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The Ability Of Alpha Radiation To Penetrate Human Skin

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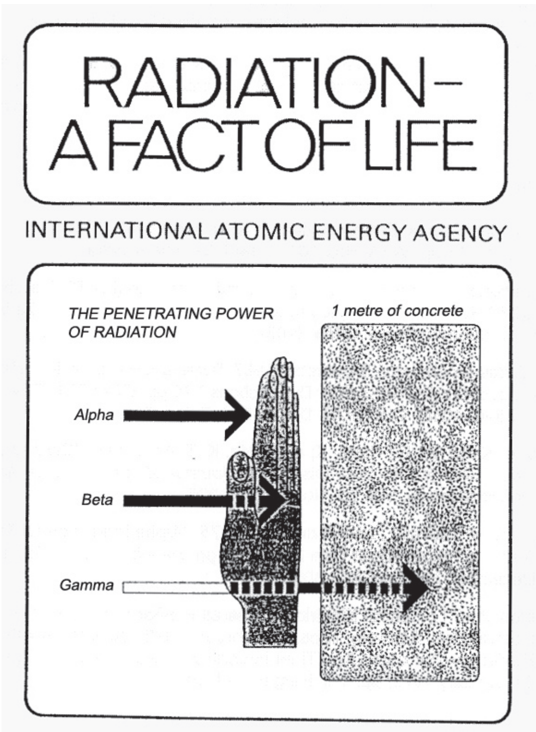
Compared to other forms of radiation, alpha radiation has a relatively low penetrating power. Authors for or against nuclear power, worried or not worried about the effects of radiation, use the same type of graphics illustrating the penetrating ability of radiation. In these graphics, alpha radiation is illustrated as being stopped by the skin or a piece of paper. An example of such a graphic is included below. It was published in 1982 by the IAEA in a booklet titled “Radiation Is A Fact Of Life.” [1]



The main perpetrator of the belief that alpha radiation cannot penetrate the skin is the International Commission For Radiological Protection (ICRP). It is ICRP recommendations, based on the belief that alpha radiation cannot penetrate the skin, that are the basis for many official claims that alpha radiation presents a low radiological hazard. For example, the U.S. Department of Energy (DOE) wrote in 1987 that,

> *“Alpha particles resulting from the primary disintegration of uranium present no external radiation problem, since they do not penetrate the skin.”* [2]

Following is an examination of the validity of this belief. However, it is not contested that radionuclides pose the greatest threat to human health when they are inhaled or ingested. With regards to alpha radiation, the short distance alpha particles are capable of travelling and their low penetrating power make it especially important to distinguish between internal and external exposure. This is particularly important where radiation exposure to workers determines the time limit the workers are allowed to carry out certain tasks.

In the event of external exposure to alpha radiation the skin will receive a radiation dose. To determine if alpha radiation can penetrate human skin deep enough to reach living cells it is necessary to define thickness of the outermost skin layer (called epidermis) and determine the significance of sweat pores. These problems are discussed below, followed by results of a skin cancer frequency study among Czechoslovakian uranium miners.

Defining Epidermal Thickness, The Study By Judi Whitton

In the early 1970s Judi Whitton recognized the significance of epidermal thickness for radiological protection. Sponsored by the Central Electricity Generating Board (CEGB, a then British government owned nuclear utility company), she carried out a detailed literature survey to try and determine the origin and accuracy of epidermal thickness values then in use. Whitton wrote that “ICRP Publication 2” (1959, p. 9) refers to a meeting of the Permissible Dose Conference at Chalk River, Canada in September 1949 where a value of 77 microns was chosen for minimum epidermal thickness. The source of this measurement is given as a histology [3] textbook from 1942, which in turn gives no original source of the data. [4]

A possible source of the ICRP 77 micron value was traced by Whitton from a presentation made at a 1963 symposium held in England called “Radiation and Health.” This presentation also gave a value of 77 microns for epidermal thickness, and listed the source as two German studies from 1876 and 1879. Since some of the results of the 1879 study correspond to those given in the 1942 histology textbook, it is possible that the ICRP value originates there. Whatever the purpose of the 1879 experiment, it could not have been performed for the purpose of setting radiation protection standards, as the modern nuclear era did not come into being until several decades later. Further, formation of what was to become the ICRP did not happen until 1928, about a half-century later.

A fundamental aspect of any epidermal thickness experiment is whether or not it takes into consideration the natural elasticity of the skin. When epidermis is removed from a body it naturally shrinks and curls up. Results of an epidermal thickness experiment are therefore much more accurate when correction is made for shrinkage of the epidermis. Comparison of results from experiments that did and did not take into consideration shrinkage of the epidermis shows that the value for epidermal thickness is about half when shrinkage is taken into account. [5] Regardless of the origin of the ICRP value of 77 microns, the number is clearly within the range of results from experiments that did not take into consideration shrinkage of the epidermis.

As Whitton’s literature survey was unable to confirm the origin and accuracy of epidermal thickness values then in use, a project was set up to make original measurements that overcome the inadequacies of previous experiments. The problem of shrinkage of the epidermis was overcome by marking a circular area of epidermis to cut out, tracing the size of this area onto a template, cutting the epidermis around the mark, then stretching and pinning it down onto the template corresponding to the original size. The normal measuring procedure can then be carried out. Since large samples of epidermis are required for this technique, the thickness measurements derived from epidermis from a dead body were converted to weight measurements of a small sample. Sampling was then carried out on live volunteers using a three millimeter diameter punch. Two weight/thickness correlation factors were used; one for thick epidermal areas such as the palm of the hand and soles of the feet (100 micrograms is approximately equal to 33.3 microns) and the second for other epidermal areas such as the face and trunk (100 micrograms is approximately equal to 24.4 microns).

Whitton concluded:

“Epidermal thickness has been shown to be in general less than is usually assumed at present. In particular the value of 7 mg/cm2 (77 microns) [6] suggested by ICRP for ‘minimal epidermal depth’ appears to be an over-estimate for most body sites.

“As health physicists have assumed in the past that minimal epidermal depth is 7 mg/cm2 (77 microns), skin dose from alpha emitters external to the body has been ignored. From the present study it is clear however that on many parts of the body the basal layer [7] lies within the range of several high energy alpha emitters.” [8]

This conclusion is supported by observations that alpha sources can cause abnormal redness of the skin, [9] and by studies of skin cancer frequency among Czechoslovakian uranium miners (discussed below).

Whitton found that epidermal thickness can vary over the body from a mean of 44 to 440 microns. [10] However, the ICRP uses a uniform value for the whole body, despite it being common knowledge that epidermal thickness varies greatly between different parts of the body. For general skin dose control, Whitton recommended replacing the value of 77 microns for minimal epidermal thickness with a value of 44 microns for mean epidermal thickness. [11] In 1977, the ICRP recommended use of a mean epidermal thickness value of 70 microns, and noted epidermal thickness may range from 50 to 100 microns. [12] This ICRP recommendation was made four years after publication of the research by Whitton reviewed here.

Providing Whitton's measurements are correct, several alpha emitting isotopes, including U238 and U235, have a particle energy great enough to penetrate the epidermis where it is thinnest on the body. Some examples of the approximate mean depth different alpha particles can penetrate tissue are: americium-241, 54 microns; U235, 43 microns; and U238, 41 microns. [13] Though these U235 and U238 values are below the mean minimum epidermal thickness of 44 microns noted above, it must be remembered that 44 microns is the mean minimum not the absolute minimum. In some cases epidermal thickness is greater and in some cases less than 44 microns.

Whitton further concluded:

> *"No obvious correlation of epidermal thickness with sex was observed on any of the body sites. Similarly there appears to be no consistent change in epidermal thickness with increasing age on any body site."* [14]

Sweat Pores

One may assume from the Whitton study that parts of the body where the epidermis is thickest, such as the palm of the hand and finger tips, that the epidermis is sufficiently thick to block the most energetic alpha particles. This is not the case. Whitton fails to mention that for fragments as tiny as alpha emitters the existence of eccrine sweat glands, commonly called sweat pores, and hair follicles all over the skin present a barrier with few but large holes. What is more, the palm of the hand, though having extra thick epidermis, has a greater density of sweat pores than areas of the body where the epidermis is thinner.

The average density of sweat pores varies greatly with the individual and body site. The total number of sweat pores distributed over the entire body has been estimated at from 1.6 to four million; and the number on specific body sites as 64/cm2 on the back, 108/cm2 on the forearm, 181/cm2 on the forehead, and 600 to 700/cm2 on the palms of the hand and soles of the feet. [15]

The size of the sweat gland has been found to vary as much as fivefold between individuals. The dimension of the coil leading down from the opening in the epidermis is about two to five mm long and about 60 to 80 microns in diameter, with the duct having a slightly smaller diameter. [16] In contrast, the diameter of a uranium oxide particle is about one micron. [17] The diameter of an alpha emitter itself is more than one thousand times smaller than the diameter of a sweat pore. The spiraling nature of the sweat gland coil leading down from the opening may limit the depth into the epidermis that alpha particles and emitters reach. Further, the percentage of total surface area of epidermis made up of sweat gland openings is small, being only a few percent in areas where sweat pores are most dense. Nevertheless, alpha emitters can cause skin cancer after fastening in sweat pores despite:

- the small percentage of total surface area of the epidermis made up of sweat gland openings,
- the coiling nature of sweat glands,
- and other considerations such as sweat gland openings being plugged, and the angle of entry.

In addition, alpha emitters can stick to any part of the skin.

Skin Cancer Among Czechoslovakian Uranium Miners

Analysis has been done of skin cancer frequency in a group of several thousand Czechoslovakian uranium miners over an eight year period (1968-1975). The study concluded that the incidence of skin cancer (basal cell carcinoma) was significantly higher than expected (by almost 10 times), especially among miners who had worked for 10 years or more. The predominant location of facial cancers was the cheek and forehead, places where skin is especially thin. [18]

Dose estimates were made from radon daughters to the skin. The dose from uranium and other alpha emitters was not included. It was found that after working 10 years or more, miners could receive a cumulative dose equivalent of 10-20 Sv. The study concluded that such high doses to the basal epidermal layer (where live cells nearest to the surface of the skin are located) is evidence that external alpha radiation from radon daughters may be the cause of the cancers. [19] The authors concluded,

> *"The results of this short-term observation indicate the actual possibility of a carcinogenic effect of external alpha irradiation of the skin."* [20]

Adding hope to their dismal conclusion, the authors noted,

> *"The consequences of skin cancer are much less severe than the consequences of malignant tumors in other organs because skin cancer occurs in accessible places, allowing an early diagnosis and more successful surgical therapy."* [21]

Conclusion

Contrary to popular belief, alpha radiation is not always blocked by the outermost skin layer (the epidermis) and external exposure to alpha radiation may cause cancer. Several alpha emitting isotopes, including U238 and U235, have a particle energy great enough to penetrate the epidermis where it is thinnest on the body. In addition, alpha emitters can fasten in hair follicles and sweat pores and stick to any part of the skin. For these reasons, external dose to the skin from alpha emitters must be taken into account in determining the health effects of alpha radiation.

Notes

[1] IAEA, June 1982, p. 3.
[2] Oak Ridge Operations, September 1987, p. 56.
[3] Histology is the branch of biology dealing with the study of tissues.
[4] Whitton, 1972, p. 1; in: Health Physics, Vol. 24, January 1973.
[5] Whitton, 1972, pp. 4-5; in: Health Physics, Vol. 24, January 1973.
[6] One mg/cm2 is approximately equal to 11 microns for tissue, according to Whitton, p. 1; in: Health Physics, Vol. 24, January 1973.
[7] The “basal layer” contains the live cells closest to the surface of the skin.
[8] Whitton, 1972, pp. 7-8; in: Health Physics, Vol. 24, January 1973.
[9] Whitton, 1972, p. 7; in: Health Physics, Vol. 24, January 1973.
[10] Whitton, 1972, p 1; in: Health Physics, Vol. 24, January 1973.
[11] Whitton, 1972, p. 8; in: Health Physics, Vol. 24, January 1973.
[12] International Commission For Radiological Protection (ICRP), March 1987, p. 13.
[13] These micron values are based on a formula presented in: Sorenson, James A. and Phelps, Michael E., 1980, p. 148. The average alpha particle energies are listed in: Browne, Edgardo and Firestone, Richard B.; Shirley Virginia S. (ed), 1986.
[14] Whitton, 1972, p. 5; in: Health Physics, Vol. 24, January 1973.
[15] Sato, et. al., 1989, p. 538; in: Journal Of The American Academy Of Dermatology, Vol. 20, No. 4. April 1989.
[16] Sato, et. al., 1989, p. 539; in: Journal Of The American Academy Of Dermatology, Vol. 20, No. 4. April 1989.
[17] The size of uranium oxide particles is taken from a 22 January 1981 report by Mark Goldberg prepared for the Bjarnie Paulson court case on behalf of the Canadian Coalition For Nuclear Responsibility, Box 236 Snowdon Post Office, Montreal, Quebec, Canada. H3X 3T4. Tel. 1-514-489-2665.
[18] Sevcova, et. al., 1975, p. 805; in: Health Physics, Vol. 35, December 1978.
[19] Sevcova, et. al., 1975, p. 805; in: Health Physics, Vol. 35, December 1978.
[20] Sevcova, et. al., 1975, p. 806; in: Health Physics, Vol. 35, December 1978.
[21] Sevcova, et. al., 1975, p. 806; in: Health Physics, Vol. 35, December 1978.

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