RADIOLOGICAL HAZARDS

BY

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Intensity of Radiation from Nuclear Explosions

There has recently been a considerable amount of discussion in Parliament and elsewhere on the biological effects of nuclear explosions. The greatest interest appears to be taken in the world-wide contamination which comes from test explosions. The most important source of contamination is the hydrogen bomb, since it produces 100 to 1,000 times more radio-active products than an atom bomb. The contamination is, however, of the same kind. The same radio-active fission products are produced and their activity decays in the same way. Thus the γ-ray intensity decreases by a factor of 50 between one hour after the explosion and one day. By the end of ten days it has decreased by a further factor of 20, and by a hundred days by a further factor of 10.

The explosion of a hydrogen bomb on the ground mixes millions of tons of soil with the radio-active products. Particles of all sizes from 1/50 in. diameter down to less than a thousandth of an inch are produced. These particles are transported by the wind. The larger particles fall out quickly. At Bikini they heavily contaminated a cigar-shaped area of the order of 7,000 square miles—220 miles long and about 40 miles wide. A large proportion of the radio-activity may come down in this local fall-out of the larger particles. The remainder of the radio-activity is carried into the stratosphere—about 50,000 ft—and is carried on very fine particles. These are carried round and round the world, gradually spreading out and falling slowly over a period of years.

Air-burst hydrogen bombs differ from ground-burst bombs in that practically all the radio-activity will go into the stratosphere and from there be deposited fairly uniformly.

In Great Britain we have monitored the contamination of the atmosphere by flights with aeroplanes carrying filters and by measurement of the radio-activity precipitated in rain water. From the aeroplane measurements we know that the intensity of radio-activity in the stratosphere, arising from the explosion, is very much greater than the activity at ground level. From rain water measurements we can determine the amount of radio-active contamination which is deposited on the ground. We can then calculate an upper limit to the γ-radiation which is emitted by assuming that the radio-active products have not diffused far into the ground and that the radiations from them are not appreciably absorbed.

We find that the average concentration of radio-activity in the air at ground-level during the past three years, due to bomb explosions of all types, is about 1 per cent of the average natural radio-active dust content. The highest peak of activity was half the average natural level. The natural level itself fluctuates, and in some periods reaches fifteen times the average level. This is probably due to changes with meteorological conditions in the concentration of the natural radio-active gas, radon, which comes out of the ground.

Coming now to the radiation or radio-activity effects of bomb explosions on human beings, the accumulated dose which will ultimately have been received in Britain by completely unprotected people from the fall-out which has so far occurred is about 0·01 r. An additional dose will be received from the fall-out of the debris which is still airborne. This is expected to increase the total dose to 0·03 r. In the United States, where local fall-out from Nevada is important, the average dose received from bombs so far exploded will total 0·1 r. The actual dose varies by a factor of 2 in different areas.

It is important to note, however, that the radiation is strongly absorbed by brick houses, and in the lower part of a house the radiation-level is decreased about twenty times. Since the average person spends a good deal of time indoors, the dose received will be reduced by a factor of at least 10. The radiation will also be reduced by the washing of the radio-activity down drains and into crevices in the ground ; the average dose in Britain is thus likely to be less than 0·003 r over a generation. How small this is can be judged from the fact that natural sources of radiation in the ground, cosmic rays and the natural radio-activity of the human body give us each a dose of 3 r over a generation of thirty years. So our additional dose from bombs so far exploded is something like a thousand times less than our natural dose.

Genetic Effects of Radiation

I turn now to the much debated genetic effects, with diffidence as a physicist. The effect of radiation is to increase the natural mutation-rate of the genes responsible for transmission of hereditary characteristics. The mutations produced by radiation are identical with the naturally occurring mutations, which have widely varying effects, ranging from pre-natal death and serious malformation to minor disabilities, such as loss of fitness, personality defects and minor mental changes. These mutant genes are transmitted from generation to generation as a genetic load of ill-health, until they are eliminated by death before reproduction or failure to reproduce.

Dr. H. J. Muller, one of the leading geneticists of the world, considers that to double the natural mutation-rate generation after generation would produce disastrous results in a civilized population. In his opinion, it is advisable, as a protective measure, to limit the dose received before reproduction to a quarter of the doubling dose—so that the mutation-rate would not be increased by more than 25 per cent. It is probably fair to say that the opinion of geneticists would differ widely on the maximum permissible level.

The best evidence on the radiation dose required to double the natural mutation-rate in mammals comes from experiments with large doses of radiation on mice in the Oak Ridge Laboratory of the U.S. Atomic Energy Commission. These suggest a doubling dose of about 50 r for mice. The extrapolation from mice to men is obviously an uncertain one. There is also a variation from gene to gene. If we accept Dr. Muller's criterion and apply the mice results to men, it would restrict us to a dose of 12·5 r per generation.

I have said that from the bombs exploded so far, the radiation dose received by most of us, shielded by houses and offices, will be less than 0·003 r per generation. We are therefore several thousand times below Dr. Muller's maximum level and our additional dose from bombs so far exploded is perhaps a thousand times less than the dose we received from natural sources.

Other harmful effects of test explosions have been suggested in a recent communication by M. Charles Noel-Martin to the Paris Academy of Sciences. He suggested that a 20-megaton bomb could form 500,000 tons of nitrous oxide gas, leading to production of nitric acid and a harmful increase in the acidity of rain water. He also stated that a ground explosion of this magnitude would send up 1,000 million tons of matter and that this would appreciably diminish the transmission of solar radiation ; and that enough radio-active carbon-14 might be formed to increase the natural radio-carbon content of the atmosphere by 10–30 per cent.

We have made some estimates of these effects at Harwell. American figures for the production of nitric acid by explosions suggest that M. Martin's figure is about ten times too high. The amount produced by thunderstorms every day is likely to be about equal to that for one hydrogen bomb explosion, so this effect cannot be important.

We have experience from the Krakatoa volcanic explosion (1883) of a diminution of 10 per cent in the intensity of sunlight at the earth's surface, due to the dust thrown into the atmosphere. This has been variously estimated at between 100 million tons and a figure 200 times higher. This great amount of dust had no effect upon the weather. Our own measurements of the amount of additional dust in the atmosphere due to nuclear explosions suggest that it is thirty times lower than M. Noel-Martin's estimates. The effect on solar radiation and weather must therefore be extremely small.

The radio-active carbon produced by a large thermo-nuclear explosion has been estimated at 300,000 curies. This will rise into the stratosphere and diffuse slowly downwards. The equilibrium amount will then be only one-thousandth of the amount naturally present in the atmosphere produced by cosmic rays. Since the natural carbon-14 contributes only 1 per cent of the natural dose to the human body, the effect is negligible.

If we turn from test explosions to the radiological effects of a full-scale hydrogen bomb war, the picture is a very different one. A great deal of information has been released by the U.S. Atomic Energy Commission on the radio-active fall-out from the Bikini H-bomb explosion of March 1st, 1954. The Commission has reported that an elongated cigar-shaped area down wind from the explosion, about 200 miles long by up to 40 miles wide, was heavily contaminated by the radio-active fall-out. In an area 140 miles in length and up to 20 miles in width, the lives of all persons who did not take shelter would have been seriously threatened. For example, on one part of Rongelap Atoll, 110 miles away, the total dose in 36 hr was 2,000 r.

Some distance farther from the point of detonation, at about 160 miles down wind and along the axis of the ellipse, the amount of radio-activity would have seriously threatened the lives of about half of the persons in the area who failed to take protective measures, that is, proper shelter from the radiation. It is estimated that the radiation dosage at that point was about 500 r for the first 36-hr period.

Near the outer edge of the cigar-shaped area and extending to approximately 190 miles down wind, it is estimated that the level of radio-activity would have been sufficient to have seriously threatened the lives of 5–10 per cent of persons who might have remained exposed out of doors for the first 36 hr. In this area the radiation dosage is estimated at about 300 r for the first 36-hr period.

The Japanese fishermen at a distance of 85 miles from the explosion received a dose estimated by Japanese radiologists as greater than 100 r.

The Home Secretary has spoken in the defence debate on the consequences of fall-out for civil defence in Great Britain. Those living outside the areas destroyed by blast and heat, but exposed to heavy radiation, would have at once to seek shelter in houses or other buildings. Measurements carried out at Harwell have shown that an ordinary brick house would probably reduce the intensity of radiation by a factor of at least 20, while additional shelter can be provided by a cellar or slit trench. It has been said in the United States that an old-fashioned cyclone cellar with a covering of earth 3 ft thick reduces the radiation intensity by 5,000. Having taken shelter, the occupants would have to stay inside until the radiation intensity had fallen to such a level that they could go out—at first for short intervals and then for longer periods. However, even after one week from the explosion, 36 per cent of the total dose has still to be delivered. In other words, in a zone contaminated so that the total long-term dose would have been 1,000 r, people coming out of shelter after one week for eight hours a day could still receive a long-term dose of 120 r. In these circumstances, a very large part of the population might receive more than the doubling dose. It is scarcely conceivable, however, that such an experience could recur in successive generations, and the genetic effect would seem to be a minor part of the overall catastrophe.

The world-wide contamination from a full-scale hydrogen bomb war can best be estimated by scaling up our estimate of the dose of 0·03 r which would be received in the open in Britain from all bombs exploded so far. If the number of hydrogen bombs were to be 1,000 times the number so far exploded—which seems very unlikely—there would be a hemisphere contamination corresponding to a dose of about 25 r. This would be somewhat beyond Dr. Muller's danger level if the experience were to be repeated generation after generation.

Before I leave this subject, I will try to dispose of another popular horror—the so-called cobalt bomb. There seems to be a general belief that still more lethal types of bombs could be produced by incorporating cobalt into a hydrogen bomb, and that such bombs might poison the whole earth. Our studies lead us to the conclusion that there is nothing in this idea—the cobalt bomb would offer no advantages to a lunatic designer.

Radiation from Nuclear Power Development

The large-scale development of nuclear power from uranium fission will necessarily produce large amounts of radio-active waste products having properties identical with those produced in nuclear explosions. The radiations are, however, mainly confined to the nuclear reactors which are the source of heat for nuclear power stations, and to the chemical plants where the radio-active wastes are extracted from the spent uranium fuel.

The radiation in the vicinity of the nuclear power units can be kept below the internationally agreed safe levels without difficulty by the use of suitable shielding. The average radiation dose received by Harwell workers is 0·25 r per annum. This is one-sixtieth only of the level agreed internationally as permissible for workers employed in such circumstances.

The public health problems are thus largely transferred to the chemical processing plants. The radio-active waste products include radio-active gases, such as radio-krypton and xenon ; these are at present allowed to escape from the processing plant in conformity with safety regulations, providing that no harm can be caused to the neighbourhood. It is likely that in future they will be bottled and turned to useful purposes. The emission of gaseous wastes will not increase to any significant extent as we develop the atomic power programme.

The radio-active solid wastes can be divided into three groups, only one of which presents a serious problem. The first group contains those isotopes which are only slightly radio-active ; these are comparable to the natural radio-active elements of the earth's crust, and dispersal is a satisfactory method of dealing with them. The second consists of the great majority of the radio-active elements produced in fission, and these decay fairly rapidly. Storage, for a period of about ten years, would reduce the activity to a level at which dispersal would be practicable and completely safe.

The third group is the one which presents difficulties. It consists essentially of two elements, strontium and caesium. Each of these has an isotope which decays moderately slowly, so that dispersal would only be possible after an unreasonably long storage period (hundreds of years). These two isotopes are finding increasing use in industry and medicine, and it appears there will be a commercial market for all available quantities of them for the next few years. Chemical separation of these isotopes will enable the Atomic Energy Authority not only to dispose of the first two groups without difficulty but also to market a valuable by-product.

It will, of course, be necessary to apply the same standard of radiation protection as has been adopted in the Atomic Energy Authority. By the time the supply of strontium and caesium exceeds the demand, the methods of permanent storage of these isotopes, on which work is proceeding vigorously, will have been fully worked out. The present safe procedures of disposal at sea and of long-term storage may still be valuable for a small amount of certain types of high-activity waste ; but it is probable that newer methods will supersede them. The problems of radio-active wastes in the atomic power programme seem likely to be solved by the technological developments now in hand.

General Conclusions

The level of radio-active contamination in the world produced by all the nuclear bomb explosions and peaceful atomic energy activities is at present so low that it should cause no anxiety. The radiation-level which would give rise to serious harmful effects is probably at least a thousand times the present level of contamination. We do not at present know this figure with any accuracy, and long-term genetic studies are required to determine this. A Committee of the Medical Research Council has been formed to investigate these problems.