Letter to the Editor

An Integration Technique for Rapid Estimation of Activity of Waste in Storage

In the hospital environment the decay-in-storage method of radioactive waste disposal has become increasingly popular in recent years. Radionuclides with short half-lives (usually less than 65 days) are allowed to decay at the user's facility until they can be disposed of as nonradioactive waste. The time in storage is usually designated as 10 half-lives of the radionuclide. The Nuclear Regulatory Commission (NRC) has encouraged licensees to pursue this option in order to reduce the volume of low-level radioactive waste sent to shallow-land burial sites (*1*). The hospital derives a financial benefit using the decay-in-storage method, since the amount of waste transferred to a commercial disposal company is reduced or eliminated altogether.

Radioactive wastes held in storage contribute to the overall activity which is in the user's possession. In order to ensure that a user does not exceed the respective possession limits of various radionuclides, a method of determining the activity of radioactive waste held in storage must be instituted. Various computer programs have been written to maintain an inventory of radionuclides (*2,3*). The disadvantage of such programs is that data input is necessary each time a change in source status occurs (e.g., material transferred from one location to another). However, this is the method of choice for institutions which demonstrate complex patterns of use.

In a facility where the usage rate of a radionuclide is well defined and relatively constant, the total activity of this radionuclide held in waste storage (A) can be calculated. Mathematically, the change in activity (A) as a function of time (t) is expressed as the difference between the rate at which waste is placed in storage and the rate of decay:

$$\frac{dA}{dt} = fR - \lambda A, \qquad \text{Eq. 1}$$

where R is usage rate of the radionuclide, f is the fraction of the used activity which is transferred to storage, and λ is the decay constant of the radionuclide. Equation 1 is a linear differential equation which when integrated yields

$$A = \frac{fR}{\lambda}(1 - e^{-\lambda t}).$$

The activity accrued in storage increases as a function of time. As time becomes large, the activity approaches an equilibrium value (A_e) which is given by

$$A_e = \frac{fR}{\lambda}. \qquad \text{Eq. 2}$$

The equilibrium activity is approached rapidly. After an elapsed time of four half-lives, the activity is equal to 0.94 A_e.

The difference between the license possession limit (P) and the equilibrium activity (A_e) can be used to designate a possession limit for the activity on hand in the laboratory (L):

$$L = P - A_e.$$

As long as the usage rate does not change, activity on hand in the laboratory which is < L will ensure that the license possession limit is not exceeded. The equilibrium activity will not change by more than 15% by averaging the usage rate over a time period equal to 50% of the half-life.

As an example, consider a laboratory which uses iodine-125 ($\lambda = 0.081$ wk^{-1}) for in-vitro labeling procedures. The license possession limit is 111 MBq (3 mCi). The usage rate is assumed to be 7.4 MBq (200 μCi) per week, of which 20% is transferred to waste storage. From Eq. 2, the equilibrium activity of the waste in storage is ~ 18.5 MBq (500 μCi). The activity on hand in the laboratory is limited to 92.5 MBq (2.5 mCi), which is 83% of the license possession limit.

If the usage rate is not constant, then the total activity in storage will deviate from the equilbrium value. For example, an increase in the usage rate by a factor of 2 for a period of time equal to the half-life will result in a peak activity in storage of 1.5 A_e. If, however, the time of this higher usage rate is decreased to 25% of the half-life, then the peak activity in storage is 1.16 A_e.

The maximum usage rate can be utilized to predict the activity in waste storage. This overestimates the activity in storage which results in a conservative restriction on activity on hand in the laboratory. If various radionuclides are disposed of through the decay-in-storage method, then a separate calculation is necessary for each radionuclide.

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REFERENCES

1. U.S. Nuclear Regulatory Commission, Guide for the Preparation of Applications for Medical Programs, Regulatory Guide, 10.8, Rev. 1, 1980.

2. Chu WK, Raeside DE, Adams GD. A computerized radiation safety system. *Health Phys* 1977;32:116–17.

3. Herron DS, A computerized radioactive material inventory system. *Health Phys* 1979;37:598–600.