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P5_2 Praimfaya: The Second Nuclear Apocalypse

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Abstract

In Season 4 of *The 100*, all of Earth's unattended nuclear reactors melt within 6 months of each other, rendering the Earth uninhabitable for the second time in the shows history. We produce a model for the rate of decay in Caesium-137 fallout radiation levels. We discover that the total radiation, when averaged over the surface of the Earth, is 4.63 Sv $yr^{-1}km^{-2}$. We also calculate that it would take 156 years until the Earth's surface reached a safe level of radiation.

Introduction

Season 4 of the science fiction television show *The 100* concludes with a small crew leaving Earth in a rocket to escape an apocalypse caused by the near-simultaneous melting of all of Earth's nuclear power stations. This event, known as 'Praimfaya', is explained by the nuclear power stations being unmanned since the first nuclear war disaster from Season 1. In the epilogue scene, Clarke, a miraculous survivor of Praimfaya due to genetic modification, radios the escapees' spaceship. She says "...it's been 2,199 days since Praimfaya . It's been safe for you to come down for over a year now."[1]. We will model the radiation levels caused by the fallout from Praimfaya and assess the accuracy of Clarke's assertion.

Theory and Results

The 100 is set in the year 2150 and due to a previous apocalypse modern technology ceased development in 2052 [2]. To estimate the number of active nuclear reactors in 2052 we used a forecast by the UN International Panel on Climate Change [3]. They recommend doubling the world's nuclear power capacity by 2050 so we doubled the current number of nuclear power stations [4] and used 898 power stations in our model.

The Chernobyl disaster initially produced radiation at 300 Sv hr^{-1} [5] near the core. We converted this value to Sv yr^{-1} and multiplied by the number of power stations. We assumed that the radiation would cover the Earth evenly, so divided by Earth's surface area, 5.101×10^6 km [6], giving us initial radiation of 4.63 Sv $yr^{-1}km^{-2}$.

In order to calculate the time for this level to decrease to the safe level, we used Eq. (1):

$$N(t) = N_0 e^{-\lambda t} [7] \tag{1}$$

Where $N(t)$ is the 'long-term safe level of radiation after a radiological accident', 130 mSv yr^{-1} [8], N_0 is the initial radiation level , λ is the decay constant and t is the time for N_0 to decrease to $N(t)$. Substituting the decay rate equation $\lambda = ln2/t_{1/2}$ [7], where $t_{1/2}$ is the half-life, and rearranging for t, gives:

$$t = -\frac{t_{1/2}}{0.693} ln\left(\frac{N(t)}{N_0}\right) \tag{2}$$

The three main fallout isotopes from Chernobyl were Iodine-131, Caesium-134 and Caesium-137 [9]. We used the longest-lived isotope, Caesium-137, where $t_{1/2}$ is 30.17 years, as we wanted to be conservative in our model. This will result in an overestimate however the model could be adapted in further work to include a mixed isotope ratio when the ratio is known.

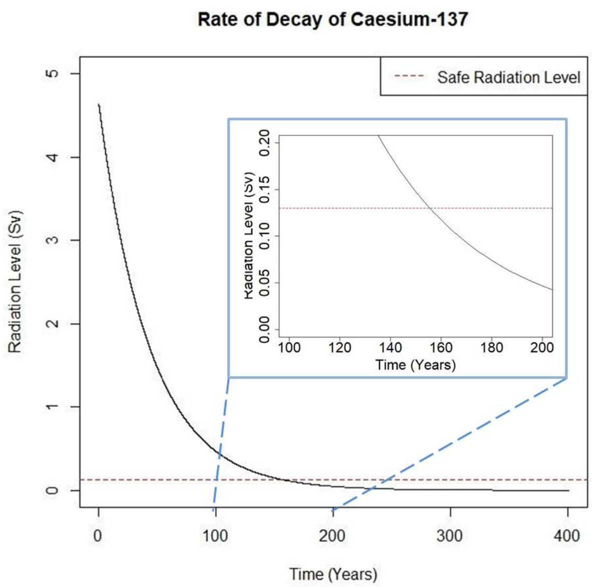

Figure 1: This graph shows the exponential decay of Caesium-137 produced in the fallout. Inset shows inflated view of safe radiation level intersect.

We calculated that t=156 years and also showed this in a graphical model (Fig. 1). This is considerably longer than the 5 years Clarke implied. This discrepancy is discussed below.

Discussion

It is possible that the escapees may be able to return to Earth earlier than we calculated as in the show they have a higher tolerance to radiation from their time in space. However it is unlikely to be as early as Clarke claims since our model shows radiation would be ~4.0 Sv yr^{-1} after 5 years, which is likely to be fatal.

We assume the reactors are evenly distributed so to further develop the accuracy of this model, we suggest creating a 2D map of fallout based on the worldwide locations of nuclear reactors.

In reality, there are sufficient safety mechanisms in place to ensure a nuclear reactor would shut itself down in the event of it running out of coolant. In the case of there being sufficient coolant, the nuclear reactors would expend their fuel supplies over time, eliminating the risk of nuclear meltdown.

We recognise that these constraints are likely to prevent an event like this happening however our model is relevant within the confines of the show.

Conclusion

Clarke claimed that the radiation dropped to a safe level 5 years after Praimfaya. From our model we judge that this is a severe underestimate and conclude that the radiation levels would be survivable 156 years after Praimfaya.

References

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[7] P. A. Tipler and G. Mosca, *Physics for Scientists. 6th edition*, W. H. Freeman (2007).

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