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P1 1 Peta Bombs and You

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Abstract
In this paper, we discuss the *Fallout* universe's radiation levels, specifically the values in *Fallout 3*. Values are based upon the measured Rads that the player character intakes when drinking water from contaminated sources and the known length of time following the bombs being dropped. The number of 10 kiloton (kT) bombs dropped during *The Great War* was calculated to be 2.3×10^{17}.

Introduction

In the video game *Fallout 3*, the world has been reduced to an irradiated wasteland due to nuclear warfare, with the majority of humanity having to live in horrifying vaults to survive. Approximately 181 years after the bombs fell, humans have formed settlements outside of the vaults due to the significantly decreased radiation levels [1].

Theory

Nuclear fallout is caused by the fission products of nuclear detonation, such as the caesium-137 that is produced in the Uranium based weapons that we will use for our calculations, polluting the nearby area with a layer of radioactive dust. The dust spreads through the atmosphere before settling on the surface and reacting with available water. This reaction produces caesium hydroxide [2] which spreads uniformly throughout a body of water and has a similar half life to that of caesium.

$$2\,\mathrm{Cs} + 2\,\mathrm{H_2O} \longrightarrow 2\,\mathrm{CsOH} + \mathrm{H_2} \qquad (1)$$

The game uses a now defunct unit known as Rads (radiation absorbed dose). In standard units, 1 Rad is equivalent to 0.01 Gray (Gy) (J kg^{-1}). This is a direct measure of the energy absorbed by tissue or the body as a whole, as in our case, and is equivalent to the more common measurement Sieverts (Sv) in the case of gamma and beta radiation, of which makes up all of Cs-137 decay [3].

Calculation

The game *Fallout 3* takes place 181 years after the bombs dropped and contains the item *Dirty water*, a bottle of water collected from a contaminated freshwater source. The drinking of this water results in the character acquiring 5 Rads instantaneously [1]; this is inconsistent with the slow release of radiation that would occur in real life. We can assume, then, that this is the total dosage accounting for the time the water takes to pass through the body. From this we can calculate the intake dose rate using the following formula:

$$\int_{t_0}^{t_1} N_0 (1/2)^{t/t_{1/2}} dt = 5 \qquad (2)$$

Which is simply an integration over time t of the Decay rate formula, where N_0 is the initial decay rate and $t_{1/2}$ is the Cs-137 half life of 30 years.

The average adult bladder size is 16-24 ounces [4], this is considered here to be $\approx$ 500 mL and is, therefore, considered full after drinking what we assume to be a 500 mL water bottle. It "takes your body [up to] 9 to 10 hours" to produce urine with a full bladder [4], so taking $t_1 = 9.5$ hours gives $N_0 = 1.46 \times 10^{-4}$ Rad s^{-1}

Assuming an average water bottle to be 500 mL and using the total volume of above-ground freshwater in the United States as 2,360 km^3 [5], the total radiation within the water in the US can be calculated as 6.9 $\times 10^{11}$ Rads s^{-1}.

Since the total surface area of the water in the US is 699,000 km^2 [6] and total surface area of the US is 9.83 $\times 10^6$ km^2 [7], we see that 7.1% of the US surface area is water. Using this, the total surface radiation can be calculated as 9.7 $\times 10^{12}$ Rad s^{-1}.

By using the formula for half-life once again

$$N(t) = N_0 (1/2)^{t/t_{1/2}} \tag{3}$$

where $N(t)$ is the radiation dose rate after 181 years, the radiation on the U.S surface 48 hours after the bombs dropped, N_0, can be calculated as 6.4 $\times 10^{14}$ Rad s^{-1}. 48 hours is used as radiation levels decrease significantly during that time and then level off into the normal decay rate [8].

Considering that 48 hours after detonation, the dose rate from fallout of a 10 kT bomb is equivalent to 0.00278 Rads s^{-1} [8], the amount of nuclear bombs required to irradiate the surface to the calculated values would be 2.3×10^{17}.

Discussion and conclusion

We make several assumptions when making our calculations; most notably the complete disregard of water precipitation and runoff, which would reduce the percentage of radiation on the land and increase the amount in the water. This would also reduce the number of nuclear bombs required to replicate the scenario presented in the game. Another assumption is that the US is an enclosed space, whereas in reality the winds would carry away a lot of the radioactive residue across the seas, though the fact that the rest of the world would also be irradiated would make this difficult to account for.

In conclusion, we find the number of 10 kT bombs required to irradiate the U.S to be 2.3×10^{17}. This is a huge number of bombs and therefore could be seen as unrealistic since, in 2024, there are only approximately 12,000 nuclear warheads [9].

References

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