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P3 1 Radiation Exposure in Ecuadorian Banana Factories

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Abstract

Physics students have known that bananas are radioactive for years, but none have ever considered the plight of the banana packer. In this paper, we investigate the total dose a banana packer would receive over a year of working, and find that the dose is 4.42 μSv of radiation per year, which is less than ingesting a banana a day (estimated dose of 36.5 μSv) and thus unlikely to be a concern.

Introduction

Individuals who work in banana farming may be at risk of radiation poisoning due to their proximity to large quantities of bananas, which are slightly radioactive due to the presence of potassium. Ecuador in 2017 had 5,000 small farms produce a total of 6.28 million metric tonnes of bananas [1].

We will estimate the annual exposure a worker may experience with a 9am-6pm 5-day working week (260 days) [2] while packing bananas for Del Monte's Premium Single Finger Banana Box, and compare this to the radiation received by eating bananas. This box was chosen because it contains exactly 24 bananas and thus estimates in radiation exposure can be more precise [3]. We will assume that all the harvested bananas maintain a steady unchanging flow through the packing facility, approximating a constant source.

Theory

Radiation exposure is the intensity of radiation at a given distance to a source. From this, we can derive a formula for calculating the worker's radiation exposure. We first being with the formula for intensity:

$$X = \frac{P}{4\pi}\frac{1}{R^2} \tag{1}$$

Where X is the exposure, P is the power output of the radioactive source, and R is the radius of the sphere. From this, we can see that the exposure follows the inverse square law which is to be expected as it is a measure of intensity.

Importantly, equation 1 also shows that the exposure multiplied by the distance squared will always equal $\frac{P}{4\pi}$, hence we can form a new formula that removes this altogether, comparing the exposure from two similar sources:

$$X_{worker}R^2_{worker} = \frac{P}{4\pi} = X_{ingest}R^2_{ingest} \tag{2}$$

$$X_{worker} = \frac{X_{ingest}R^2_{ingest}}{R^2_{worker}} \tag{3}$$

Where X_{worker} and R_{worker} are the exposure (in Sv/hr) and distance for a worker in a banana farm (in metres), and X_{ingest} and R_{ingest} are the exposure and distance for a person receiving radiation from ingesting a banana.

The United States Environmental Protection Agency states that "each banana can emit 0.1 μSv [1.0 x 10^{-7} Sv] of radiation," which can be used to determine X_{ingest} [4]. Food spends on average 41.5 hours in the body [5], so we can deduce that the hourly exposure from ingesting 1 banana is 2.41 x 10^{-9} Sv/hr. This will be X_{ingest}.

Of the 41.5 hours food spends in the body, most of its time will be in the intestines which sits just below the centre of the body [5]. Hence, the most practical estimation for the distance to the source, R_{ingest}, would be the mean distance to the center of the body from the intestines which is 0.0625 m based on an average descending colon length of 0.125 m [6].

Bananas are packed in boxes within arm's reach in order to be as efficient as possible, so we will estimate R_{worker} to be half the size of the arm, which is approximately 0.346 m [7].

We will assume that the worker will have a steady flow of 24 bananas within arm's reach while working from 9am to 6pm 5 days a week. The exposure, X_{worker} will be calculated using equation 3 by substituting calculated values for X_{ingest}, R_{ingest} and R_{worker}. This will then be scaled up to account for all 24 bananas, and then scaled again to find the annual dose.

Results

Substituting X_{ingest}, R_{worker} and R_{ingest} returns an hourly exposure of X_{worker} = 7.86 x 10^{-11} Sv/hr for 1 banana, which is 1.89 x 10^{-9} Sv/hr for all 24 bananas.

For a 260 day 9am to 6pm working year, this equates to an annual dose of 4.42 x 10^{-6} Sv, or 4.42 μSv.

This level of radiation is 8.26 times smaller than the dose received by eating a banana a day for a year (36.5 μSv), and thus will likely have no long-term effects on workers. However, we also must consider that there are many more than 24 bananas in proximity to the workers at any time. Further investigation into the exposure received by different workers may be useful in identifying dangerous positions in the supply chain, but the outcome is likely to be that the dose is non-lethal in any case.

Conclusion

In this paper, we estimated the dose a worker may experience while packing bananas in Ecuador. We found that the typical worker may experience around 4.42 μSv of radiation per year, which is 8.26 times smaller than ingesting a banana a day. It is thus highly unlikely that workers are at any health risk from packing bananas, and the paper also outlines a few other concerns regarding the health of banana workers.

References

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