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Mathematical Modeling on decay of radioactive material affects Cancer Treatment

[1] L.R.Hatwar, [2] R. B. Pohane, [3]S.P. Padole, [3]S.D. Bhoyar
[1] Department of Physics, Suryodaya College of Engineering and Technology, M.S. India, Nagpur
[2,3] Department of Mathematics, Suryodaya College of Engineering and Technology, M.S. India, Nagpur
lekhrajhatwar3@gmail.com[1], +91-9373316708

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Abstract

In this paper we report the mathematical model on radioactive material Co- 60 decay over the period of time and the step by step decaying the material over the stipulated time, half-life period of Co-60 leads changes in the treatment time during radiotherapy cycle, potentially impacting treatment efficacy. Mechanisms on mathematical model help to understand the interfacial effect and the facial effect on patient body using nuclear disintegration process of material decaying during half-life period of C-60.

Introduction

Mathematics as a collection of theoretical, abstract ideas that are taught in schools apart from everyday life. This viewpoint, however, ignores how vital mathematics is to both professional and everyday life. Indeed, mathematics permeates every aspect of our lives and is essential to many different areas. We practically always employ mathematics in our daily lives. The ability to use mathematics in practical contexts fosters critical thinking and problem-solving abilities. Because it enables people to handle complex circumstances and come up with creative and practical solutions, this skill is highly recognized in the professional world. This paper revels that that solving the real life problem on radiotherapy treatment of radioactive material cobalt -60 and their sequential changes on patient body due to nuclear disintegration process.

Mathematical Modeling

We can use this formula to determine the number of radioactive atoms that remain after a given period of time. We just care about the fundamentals here, however there are numerous general versions of the equation that deal with chains of nuclides. We begin by pointing out that the quantity of radioactive atoms in a sample determines how quickly radioactive decays occur in that sample Co-60.
Mathematically, we represent this as,
Let M be the amount of Co-60 at time t
The rate of disintegration of Co-60 is always proportional to amount present at that time t

$\frac{dm}{dt} \alpha$ m

$\frac{dm}{dt}$ = -km, k is constant of proportanility

$\frac{dm}{m}$ = -k dt

Integrate

Logm = -kt + log c , log c is constant

Initially m = 10 gm, t=0 year

m = 5 gm t=1 year

m=?   t = 5.27 year

$\log 10 = 0 + \log c$

$\log m = -kt + \log 10$

$\log \frac{m}{10} = -kt$

$\log \frac{5}{10} = -k$

$-k = \log \frac{1}{2}$

$\text{Log}(m) = t \cdot \log \frac{1}{2} + \log 10$

t= 5.27

$\log \frac{m}{10} = 5.27 \cdot \log \frac{1}{2}$

$\log \frac{m}{10} = \log \left(\frac{1}{2}\right)^{5.27}$

m = 0.2591 gm which is negligible amount after 5.27 years

Now let n is Number of nuclides

The rate of disintegration of nuclides is always proportional to amount present at that time t

$\frac{dn}{dt} \; \alpha \; n$

$\frac{dn}{dt} = -kn$, k is constant of proportanility

$\frac{dn}{n} = -k\,dt$

Integrate above equation, we get

Log (n) = -kt + log c, log c is constant

initially t=0 years , $n = 10^6$

t= 5.27 years, $n = 5 * 10^5$

t= 10*5.27=52.7 years , n = ?

$\log 10^6 = 0 + \log c$

$\log \frac{n}{10^6} = -kt$

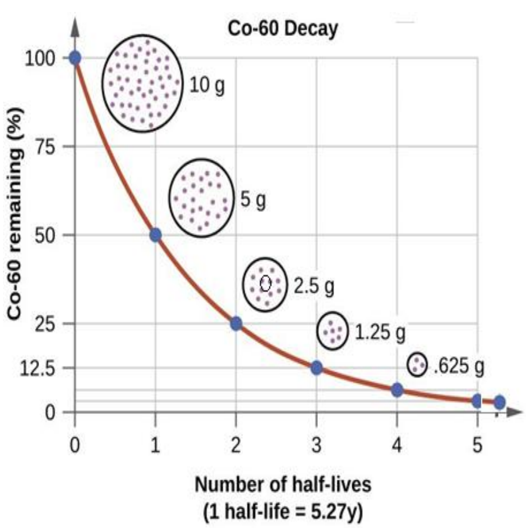
$\log \frac{1}{2} = -k * 5.27$

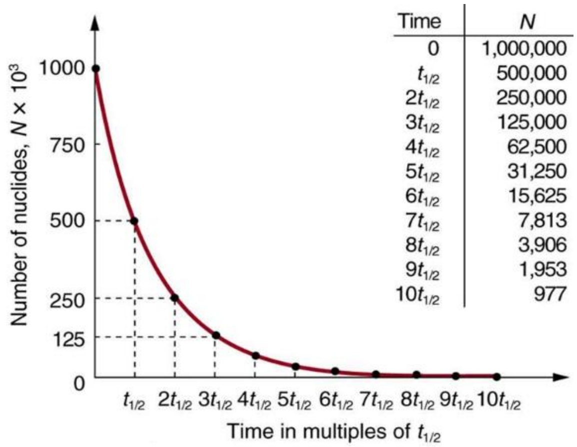
$-k = \frac{1}{5.27} \log \frac{1}{2}$

$\text{Log } n = \frac{1}{5.27} \log \frac{1}{2} * t + \log c$

$\log \frac{n}{10^6} = \frac{52.7}{5.27} * \log \frac{1}{2}$

n= 976.56 = 977 nuclides.





Impact On Patient Treatment

1. Reduced dose rate: The dose rate given to the tumor likewise drops as the radiation intensity does. To make sure the tumor gets the proper dosage, the treatment strategy may need to be modified.

2. Increased Treatment Time: Treatment durations may need to be prolonged in order to administer the same total dose in order to make up for the decreased dose rate. Patients may find this bothersome, and there may be a higher chance of radiation-related side effects.

3. Potential for Tumor Repopulation: The tumor may repopulate with new cancer cells if treatment is prolonged, which would decrease the treatment's efficacy.

4. Impact on Treatment Outcome: The gradual reduction in radiation intensity may affect the treatment outcome, potentially leading to reduced local control or increased recurrence rates.

Radiation Intensity Induced Side Effects

Acute Effects (During or Immediately After Treatment)

1. Fatigue: Feeling tired or exhausted due to radiation exposure.
2. Skin Reactions: Redness, itching, burning, or desquamation (skin peeling) in the treated area.
3. Hair Loss: Temporary or permanent hair loss in the treated area.
4. Nausea and Vomiting: Feeling queasy or vomiting due to radiation exposure.
5. Diarrhea or Constipation: Changes in bowel movements due to radiation exposure.

Sub-acute Effects (Weeks to Months after Treatment)

1. Radiation Dermatitis: Inflammation of the skin, which can lead to scarring or fibrosis.
2. Mucositis: Inflammation of the mucous membranes, leading to ulcers or bleeding.

3. Xerostomia: Dry mouth due to reduced saliva production.
4. Dysphagia: Difficulty swallowing due to radiation-induced inflammation or scarring.

Late Effects (Months to Years after Treatment)

1. Fibrosis: Scarring of tissues, which can lead to organ dysfunction.
2. Radiation-Induced Cancer: Increased risk of developing secondary cancers due to radiation exposure.
3. Cardiovascular Disease: Increased risk of cardiovascular disease due to radiation exposure.
4. Hypothyroidism: Underactive thyroid gland due to radiation exposure.
5. Infertility or Sterility: Radiation-induced damage to reproductive organs.

Organ-Specific Side Effects

1. Brain: Radiation-induced cognitive impairment, memory loss, or seizures.
2. Lungs: Radiation-induced pneumonitis or fibrosis.
3. Heart: Radiation-induced cardiomyopathy or coronary artery disease.
4. Gastrointestinal Tract: Radiation-induced bowel obstruction, fistula, or perforation.

Managing The Impact

1. Regular Source Replacement: Regularly replacing the Cobalt-60 source with a new one can minimize the impact of radiation intensity reduction.
2. Treatment Planning Adjustments: Adjusting the treatment plan to account for the reduced dose rate can
help ensure the tumor receives the prescribed dose.
3. Dose Rate Compensation: Using dose rate compensation techniques, such as increasing the treatment time or using a booster dose, can help maintain the desired dose rate.
4. Patient Monitoring: Close monitoring of patients during treatment can help identify any potential issues related to the reduced radiation intensity.

Alternative Technologies

1. Linear Accelerators: Linear accelerators (linacs) can provide a more consistent and reliable dose rate compared to Cobalt-60.
2. Intensity-Modulated Radiation Therapy (IMRT): IMRT can provide more precise dose delivery and reduce the impact of radiation intensity reduction.

Conclusion

Mathematical modeling plays a crucial role understanding the decay of radioactive elements is essential for cancer treatment, and mathematical modeling is a key component of this process. The dose rate and treatment result are impacted by the decay of radioactive elements like Cobalt-60. By predicting the radiation intensity over time, mathematical models like the exponential decay model enable medical professionals:
1. Optimize treatment plans: Modify treatment schedules and dosages to guarantee the tumor receives the necessary amount of radiation.
2. Reduce side effects: Optimize treatment regimens to lower the chance of radiation-induced adverse effects.
3. Improve treatment results: By taking radioactive material decay into account, cancer treatment can be more successful.

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