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To the Editor of the New York Times:

I have read with interest the letter from Drs. J. Laurence Kulp,
Wallace S. Broecker, and Arthur R. Schulert in your issue of 2 May 1958.

In this letter they say that my statement that carbon 14 represents "a far
more serious long-term menace than all other radioactive by-products of
an atomic explosion" is incorrect, and ~~they deplore exaggerated statements~~
~~by respected scientists~~ ~~in fact~~ They say that carbon 14 will contribute only a
minor fraction of the radiation produced by strontium 90 and cesium 137.

~~I cannot accept their statements. Their statements~~
~~The statement made by these authors is not true. I think that we must~~
In fact, it is their statements that are incorrect.

~~say~~ that when the cumulative ~~total~~ dose to the entire population over

the total lives of all isotopes is considered, the radiation from the

carbon 14 produced by bomb tests ~~is found to be~~ is found to be

considerably larger than the amount attributed by the AEC to other isotopes,

and the number of defective children that can be predicted to be pro-

duced by the radiation from carbon 14 is far greater than the number

predicted for the other isotopes.

In his 1956 paper on radioactive fallout Dr. W. F. Libby pointed
out that neutrons released in the explosions of nuclear weapons in air
react with nitrogen nuclei to make carbon 14; he said that "Fortunately

this radioactivity is essentially/^{safe}because of its long lifetime and the enormous amount of diluting carbon dioxide in the atmosphere." Perhaps because of a feeling of reassurance engendered by this ~~a~~ statement and others by Dr. Libby I did not make any calculations of the genetic and somatic effects of the carbon 14 produced in the testing of nuclear weapons until last month. In his 27 March 1958 address in Lausanne, Dr. Libby gave additional information about carbon 14, including ~~that~~ a statement ~~that~~ about the amount of carbon 14 generated per megaton, with fusion and fission weighed as they had actually occurred; this amount is 7.4 kilograms, about 7 times the amount that he had reported in 1956 for a pure fission weapon. He stated that a considerable part of the carbon 14 (which I estimate as two-thirds) falls back as calcium carbonate, the rest of it entering the reservoirs of which the biosphere is a part. At the present time the concentration of carbon 14 in the atmosphere has been increased by the bomb tests ~~by~~ ^{to} a value 10 percent greater than its former value. As carbon dioxide dissolves in the ocean, this percentage will, ^{ultimately} decrease if the bomb tests are discontinued.

I shall calculate the effect of carbon 14 on the basis of the following assumptions: ^{The rate} ~~A standard weight~~ of bomb testing ^{is} ~~at~~ 30 megatons per year;

one-third of the generated carbon 14 is released to the atmosphere; there is moderately rapid equilibrium with a large reservoir, including the ocean, with normal content 74,000 kilograms of carbon 14; the mean life of carbon

14 is 8070 years; the effect of a single gonad exposure of 0.1 roentgen

of a world population equal to that at present is to cause ultimately a

total of 380,000 seriously defective children (gross physical or mental

defect, stillbirth, childhood death) plus 700,000 embryonic ^{and} neonatal

deaths, as ~~given~~ estimated by Professor James F. Crow, a member of the

National Academy of Sciences-National Research Council Committee on Genetic

Effects of Atomic Radiation, in his testimony before the Congressional

Subcommittee on Radiation on 4 June 1957; the population of the world,

which has increased ^{over} by 1 billion during the last 100 years, will continue

to increase and will have an average value during the next 10,000 or

20,000 years such that there will be five times as many children born as

at present, the normal amount of carbon 14 in the human body produces a

gonad exposure of 0.0015 roentgen per year, as stated in 1956 by Dr. Libby;

A straightforward calculation based on the above assumptions leads

directly to the conclusion that 1 year of testing at the standard rate

of 30 megatons per year (~~2 x 15 megatons~~ two 15-megaton bombs, similar to the one detonated by the United States on 1 March 1954) will ultimately be responsible for the birth of **230,000** ~~225,000~~ seriously defective children and also for ~~420,000~~ 420,000 embryonic and neonatal deaths.

For comparison, we need to have a value of the amount of radiation produced by the other isotopes. ~~This~~ The calculation of the effect of other isotopes is most readily made by the steady-state method. In the NAS-NRC report of 4 June 1956 it is said that if weapons testing were continued at the rate of the preceding five years it is estimated that a total 30-year gonad dose of about one-tenth of a roentgen would be produced, or, since the accuracy involved is probably not better than a factor of 5, a dose between 0.02 roentgen and 0.50 roentgen. The value in 30 years 0.1 roentgen/has been reported as recently as ~~February~~ this year, 1958, in the 23rd Semi-annual Report of the Atomic Energy Commission. It corresponds to 0.0033 roentgen per year, and accordingly to the production of 13,000 seriously defective children plus 23,000 embryonic and neonatal

deaths, *as the result of one year of bomb testing.* These numbers are far less than the numbers predicted as the

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effect of carbon 14 ~~is~~ per year of testing, and accordingly the statement is justified that carbon 14 is a far more serious long-term/^{genetic} menace than the other products of atomic explosions.

Although the Atomic Energy Commission has not released any statement about this matter, it seems to me not unlikely that the world-wide fallout corresponds more closely to the upper limit given by the NAS-NRC committee, 0.5 roentgen in 30 years, than to the ~~smaller~~ value ^{0.1 roentgen.} If the upper limit is in fact to be used, the number of defective children ^{per year of testing.} ~~produced by radioactive products~~ ^{corresponding to radiation other than carbon 14} becomes 65,000 and the number of embryonic and neonatal deaths becomes 115,000. These numbers are still far less than those estimated for ~~the~~ carbon 14, ~~effect~~. On the other hand, it must be pointed out that if the world population *were to* remain ^{constant} the effect of carbon 14 would be only about equal to that of the other isotopes, assuming that the other isotopes irradiate the gonads in amount 0.5 roentgen in 30 years, rather than the usually quoted value 0.1 roentgen in 30 years.

The somatic effects of the bomb tests are more difficult to discuss, because they involve more assumptions about the nature of the interaction

of high-energy radiation with the human body, and because ~~nuclear~~ scientists are not in such overwhelming agreement as they are about the genetic effects. I shall content myself with the statement that it is likely that the somatic effects of carbon 14 are/roughly equal to those of the other isotopes, including strontium 90.

The bomb tests carried ~~up to and~~ ^{out so far} (including 1958, which is starting off as a bad year) can be estimated to correspond roughly to ^{five} 30-megaton years. Accordingly we may say that the predicted effect of the carbon 14 released in ~~the~~ ^{these} bomb tests will be to produce about 1 million seriously defective children and about 2 million embryonic and neonatal deaths, and that the predicted effects of the other ~~isotopes~~ ^{isotopes} will be ~~to produce~~ ^{somewhat smaller.}

As other people have pointed out, these numbers ^{will} represent a minute fraction of the total number of seriously defective children ~~who will~~ ^{during coming centuries:} ~~be born~~ and of embryonic and neonatal deaths ^{less than 0.01 percent.}

~~The effects of the bomb tests carried out so far, some millions of defective children individuals, are approximately the numbers corresponding to one year at the present time; that is, approximately 1,500,000 seriously~~

~~defective children are born each year, and ~~and~~ there are approximately~~

~~twice that number of embryonic and neonatal deaths. The effect of carbon 14~~

~~will be spread out over thousands of years. Nevertheless,~~ ^{But} I feel that

each ~~individual~~ human being is important, and that it is well worth while

to calculate the numbers of individual human beings who will be caused

to suffer or to die because of the bomb tests, rather than to talk about

"negligible effect," "undetectable increase," "extremely small fraction."

Linus Pauling

Pasadena, California

8 May 1958