.C.: USEPA/ORP, July, 1976), pp.7-12. The C-14 is also found as CH_4, C_2H_6, and other hydrocarbons.

6 EPA-520/4-77-013 Assessment of Carbon-14 Control Technology and Costs for the LWR Fuel Cycle, USEPA/ORP, September 7, 1977, Section 1 and Section 2.

7 Ibid, Reference #6 section dealing with C-14 discharges from reprocessing sites.

8 NUREG-0116 Environmental Survey of the Reprocessing and Waste Management Portions of the LWR Fuel Cycle, USNRC/ONMSS, October, 1976:

p.4-70, Section 4.3.5 Disposal; subsection "Release of Gas from Waste".
p.4-75 to p.4-77, Section 4.4.1.2 "Waste and Medium Interactions".
p.4-79 to p.4-81, Section 4.4.1.3 Operational Impacts; subsection "Effluents"
p.4-82, "Long Term Surface Elevation Changes".
p.4-86 to p.4-88, "Possible Events Causing Repository Failure".
p.4-88, Section 4.4.2.2 "Consequences of Waste Repository Failure".

NUREG-0002, Volume 3, Final Generic Environmental Statement on the Use of Recycle Plutonium in Mixed Oxide Fuel in Light Water Cooled Reactors, (GESMO), Health, Safety and Environment, USNRC/ONMSS, August, 1976:

Chapter IV Part H: Radioactive Wastes from the LWR Industry, Section 3, Disposal of Radioactive Wastes from the LWR Industry, subsections 3.2.1.1 3.2.1.2, and 3.2.1.3, of which the latter subsection states:

"It is estimated that all gases produced in the mine will eventually be discharged to the surface..."

NUREG-0002, Volume 4, Final Generic Environmental Statement on the Use of Recycle Plutonium in Mixed Oxide Fuel in Light Water Cooled Reactors, (GESMO), USNRC/ONMSS, August, 1976:

Chapter VIII Section 6, subsection 6.2.4.2 "Radiological", part: Effluents, p.VIII-25 states:

"The most significant radioactive release from the fuel cycle occurs during the reprocessing step. Nearly all of the Krypton-85, most of the tritium and C-14, small quantities of radioiodine, and very small quantities of other fission products and transuranium isotopes created in the nuclear reactor fuel are released to the atmosphere from the reprocessing plant operations. The reprocessing step contributes about 39 % of the dose committment to the general population for the fuel cycle (excluding reactor operation)."

EPA-520/4-78-004 State of Geological Knowledge Regarding Potential Transport

of High-Level Radioactive Waste from Deep Continental Repositories: Report of an Ad Hoc Panel of Earth Scientists, USEPA/ORP, 1978.

This report is an indictment of all proposed methods for deep burial of high-level wastes. Further demonstrates the point that the carbon-14 contained in spent-fuel bundles will eventually be discharged to the surface.

9 Ibid, Reference #6 , Section 3.

10 G.G.Killough and J.E.Till, Scenarios of ^{14}C Releases from the World Nuclear Power Industry from 1975 to 2020 and the Estimated Radiological Impact, contained in Nuclear Safety, Volume 19, #5, (September- October, 1978), pp. 602-615.

This study was sponsored by the US Department of Energy under contract with Union Carbide Corporation. This article presents an assessment of the radiation dose to the world population and the associated potential health effects from three scenarios of ^{14}C releases by the nuclear industry between 1975 and 2020. Measures of health impact are derived from source terms through the use of a multi-compartment model of the global carboncycle, dose rate factors based on ^{14}C specific activity in various organs of man, and health effect incident factors recently recommended by the International Commission on Radiological Protection (ICRP). The three scenarios for worldwide ^{14}C releases considered are (1) a pessimistic scenario in which all the ^{14}C projected to be produced in fuel cycles is released, (2) an optimistic scenario that assumes a decontamination factor of 100 for fuel reprocessing, and (3) an intermediate scenario that simulates a phased improvement in the effluent treatment technology at reprocessing plants. The estimates of cumulative potential health effects based on integration over infinite time (effectively 46,000 years or about 8 half-lives of ^{14}C) are as follows: 110,000 cancers and 75,000 genetic effects from the pessimistic scenario; 21,000 cancers and 14,000 genetic effects from the optimistic scenario; 22,000 cancers and 15,000 genetic effects from the intermediate scenario; 100,000 cancers and 68,000 genetic effects from the ^{14}C formed in nature between 1975 and 2020; and 380,000 cancers and 250,000 genetic effects from the ^{14}C formed by the detonation of nuclear explosives from 1945 to 1974. Comparable effects from the naturally formed ^{14}C in steady state in the environment , also integrated over 46,000 years, are approximately 66 million cancers and 41 million genetic effects. These estimates are based on a world population that is assumed to remain stationary at 12.2 billion after 2075.

11 Honicker Vs. Hendrie: a lawsuit to end atomic power, (The Farm, 156 Drakes Lane, Summertown, Tennessee: The Book Publishing Company, 1978), p.62.

12 Ibid, Reference #11. see also, Reference #24, p.1491 which states the "DNA is approximately 37 % carbon."

13 Dr. Linus Pauling, "Genetic and Somatic Effects of Carbon-14", Science, Vol. 128, #3333, pp. 183-1186.

14 Ibid, Reference #1.

15 "The Biological Effects of Radiaition", The National Academy of Science - National Research Council Publication, (1956).

16 W.F.Libby, "Carbon-14 from Bomb Tests", statement delivered before the Federation of American Scientists, Washington, D.C. : May 1, 1958.

17 Ibid, Reference #1, see also, Reference 24.

18 Ibid, Reference #1, ppl 020-1021.

19 O.I.Leipunsky, "The Radiation Hazards of Ordinary Explosions of Pure Hydrogen and Ordinary Atomic Bombs". Atomnaya Energie Volume 3, p.530, (1957). Available in translation through the United Nations.

20 Based on data obtained from, Fallout, Radiation Standards, and Countermeasures, (Washington, D.C.: U.S. Government Printing Office, 1963), Superintendant of Documents # Y4.At7^2: F19 pt.1 and Y4.At7^2: F19 pt.2. Part 2 contains a study by Dr. Gordon M. Dunning and Dr. Paul C. Tompkins, "Fallout Estimates

for Continuous Testing at the 1962 Testing Rate", pp.460-471. On page 471 is Appendix 13, prepared by the JCAB staff, July,1963, which shows:

Summary of total and fission yields,1945-1962 (in megatons)

	approx. Yields US + UK		approx. Yields USSR	
Year	Total	Fission	Total	Fission
1945-58	124	66	50	26
1961	underground only		120	25
1962	37	16	180	60
Total	161	82	350	111

The AEC study cited in Reference #1 stated approximately 1,080,000 genetic mutations would result from 30 years testing at the 1956 testing rate. The rate that year was approximately 30 megatons, half atomic and half hydrogen. To account for the difference in the amount of carbon-14 produced by atomic and hydrogen bombs we will use Leipunsky's ratio of 1-7, respectively. Therefore, 15 megatons atomic x 30 years = 450 C-14 units; 15 megatons hydrogen (7) x 30 years = 3150 C-14 units. Thus, the 1956 testing rate was equivalent to 3600 atom bomb carbon-14 units. The data in the table above shows a 1962 total of 193 megatons of atomic bomb yield and 318 megatons of hydrogen bomb yield. This translates into 193 + 318 (7) = 193 + 2226 = 2419 megatons of atomic bomb carbon-14 units.

Thus, 2419 C-14 units divided by 3600 C-14 units = 0.67. And 1,080,000 genetic mutations x 0.67 = 723,600 genetic mutations.

21 Ibid, Reference #1, pp.1020-1021.

22 G.G.Killough and P.S.Rohwer, "A New Look at the Dosimetry of ^{14}C Released to the Atmosphere as Carbon Dioxide", Health Physics, Vol. 34,(February),pp. 141-159, (Great Britain" Pergamon Press,1978), pp.141-142.

23 A.W.Fairhall and J.A.Young, "Radiocarbon in the Environment" in Radionuclides in the Environment, Advances in Chemistry,Series #93,pp. 401-408, (Washington, D.C.: American Chemical Society,1970). This is listed as Reference #7 by Robert O. Pohl in his "Nuclear Energy: Health Impact of Carbon-14", Radiation and Environmental Biophysics, 00,00-00(1976), Springer-Verlag, 1976.

24 John R. Totter, M.R.Zelle, and H. Hollister, "Hazard to Man of Carbon-14", Science, Volume 128, pp.1490-1495.

25 Ibid, Reference #13.

26 Ibid, Reference #22, p.141.

27 Ibid, Reference #1

28 Ibid, Reference #22, p.141.

29 Ibid, Reference # 13 and Reference #24.

30 Draft Environmental Statement: Environmental Radiation Protection Requirements for Normal Operations of Activities in the Uranium Fuel Cycle, USEPA/ORP, May 12,1975, Roger Strelon, Assistant Administrator for Air and Waste Management,pp.73-86, specifically p.76.

Also, EPA/520/4-76/016-A Environmental Radiation Protection Requirements for Normal Operations of Activities in the Uranium Fuel Cycle, USEPA/ORP, Washington,D.C.: USEPA/ORP, November 1,1976, pp.79-97, specifically,p.83.

31 WASH-1139 (74), USAEC, case B projections, (Washington,D.C.: US Government Printing Office, 1974).

32 Ibid, Reference #10.

33 Ibid, Reference #30.

34 H.Stephen Stoker and Spencer L. Seager, Environmental Chemistry: Air and Water Pollution, (Dallas,Texas: Scott, Foresman and Co., 1976), p.18.

35 Herbert and Mabel Frings, Concepts of Zoology, (New York: Collier-MacMillan Publishing Company, 1970),p.242.

Ibid, Reference #1, p.1009:
"All high energy radiations increase the rate of mutations."

Ibid, Reference #1, p.1010:
"Almost all mutations that have been studied have been harmful."

Ibid, Reference #1, p.1013:
"Evidence from experimental animals, principally Drosophila, indicates that the number of mutations produced is strictly proportional to the amount of radiation received."

Ibid, Reference #2, p.1031:
"Because a mutation can be produced by a single ionization in the right place, there is no threshold below which the amount of radiation is too small to produce mutations- that is, every dose produces mutations with a probability equal to its magnitude.
This is to repeat what Dr. Crow said, that there is no safe dose of radiation."

M.H.Marcovich, "The Problem of the Biological Action of Low Doses of Ionizing Radiation", Proceedings of the International Conference on the Peaceful Uses of Atomic Energy, Held in Geneva,8,August - 20,August, 1955, Volume II, "Biological Effects of Radiation", (New York: United Nations Publications,1956), pp.242-247, which states:
"The very nature of such a threshold is difficult to conceive, since the factors of carcinogenesis are always many, and the interactions complicated. Nevertheless, it seems reasonable to assume that, all conditions being equal, ionizing radiations give us another means of inducing cancer, which one may not rule out even at the smallest doses."

Bruce Wallace, "The Genetic Structure of Mendalian Populations and its Bearing on Radiation Problems", Proceedings of the International Conference on the Peaceful Uses of Atomic Energy, Held in Geneva, 8,August - 20,August,1955, Volume II,"Biological Effects of Radiation", (New York: United Nations Publications,1956), pp.377-381, which states:
"...we have no doubt that irradiation induces gene mutations in man. This and the additional assumption that these mutations enter the gene pool of the human population are made without discussion. Arguments supporting these assumptions are made elsewhere[1,2]. The acceptance of these assumptions leads to the admission that our population is confronted with a radiation problem."
and also:
"Under a system of co-adaptation as under any other system, gene mutations whose average effect is to lower the viability or "fitness" of individuals must be eliminated by natural selection. In human populations this elimination must be recognized in terms of human suffering and individual misery. Since the preponderance of newly induced mutations are probably deleterious in virtually all genotypes, these mutations will harm individuals and handicap their families. We cannot wantonly bestow pain and misery upon individuals of succeeding generations..."

T.C. Carter, (on behalf of the Medical Research Council, Atomic Energy Research Establishment, Harwell, United Kingdom), "The Genetic Problem of Irradiated Human Populations", Proceedings of the International Conference on the Peaceful Uses of Atomic Energy, Held in Geneva, 8, August - 20,August,1955,Volume II, "Biological Effects of Radiation", (New York: United Nations Publications,1956),pp.384-386, which states:
"During the last year or two the public at large has become aware that even the peacetime use of nuclear power, with its benefits to the many, may entail danger to the few; and the public has become seriously disquietened by this realisation...The awakening of the public conscience in this matter is mainly due to the writings of geneticists, notably H.J.Muller and A.H.Sturtevant. They pointed out that there is no threshold for the induction of genetic effects by ionising radiations, and that any exposure, however slight, implies the induction of some mutations: that when a population is in genetic equilibrium every new mutation must be balanced, on the average, by the loss of a mutant gene through selection; and that this loss ("genetic death"), to use Muller's term[1,2], often means suffering

for the individual or his family."

35 Ibid, Reference #11, the list of evidence goes on and on. This book has been selected to best represent a summation of that numerous studies, both experimental and epidemiological, which have well documented that there is no such thing as a safe level of radiation.

36 Ibid, Reference #1 and Reference #35.

37 Ibid, Reference #1

38 Ibid, Reference #30, pages 82 and 89, respectively.

39 Biological Effects of Ionizing Radiation: 1972 Report, completed by the 1972 BEIR Committee for the USEPA, members representing the National Academy of Science and the National Research Council, (Washington,D.C.: USGPO, 1972. see also, Reference #38.

40 Ibid, Reference #30, pages 81-83 and pages 88-90, respectively.

41 Ibid, Reference #30, pages 83 and 90, respectively.

42 Ibid, Reference #1 and Reference #2, pages 1009-1085, including testimony of Dr. James F. Crow, Dr. Bentley Glass, Dr. A.H.Sturtevant, Dr. Hermann J. Muller, and Dr. W.L.Russell., see also, Reference #35.

43 Ibid, Reference #1 and Reference #35. see also, from Reference #1, pp.1012-1013:

"My third main point is that one might perhaps think that mutations that cause only minor impairment are unimportant, but this is not so for the following reason: Deleterious mutant genes are eventually eliminated from the population since they generally increase the death rate or lower the fertility of the person carrying them. A mutant that causes a great deal of harm is eliminated in a few generations. But one that causes only a small amount of harm will persist much longer, and thus effect a correspondingly larger number of persons. On the average, the larger number affected by a mild mutation roughly compensates for the lesser effect on the individual.

Since minor mutations in the long run can do as much harm as more drastic ones and occur much more frequently, it follows that most of the mutational damage in a population is due to the accumulation of individually minor effects. This means that an estimate of mutational damage that considers only obvious hereditary diseases and conspicuous abnormalities is probably a gross underestimate of the total damage. The effect of minor mutations, though intangible in the sense of ordinarily being indistinguishable from the other ills that we are beset with, is probably in the aggregate much more important."

and, furthermore, from the testimony of Dr. Bentley Glass in Reference #2:

"There is also evidence that even in single dose most mutant genes do harm, although it is of an intangible sort, affecting general resistance, shortening the life-span, or reducing fertility of the carrier."

44 Ibid, Reference #30, pages 83 and 90, respectively.

45 "Specific Consideration of Health Effects from Carbon-14", Draft Environmental Impact Statement: Management of Commercially Generated Radioactive Waste, Volume 2,"Appendices", (Washington, D.C.: USDOE,April,1979), p. E-13.

46 Ibid, Reference #45.

47 Ibid, Reference #13.

48 H. S. Benonde and M. Friedkin,"Radiation Effects of Thymidine-^{3}H and Thymidine-^{14}C", Experimental Cell Research, Volume 21, (New York: Academic Press, 1960), pp.118-125.
see also, Reference #49.

49 Robert R. Kirsch and M.R.Zelle, "Biological Effects of Radioactive Decay: The Role of the Transmutation Effect", Advances in Radiation Biology, Vol. 3, Edited by L.G.Augenstein, R. Mason, and M. Zelle, (New York:Academic Press,1969), pp.177-213.

50 Ibid, Reference #48.

51 Ibid, Reference #49.

52 ERDA-tr-38 G.P.Golenetskii, I.I.Suskov, and V.V.Stepanok,"Evaluation of the Mutagenic Effectiveness of the Isotope ^{14}C", <u>Radiobiology</u>, Vol.15, #1, pp.39-46, specifically, pp.39-40.

53 Ibid, Reference #52, p.42.

54 Ibid, Reference #52, p.42.

55 Ibid, Reference #52, p.43.

56 Ibid, Reference #52, p.44.

57 Ibid, Reference #43.

58 Ibid, Reference #5,pp.43-44.

59 Ibid, Reference #31 and Reference #58.

60 Ibid, Reference #11, p.17.

61 Ibid, Reference #2, p.1031, which states:
"But recessive genes are nonetheless harmful, and in many cases kill or severely handicap those persons in the population who eventually happen to inherit the same mutation from both parents. This may occur only after many generations. As Dr. Crow said, 30 or 50 generations - have elapsed since the mutation originated. Consequently, harmful mutations can accumulate and be carried in a population without visible damage until at length an equilibrium is reached at a frequency where the mutation rate that produces each particular kind of harmful gene is balanced against the elimination of that gene from the population either by the death or by the failure to reproduce of some person who gets a double dose of the gene."

62 Ibid, Reference #61.

63 Ibid, Reference #1, Reference #2, Reference #35, Reference #42, Reference #43, and Reference #61.