NCRP

National Council on Radiation Protection and Measurements
7910 Woodmont Avenue / Bethesda, MD 20814

Extension of the Skin Dose Limit for Hot Particles to Other External Sources of Skin Irradiation

NCRP Statement No. 9, Issued March 30, 2001

The National Council on Radiation Protection and Measurements (NCRP) has been asked by the U.S. Nuclear Regulatory Commission to consider the desirability and technical validity of establishing a single occupational limit that would apply to any external radiation exposure of the skin regardless of the source or geometry of the irradiation. This unified limit would serve to limit absorbed dose from hot particles on or off the skin, from small areas (<1 cm^2) of skin contamination, from large-area skin contamination, and from any external radiation source.

In this Statement, the NCRP recommends the adoption of the limit recommended in its Report No. 130 for hot particles as a limit applicable to all skin exposures, and provides comment on the technical and health implications of such an action. It is important to note that this Statement is an extension of the recommendations in Report No. 130 and is not a stand-alone document. It is meant to be used in conjunction with Report No. 130 and other cited documents.

In NCRP Report No. 130 (NCRP, 1999), the Council recommended an absorbed dose limit for hot particles. This recommendation was based on in-depth review and analyses of the various factors involved in understanding the response of the skin to ionizing radiation exposures. These factors included the radiation dosimetry for the skin, the structure and function of the skin (dermis and epidermis), and deterministic and stochastic effects resulting from irradiation of large and small areas of the skin.

During the development of Report No. 130, the NCRP determined that for hot particles on the skin an absorbed dose limit of 5 Gy averaged over the most exposed one square centimeter of skin at a depth of 70 μm (equivalent to 7 mg cm^{-2}) would meet NCRP's stated objective (NCRP, 1993) of preventing the occurrence of clinically significant radiation-induced effects.[1] This is a dose comparable to that resulting from exposure at the limit of irradiation of the skin with 10^{10} beta particles, as previously recommended by NCRP (1989) to prevent what was termed "deep ulceration." Even if a clinically significant deterministic effect were to result from a hot-particle exposure near or exceeding the recommended limit, the result would be an easily treated condition still involving extremely small risk of medical complications. Such occurrences would be indicative of the need for improvement in radiation protection practices, but cannot be compared in seriousness to exceeding the whole-body dose limit.

However, for hot particles off the skin, *e.g.*, on clothing or hair, the degree of movement of a particle and separation between the particle and the skin are difficult to quantify, and hence a limit had to be derived that would take account of a range of potential hot-particle skin-exposure geometries and that would prevent both early and late clinically significant deterministic effects. An absorbed dose limit of 0.5 Gy from an individual hot particle, with the dose averaged over 10 cm^2 at 70 μm depth, was found to provide a simple way to fulfill this requirement for all exposure situations involving a particle off the skin as well as for a particle on the skin, resulting in a harmonized limit. Exposure of any of the same 10 cm^2 of skin by more than one hot particle within a year, with a cumulative absorbed dose greater than 0.5 Gy would be judged as indicating that the annual general skin dose limit of 0.5 Sv (ICRP, 1991) had been exceeded.[2]

The Council also recommended that possible effects of exposure to individuals with doses that could result in even a low probability of a breakdown of the skin barrier function should be monitored and that action be taken if a lesion were to develop. As a guide, the NCRP suggested that any exposures from hot particles that could result in an absorbed dose of 0.1 Gy, or greater, averaged over 10 cm^2 at 70 μm depth be considered as indicative of the need for such monitoring.

It is recommended in NCRP Report No. 130 (NCRP, 1999) that:

> *For hot particles on skin (including ear), hair or clothing, limitation of irradiation be based on ensuring that irradiation from a hot particle would not be expected to result in breakdown of*

[1]Based on the available evidence developed in animal studies, using the pig, whose skin is similar to that of human skin.

[2]The hot particles considered in NCRP Report No. 130 were limited to those emitting beta particles and photon radiation for which absorbed dose (Gy) and equivalent dose (Sv) are numerically equal.

the skin barrier function with the consequent possibility of infection.

The dose to skin at a depth of 70 µm from hot particles on skin (including ear), hair or clothing be limited to no more than 0.5 Gy averaged over the most highly exposed 10 cm^2 of skin. This can be viewed as a per-particle limit so long as the areas of skin exposed by the hot particles do not overlap. In the event that the areas of skin exposed by two or more hot-particle exposure events overlap, then the limit applies to the calendar year rather than to the individual events.

Observation of the exposed area of skin for four to six weeks be initiated whenever the dose evaluated at a depth of 70 µm exceeds 0.1 Gy averaged over the most highly exposed 10 cm^2 of skin.

The recommendations provided by the NCRP in Report No. 130 (NCRP, 1999) include the situation in which a hot particle is assumed to adhere to the clothing of an individual and moves around relative to a fixed point on the skin. In this case, the resulting skin dose would be much more uniform than for the situation in which the hot particle was assumed to have been deposited on the skin in an essentially immobile state. In essence, the dose distribution for a hot particle that adheres to the clothing of an individual would be comparable to that from an external, broadly distributed source. For this reason, it is clear that a single radioactive particle in random motion relative to the skin could produce a dose distribution equivalent or nearly equivalent to that from either distributed contamination on the skin or an external beam that exposed the same area. The main difference is that the instantaneous dose rate to any very small area of skin would be higher for a moving hot particle or a very small beam than for uniform contamination or a uniform beam delivering the same total dose over the same area. For this reason the limits for irradiation of the skin by hot particles, 0.5 Gy averaged over 10 cm^2 at 70 µm depth, may be applied to all sources of irradiation of the skin.[3]

[3]The Council no longer recommends the use of dose equivalent or equivalent dose for skin exposures because these quantities were developed for stochastic effects whereas the principal skin effects being addressed are deterministic in nature. If it is necessary to apply the skin limit to high-LET radiations, the Council recommends the approach taken in NCRP Report No. 132 (NCRP, 2000) in which the absorbed dose is multiplied by the relative biological effectiveness of the radiation to obtain "gray equivalent." This may then be compared to the limit expressed in gray.

Just as for hot particles, the possibility of minor deterministic effects may exist in the case of irradiation of very small areas of skin at or near the limit, but these are not considered to be clinically significant radiation-induced effects (NCRP, 1993). Once the area of uniform irradiation exceeds 10 cm^2, there is no difference in the potential deterministic risks between the existing limit of 0.5 Sv averaged over 1 cm^2 at 70 µm depth (ICRP, 1991; NCRP, 1993) and the proposed limit of 0.5 Gy averaged over 10 cm^2 at 70 µm depth.

As shown in NCRP Report No. 130, the risk of a stochastic effect (skin cancer mortality) is extremely small for a hot-particle irradiation at the recommended limit (1.1×10^{-7}), and this risk would also be extremely small for other small-area irradiations. Once the area of irradiation exceeds 10 cm^2, the proposed limit is identical to the existing limit for skin (ICRP, 1990; NCRP, 1993), and the stochastic risks would be the same. Thus no increase in stochastic risk to skin is associated with the recommendations in this Statement.

For hot particles, the reader is referred to NCRP Report No. 130 (NCRP, 1999) for guidance to good practices in addition to the recommended numerical limits. This guidance may also be useful for other irradiations of very small areas.

Specifically, it is recommended that:

For skin, limitation of occupational radiation exposure from external sources be based on ensuring that irradiation from any source would not be expected to result in breakdown of skin barrier function with the consequent possibility of infection.

The absorbed dose in skin at a depth of 70 µm from any external source of irradiation be limited to 0.5 Gy averaged over the most highly exposed 10 cm^2 of skin. This can be viewed as a per-irradiation event limit so long as the exposed areas of skin do not overlap in such a way that the total absorbed dose to the most highly exposed 10 cm^2 of skin exceeds the limit during a given year. In the event that the areas of exposed skin overlap, then the limit applies to the calendar year, consistent with the annual general skin limit of 0.5 Gy y^{-1}, rather than to the individual events.

References

ICRP (1991). International Commission on Radiological Protection. *1990 Recommendations of the International Commission on Radiological Protection*, ICRP Publication 60, Annals of the ICRP **21** (Elsevier Science, New York).

NCRP (1989). National Council on Radiation Protection and Measurements. *Limit for Exposure to "Hot Particles" on the Skin*, NCRP Report No. 106 (National Council on Radiation Protection and Measurements, Bethesda, Maryland).

NCRP (1993). National Council on Radiation Protection and Measurements. *Limitation of Exposure to Ionizing Radiation*, NCRP Report No. 116 (National Council on Radiation Protection and Measurements, Bethesda, Maryland).

NCRP (1999). National Council on Radiation Protection and Measurements. *Biological Effects and Exposure Limits for "Hot Particles,"* NCRP Report No. 130 (National Council on Radiation Protection and Measurements, Bethesda, Maryland).

NCRP (2000). National Council on Radiation Protection and Measurements. *Radiation Protection Guidance for Activities in Low-Earth Orbit*, NCRP Report No. 132 (National Council on Radiation Protection and Measurements, Bethesda, Maryland)