FALL OUT

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Russia resumed nuclear weapon testing on the 1st of September, 1961. The test site at first was in the centre of the Euro-Asian land mass and later was in the Arctic region.

In Singapore no significant increase in radioactivity in the local atmosphere was reported in the first thirty days after resumption. Increased radioactivity was reported by the middle of November and was stated to be unusually high in the last four days of the month being 39.3 times the average before the resumption on the 29th, and 28 times the next day (1). In contrast radioactivity counts in Kuala Lumpur was at its highest 50% above the normal for the same period. On the 9th of February, 1962 it was announced that "it was dangerous to consume rain water directly because of the very high increase of radioactive fall out over Singapore recently". Eight days later it was made clear that rain water activity which was less than 100 micro micro curies per litre until the turn of the year, was 1789 micro micro curies per litre 31st of January, 1962 and fell to 325 micro micro curies per litre on the 2nd of February. (2)

Past experience with the 1958 Russian tests, also conducted in autumn, indicated that radioactivity carried up and stored in the stratosphere descended during the next spring. The cold air cap centred over the North Pole forms farther south the "Polar Front" where it meets the warm air. Near the top of this front is the region of the jet streams. It is in this region that in spring air is sucked down from the stratosphere together with the stored radioactive fission products to be distributed by the jet stream and washed down to earth by rain. These longer lived fission products are spread across a broad band between latitudes 35-75° N. with a peak at 35-40° N. Radioactivity not carried into the stratosphere is deposited within about a week after the explosion to the north of the above band and is usually of short lived activity. Therefore the Equator and the Tropics should get little or no fall out. In spite of the two large megaton weapons exploded at the end of October 1961, peak activities in England and U.S.A. were recorded on the 19th and 20th of September, 1961 respectively. Harwell reports that the bulk of the fall out from the 1958 Russian tests left the stratosphere in less than a year, the peak average activity being in May 1959 and the activity in reservoirs and lakes reaching a maximum in the third quarter of 1959, and decreasing thereafter.

There has been great alarm over the hazards of ionising radiations from fall out and this article seeks to present facts which may help the reader to view the problem in its true perspective.

Radiation hazards exist even before the days of fall out. Natural radioactivity came with the formation of the Universe. The earth was bombarded from outer space by cosmic radiations and on the earth itself were many naturally occurring radioactive elements, e.g., ^{235}Uranium, ^{226}Radium, ^{24}Sodium, ^{40}Potasium, ^{14}Carbon, etc. These radioactive elements give off radiations that bombard the body from without, but if taken up and incorporated in the tissues of the living body irradiate the body from within. These natural radiations from outer space and on earth constitute background radiations which were regarded as being responsible for genetic mutations.

With the advancement of science, man-made ionising radiations have come to the fore-front in the minds of the public. Of these the medical uses of X-rays for diagnostic and therapeutic purposes and radioactive isotopes for investigations and treatment form by far the most important group.

Industrial uses of ionising radiations are becoming more and more common in the examination of castings and welds, in sterilisation of articles, in thickness gauges for continuous measurement of thicknesses of moving strips, etc.

Finally there is fall out as a result of fission products in controlled nuclear reactions in a reactor or as a result of nuclear bomb explosions. Nuclear fission products can be of all elements but generally they fall into two large groups of Atomic Wt. 80-100 and 130-150. The most important of these as far as radiation hazards are concerned are radioactive ^{131}Iodine, ^{95}Zirconium, ^{90}Strontium and ^{137}Caesium.

Fall out can become very important even in controlled nuclear reactions as in the case of the runaway reactor at Windscale (3). Because of the excess of fission products the screens failed to trap radioactivity from leaving the chimney and a large amount of radioactivity was released into the atmosphere to contaminate large areas of south western Britain. The problem was so great that the Medical Research Council (4) suggested a maximum danger level for ^{131}Iodine in a limited population five hundred times the activity it proposed later for the general population i.e. 65,000 micro micro curies/litre as against 130 micro micro curies/litre of milk for a year.

The damage done to tissues is related to the energy absorbed from the ionising radiations by the tissues. The unit of energy absorbed in a medium is the rad; one rad = 100 ergs/gram of medium irradiated. The amount of energy absorbed in tissue or for that matter in any medium is related to the type of radiation, the energy of the radiation, and the "average atomic no." and "electron density" of the elements in the medium. Generally, radiations can be divided into two main groups:—

1. Corpuscular radiations
   e.g. beta particles (electrons),
   alpha particles (Helium nuclei),
   protons, and
   neutrons.
2. Electromagnetic radiations
   e.g. X-rays from man-made generators and gamma rays from radioactive isotopes.

The total amount of energy absorbed from the radiations by the body will further depend on the penetrating power of the particular radiations concerned. Thus beta and alpha rays being easily stopped by a medium will cause damage to a smaller volume than X-rays which will penetrate through the whole thickness of the body. Moreover, even for the same amount of energy absorbed in unit volume, the damage varies with the density of ion pair clusters formed along the tracks of the rays. The greater the density the greater the damage and in living tissues this results in a greater biological effect. Hence the term Relative Biological Efficiency of a type and energy of radiation. Thus a dose of one rad from neutron bombardment is twenty times more effective than one rad from X-rays, other factors being equal. To take into consideration this factor another unit the R.E.M. (Roentgen Equivalent Man)= Rad x Relative Biological Efficiency, was established. Thus the dose of one rad from neutrons is 20 rems and from X-rays one rem. The International Commission for Radiological Protection (5) has adopted the REM in presenting the maximum permissible levels of radiation, in particular external irradiation.

Any radioactive element is radioactive because it is unstable and disintegrates to give rise to corpuscular and gamma radiations thereby changing into another isotope or element. The unit of activity is the Curie.

One curie = 3.7×10^{10} disintegrations/sec.
One millicurie = 3.7×10^{7} disintegrations/sec.
One microcurie = 3.7×10^{4} disintegrations/sec.
One micro micro curie = 3.7×10^{-2} disintegrations/sec.

The time a sample of radioactive substance takes to reach half its initial activity is known as its half life and the half lives of different radioactive elements vary from a few seconds to thousands of years. In the living body there is a constant turnover of the body elements. The time in which a quantity of radioactive isotope absorbed into the body takes for its activity within the body to be reduced to one-half is known as the Biological half life of that isotope. It is naturally related to the physical half life and the rate of excretion of the isotope, and this determines in a large measure the damage the isotope will cause in the body.

Damage is also influenced by certain other physical factors. Different radioactive elements give rise to different types of radiations of different energies. Thus for the same activity a radioactive isotope giving off weak beta emissions will cause less damage than that giving off stronger beta emissions, assuming that the physiological factors are the same. Similarly gamma emitters will cause more damage than beta emitters of the same energy and activity. The damage to the body arising from 10 millicuries of Tritium is no more than that of 10 micro curies of ^{32}Phosphorous which has a thousand times less activity.

From the foregoing it can be seen that an expression of activity means exactly disintegrations per second and no more. To know whether there is danger or not we must first know the type and energy distribution of the radiations given by the activity. Having known the isotope, its activity. The damage to the body arising from and taking an average body size it is then possible to calculate the dose to the body and in particular to the gonads. From the maximum permissible level for gonad dose at 100 millirems/week for workers allowed by the International Commission for Radiological Protection (5) it is possible to calculate the maximum level of activity in the body for a given isotope — that is, the maximum permissible body burden that will give this dose to the gonads.

Taking into consideration duration of exposure and factors of metabolism, the maximum permissible concentrations of activity in air and liquid media for a given radioactive isotope to give the allowable level in the body can be calculated. The figures put forward by the International Commission for Radiological Protection are for radiation workers. For the general population the maximum permissible concentrations in air or liquid media will be a tenth of this.

The Medical Research Council (4) recommends that an average concentration of 130 micro micro curies of ^{131}Iodine/litre of milk be not exceeded over a period of one year. Higher activity of 1000 micro micro curies/litre or 300 micro micro curies/litre of ^{131}Iodine for a day or a week cannot be considered as dangerous.

Up to 1959 nuclear weapons totalling 174 megatons had been exploded and in 1958 Russian test series 50 megatons were exploded. The natural background radiation contributes an estimated dose to the gonads of 100 millirads/year; but may rise to as much as 250-400 millirads per year e.g. at high altitudes and in granite surroundings. In 1957-58 the average gonad dose from diagnostic X-rays was 14 millirads in Britain (4). Indefinite continued testing at the level prevailing in 1958 would give an annual radiation dose rate of 14 millirads to the gonads. The full effects of the 30 and 50 megaton explosions are not yet known and it is not yet possible to predict with any accuracy the total additional radiation dose to the general population.

However, it is accepted that the two large bombs exploded in October 1961 were mainly fusion explosions and not 50% fission and 50% fusion (6). Hence their radioactivity bears no linear relationship with their explosive power. It has been officially estimated that up to 2nd of November 1961 the Russians have exploded 160 megatons and the West 130 megatons (7). It can be seen thus that at its worst the average gonad dose from fall out of the present test series is not likely to equal that from natural background sources. Taking natural background at 100 millirems per year the gonad dose per generation during useful reproductive life (say to 40 years of age) is 4 rem. J. H. Muller (8) the geneticist, regards doubling of mutation rate generation after generation as leading to possible disaster for the community. He advocates a protective limit of one quarter the doubling dose per generation. The dose causing doubling of mutation is held to be about 80 rems. It is thus recommended that a gonad dose of 20 rems per generation be not exceeded. Even assuming the gonad dose from fall out to equal that from natural background, this dose is still much too small to have a measurable effect on the health of the present generation or the genetics of future generations. There are many regions in the world where generations have lived with an annual background dose to the gonads of 200-400 millirems with no apparent deleterious effects.

The Medical Research Council (9) in October 24th 1961 issued a statement on radioactive fall out in the light of the resumption of nuclear weapon testing. Paragraph 23 reads:—

> "Regular measurements of radioactivity in rain, drinking water, food including milk, air, soil, vegetation and human bone are continuing according to a country-wide programme under the supervision of the Medical Research Council and the Agricultural Research Council. The results of measurement of radioactive fall out are published at frequent intervals. Premature attempts to interpret the significance of individual early measurements directly in terms of human hazard can be extremely misleading. Variations in the measurements are to be expected both from day to day and as between one place and another. The significant factors are average levels over long periods of time".

In conclusion there would appear to be a brighter side to the picture. In 1959 Harwell (10) announced that by ion exchange systems (much like water softeners) it was possible to remove 98% of ^{131}Iodine and ^{90}Strontium in milk at a cost of 4½d. per gallon. In December this year ion exchange systems to remove these isotopes were installed in milk processing plants in Denmark.

Work is also being done to develop chelating agents which can "unhook" radioactive isotopes already fixed in the body, thereby permitting body excretory processes to remove these isotopes from the body.

SUMMARY

The development of increased radioactivity in Singapore following the Russian tests in Autumn 1961 is traced. The general pattern of fall out in the northern hemisphere is also described.

Sources of ionising radiations are considered together with factors important in the interaction of matter with these radiations. Activity is defined and distinguished from dose.

Gonadal dose from natural background is considered with fall out and maximum permissible levels in liquid media.

The danger from fall out to date is shown to be negligible.

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