APPENDIX K

Report on Emergency Exposure to External Radiation

*Recommendations of the M.R.C. Committee on Protection against Ionizing Radiations**

The Medical Research Council has continued a study of the effects on the health of persons in the neighbourhood of atomic energy installations should there be a release of radioactive material as a result of fires or other incidents. The Council's Committee on Protection against Ionizing Radiations has already reported (Medical Research Council, 1959) on the maximum permissible dietary contamination for iodine 131, strontium 89, strontium 90 and caesium 137, since it was considered that for the members of the public normally resident in the area affected ' ingestion of contaminated food would generally be the limiting source of hazard after any such accident ' and that ' intake by inhalation, or radiation from the exterior, would become of importance only in rather special circumstances '.

The present report deals with the problem of exposure from the exterior, namely, from external sources of beta and gamma radiation. This exposure might be derived from two sources, one of relatively short duration from the passage of a cloud of radioactive material, the other of longer duration from deposited material. It is necessary to consider what the biological consequences of such exposure might be; so that appropriate administrative actions can be planned. For instance, it would be possible, in spite of all the difficulties, to evacuate people temporarily to spare them the external dose from the contaminated environment. This procedure would, however, necessitate a decision as to when they could return to the area.

The only people who might be at risk are those in the immediate neighbourhood. These people might receive, from a passing cloud, exposure to gamma rays at a relatively high dose-rate, which would depend markedly, among other things, on whether they were indoors or in the open at the time. The doses so received would affect the acceptable amount of radiation they may subsequently be allowed to receive from deposited material.

The relative importance of exposure to the cloud and to the deposited material is dependent upon so many factors, including the nature of the incident itself, that the Council's Protection Committee has felt it appropriate simply to recommend certain total doses that should, if possible, not be exceeded. In deciding upon these doses the Committee has used the fullest information available at the present time, but it should be realized that knowledge of the effects of ionizing radiation is continually increasing and that the subject of permissible doses is constantly under review.

The specification of acceptable levels of exposure to radiation, whether it be for persons occupationally exposed or, as in the present case, for persons exposed as the result of an accident in a neighbouring atomic energy installation, is a complex task in which many factors have to be balanced. It is necessary to take into account both short- and long-term effects, for which, as the dose

* See page 154.

and dose-rate increase, so in general does the probability of manifestation. Since recovery plays a part, some effects may be merely temporary. Thus, although certain doses are described as acceptable, they do not represent levels below which there is no effect whatsoever and above which there will necessarily be serious consequences. This point is particularly important in relation to exposure occurring in an emergency when the evacuation of people is contemplated. There are hazards in such an operation and if doses somewhat in excess of those considered acceptable appear likely to be received, the responsible authority will have to assess the relative risks of these against those of evacuation.

The acceptable doses should be considered in the light of the previous paragraph. They are such that neither short- nor long-term effects are likely to be observed even if the irradiation were all due to the passage of a radioactive cloud and thus of short duration. There is a possible exception to this, which is discussed in more detail below, namely, the irradiation of the embryo or foetus. In deciding upon the acceptable doses the Committee has taken into consideration that it is possible but unlikely that the same persons would be significantly exposed in more than one emergency, and the levels are such that a second exposure after a period of some years should not give rise to undue concern.

The present proposals may be compared with the most recent Recommendations of the International Commission on Radiological Protection (I.C.R.P., 1959, 1960), but in so doing it should be appreciated that the Commission has not so far dealt with the problem of emergency doses for members of the general population. The I.C.R.P. recommendations refer principally to the long continuing exposure of adults in the group that is occupationally exposed to ionizing radiations, and are intended to limit both the short-term and the long-term effects to acceptable levels. Reference is, however, made to the ' accidental ' and ' emergency ' exposure of persons in this group and also to the long continuing irradiation of persons in certain special groups amongst which are ' members of the public living in the neighbourhood of controlled areas '. The Commission has also suggested a maximum permissible genetic dose for whole populations together with an illustrative apportionment of this dose to various sources of exposure. All these aspects are discussed below in relation to the present proposals.

RECOMMENDATIONS

The following total doses of radiation are considered acceptable for members of the general public as a result of an incident at an atomic energy establishment. They are to be considered as independent of the duration of the irradiation:

(1) The dose of gamma rays giving exposure to the whole body but measured in free air:

Children up to the age of 16 years and pregnant women	20 roentgens (r)
Other persons	30 roentgens

(In the circumstances envisaged, 30 r will give rise to about 25 rads in superficial tissues: 20 r will give rise to about 15 rads in superficial tissues and about 10 rads in an embryo or foetus.)

(2) Subject to (1) above, the combined dose of beta and gamma rays giving exposure to the whole body surface and estimated in any superficial tissue:

Children under the age of 16 years	75 rads
Other persons	150 rads

(3) For small areas of contaminated skin in total not greater than 1/10 of the body surface, doses from beta rays averaged over 1 cm^2 additional to those specified in (2) above:

Children up to the age of 16 years	75 rads
Other persons	150 rads

(4) In order to allow essential duties to be performed, a special category of a few persons is envisaged, consisting of adult males (preferably in the older age groups) or of females above reproductive age. For this group, a dose of gamma rays giving exposure to the whole body but measured in free air, additional to the doses specified in (1), (2) and (3) above ... ... 30 roentgens

COMMENTS ON THE RECOMMENDATIONS

General

The above recommendations refer to doses of radiation that are considered to be acceptable in an emergency for members of the general public. In applying the recommendations, however, the objective should be to minimize exposure as far as is practicable and to avoid exposure that is unnecessary.

Dose of gamma rays giving exposure to the whole body

The dose of gamma rays specified in recommendation (1) for adults is about half the maximum dose to age 30 recommended in the last report of the Medical Research Council (1956), for persons occupationally exposed to ionizing radiations. In the current recommendations of the I.C.R.P., the maximum permissible dose to age 30 from occupational exposure is 60 rems*, the rate of dose accumulation averaging 5 rems per year and being limited to 12 rems in a year. The dose specified in recommendation (1) therefore represents 5 years' accumulation at the average permissible rate and approximately 2 years' accumulation at the maximum permissible rate. It is also equal to the ' accidental high exposure ' dose which is regarded by I.C.R.P. as acceptable ' once in a lifetime ' by radiation workers without loss of radiation status, and is approximately twice the dose of 12 rems recommended by I.C.R.P. as being the basis upon which emergency operations by radiation workers should be planned. As regards the doses recommended by I.C.R.P. for persons not occupationally exposed, 25 rads represents about 17 years' exposure at the annual rate of 1·5 rems which is permitted without medical supervision to adults who may be irradiated from nearby sources.

The most difficult decision to take was that concerning an acceptable dose for an embryo or foetus. In the first place, the embryo is much more sensitive to the effects of radiation than mature tissue. There is qualitative evidence of

* For radiations of the type considered in this appendix the relative biological effectiveness is 1 and the rem and the rad can be regarded as equivalent.

this from experience in clinical radiology. There is further evidence of a semi-quantitative nature derived from irradiating pregnant experimental animals. Under these conditions, moderate doses of radiation during the earliest stages of development of the fertilised egg may lead to the death of the embryo; this would probably not be recognizable in the human case. At an intermediate stage when the various tissues are being differentiated, the embryo may not be killed by radiation but be born alive with developmental defects. Doses as low as 25 r to the pregnant mouse have been recorded as producing a significant number of detectable deformities (Russell, 1957). (In the human being this particular stage of morphogenesis may extend from somewhat before to just after the second month of pregnancy; that is, it is at a time when pregnancy may not be suspected or affirmed.) The final stage of foetal life which is short in the mouse (but long in man) is marked by a rapid increase in resistance to this type of damage by radiation.

Secondly, some recent surveys of the histories of children dying before the age of 10 years from malignant disease suggest that prenatal exposure to X-rays could have been a contributory factor. The normal death rate in England and Wales from malignant disease before the age of 10 is of 1 child in every 1,200, and a survey by Stewart *et al.* (1958) suggests that this rate may be doubled by irradiation *in utero* arising from the abdominal X-ray examination of the mother. However, a survey being carried out by Court Brown *et al.* (1960) indicates that, if there is any effect at all, it is much less than that reported by Stewart *et al.* Studies made in the United States and elsewhere have also shown conflicting results (Kjeldsberg, 1957; McMahon, 1958; Ford *et al.*, 1959).

The various surveys differ in the way in which the study and control populations were selected, and also in the way in which the fact of prenatal diagnostic examination was established. Also it is possible that the mean levels of radiation dose given in the diagnostic examinations were not the same for the different surveys. It is hoped that further investigations will clarify the issues. In the meantime the possibility of effects arising from antenatal radiography must be considered to be *sub judice*.

However, if we use the finding of Stewart *et al.*, an assessment can be made of the maximum likely effect of a dose of 10 rads to the embryo or foetus. We estimate that the mean foetal dose received during the abdominal X-ray examinations was possibly about 1 rad, although it may have been several times higher in individual cases. The rate of incidence of pregnancy in England and Wales is about 12 per 1,000 persons. Consequently (assuming a linear relationship and that the doubling dose is 1 rad), the number of childhood deaths due to malignancy before the age of 10, induced by a mean dose of 10 rads *in utero* through the exposure of 1,000 persons could be:

$$12 \times \frac{10}{1} \times \frac{1}{1200} = 0{\cdot}10.$$

If the mean foetal dose had in fact been higher than 1 rad, this result would have been proportionately less.

The I.C.R.P. recommendations do not exclude pregnant women from occupational exposure and consequently, according to the current recommendations, they would be permitted up to 9 rems during the nine months of any one pregnancy. Women of reproductive age are, however, debarred from

receiving the dose of up to 12 rems that radiation workers are permitted during planned work in ' emergencies ' which might arise in certain operations. This exclusion of such women was intended to protect an unsuspected foetus from receiving such a large dose in so short a time.

The dose of 20 r for children up to the age of 16 was chosen as being intermediate between the foetal and adult doses. It is desirable to specify a lower dose than for adults as (i) it is known that children are more radiosensitive, (ii) the mean tissue dose will be higher for a child than for an adult receiving the same superficial dose, and (iii) children have a longer period during which any potential effect could be manifested. Owing to the possible presence of children among persons living in the vicinity of radiation installations, I.C.R.P. limits the maximum whole-body dose for such persons to 0·5 rem per year; accordingly, a child would be permitted 8 rems to age 16.

Combined dose of beta and gamma rays giving exposure to the whole body surface and additional dose of beta rays to small areas of skin

Recommendation (2) permits, in the presence of the maximum recommended exposure to gamma rays, beta-ray doses of about 60 rads up to age 16 and 125 rads above age 16. Beta-ray exposure is confined to superficial tissues and the I.C.R.P. recommendations pertaining to the skin are relevant. The current I.C.R.P. recommendation for the skin for persons occupationally exposed is 30 rems per year and thus the combined doses for persons up to and over the age of 16 represent $2\frac{1}{2}$ years' and 5 years' exposure respectively at the maximum permissible rate for radiation workers.

The additional beta-ray doses referred to in recommendation (3) are mainly intended to cover the cases of (*a*) beta-active dust trapped in flexures of the skin, and (*b*) the beta-ray exposure of the hands of the category of persons referred to in recommendation (4). In this connection it should be noted that the current I.C.R.P. recommendation for the hands and forearms, feet and ankles for persons occupationally exposed is 75 rems per year.

The lens of the eye is protected to a great extent from beta radiation by its depth (about 3 mm), so that the dose received will be essentially equal to the gamma-ray dose plus a small fraction of the beta-ray dose. It is unlikely that this fraction will exceed 1/10, and it is considered that for the beta-ray energies likely to be encountered, the recommendations will ensure that the dose to the lens will be acceptably low.

Additional dose of gamma rays giving exposure to the whole body permitted for essential duties

The type of duty envisaged for the special category referred to in recommendation (4) is the tending of livestock, the maintenance of public utility services, and emergency activities of various types. The number of persons permitted this additional exposure should be small and they will need to be specially supervised. If considerable exposure to beta radiation is envisaged, the wearing of appropriate clothing should be considered and it will of course be necessary to control as far as practicable the hazards from ingestion and inhalation.

Genetic considerations

It is thought that only a few people would be involved in the conditions under consideration and indeed, provided the number were small compared with one-fiftieth of the whole population, no further limitation of the doses would be necessary on genetic grounds. In its apportionment of its suggested whole population genetic dose, I.C.R.P. allocates 1·0 rem to occupational exposure, 0·5 rem to the exposure of certain special groups and 2·0 rems to the exposure of the population at large. The present recommendations for emergency exposure will result in a ' genetic dose ' per incident which is extremely small compared with 0·5 rem, as the proposed maximum gamma-ray dose per person involved is, in general, 25 rads and it is anticipated that the number involved will be very small compared with one-fiftieth of the population.

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