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A5_2 Indiana Jones: Raiders of the Radioactive Ark

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Abstract

How much radiation does it take to melt a face? This paper looks at the infamous face-melting scene from 'Indiana Jones: Raiders of the Lost Ark'. We explore the idea that if the Ark was in fact a lead-lined box with a gamma-ray radioactive source inside; how much radiation would be needed to 'melt' a human. We find that the required dose of radiation required to 'melt' a human in 10 seconds is $H_T = 3.83 \times 10^7 Sv$, which gives the absorbed dose rate value of $2.29 \times 10^8 Gy/min$.

Introduction

In the film 'Indiana Jones: Raiders of the Lost Ark', at the climax of the film the Nazis successfully open the Ark. However, they soon find out about the forbidden power in the Ark as it quickly reduces their faces to nothing but melted goo. The Ark is said to contain "lightning ... fire ... power of God, or something", but for the purpose of this paper we will consider the to Ark to be a gamma-ray radioactive source housed in a lead-lined box.

Theory

In the movie, the Nazi leaders face melting scene lasts approximately 10 seconds whilst they're standing directly in front of the Ark. This means that we assume that they were exposed to the radiation for 10 seconds and distance between the Ark and the leader is negligible. The paper 'Complete Vaporisation of a Human Body', written by students from the University of Leicester, states that the total amount of energy required to completely vaporise a human body of average mass $78kg$ to be $2.99GJ$ [1]. In the film, the Nazi's are effectively vaporised or 'melted', hence we assume that that the full $2.99GJ$ of energy is transmitted over the 10 second period to one person through gamma radiation.

Radiation Dose

To estimate a value for the required radiation, we must first look at how radiation interacts with the human body. To account for the way in which different types of radiation cause harm in tissue or an organ, radiation dose is expressed as equivalent dose in units of Sievert (Sv) [2]. The equivalent dose, H_T in Sv is equal to the absorbed dose in the organ or tissue, D_T, multiplied by the radiation weighting factor, W_R.

$$H_T = D_T \times W_R \tag{1}$$

The energy and type of incident radiation determines the value of W_R. For example, the value of W_R for gamma rays, x-rays and beta particles is 1, but higher for protons ($W_R = 5$), neutrons ($W_R = 5 - 20$) and alpha particles ($W_R = 20$). Hence for this paper we will use $W_R = 1$ since we are assuming the Ark houses a gamma-ray source.

The absorbed dose, D_T is the amount of energy absorbed per unit weight of the organ or tissue and has units of gray (Gy) [3]. One Gray dose is equivalent to one joule of radiation energy absorbed per kilogram of organ or tissue weight (Jkg^{-1}). The absorbed dose, D_T can be calculated by dividing the radiation energy absorbed, E_D by the mass of the observer, m:

$$D_T = \frac{E_D}{m} \tag{2}$$

We can also calculate the absorbed dose rate, D_R. This is done by dividing the absorbed dose, D_T through by the time, t the observer is exposed to the radiation:

$$D_R = \frac{D_T}{t} \tag{3}$$

Results

Using $E_D = 2.99GJ$ and $m = 78kg$, we calculate the absorbed dose D to be $3.83 \times 10^7 Gy$ by using Eq. (2). We can also calculate the absorbed dose rate, D_R. This is done by dividing the absorbed dose, D_T through by the time, t the observer is exposed to the radiation: Substituting in our value for time $t = 10s$ into Eq. (3), we find the absorbed dose rate D_R to be 3.83×10^6 Gy/s ($2.29 \times 10^8 Gy/min$). Dose rate is incredibly important in determining the degree of damage done to tissue or organ. A low dose rate (LDR) is defined as equal to or below 0.1 mGy/min (equivalent to $1.66 \times 10^{-6} Gy/s$), any value higher is classed as a high dose rate (HDR) [4]. Hiroshima and Nagasaki survivors were exposed to a gamma radiation dose rate between 1.2×10^4 and $4.2 \times 10^6 Gy/min$ [4].

Now that we have the value for the absorbed dose D_T, we can determine the equivalent dose H_T using Eq. (1). As H_T is simply D_T multiplied by W_R, using the value of $W_R = 1$ gives the equivalent dose $H_T = 3.83 \times 10^7 Sv$.

Conclusion

It is widely agreed that if a population is exposed to $4Sv$ to $5Sv$, within 30 days it is predicted that 50 percent of the population will die [5], hence we take $5Sv$ to be the minimum fatal dose of radiation required for a human. In this paper, we have calculated the amount of radiation from the Ark that would cause the Nazi leaders to 'melt' to be $3.83 \times 10^7 Sv$. This 'melt' value is of an order of 10^7 larger than the fatal dose. Furthermore, the absorbed dose rate that the Nazi leaders would experience ($2.29 \times 10^8 Gy/min$) is several magnitudes larger than dose rates of Hiroshima and Nagasaki survivors. Therefore, we believe that if the Ark was a lead-lined box which contained a gamma-ray source capable of emitting $H_T = 3.83 \times 10^7 Sv$ over a period of 10 seconds (leading to a dose rate of $2.29 \times 10^8 Gy/min$), then if someone opened it they would be 'melted' - just like in the film.

References

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