

QUESTION: *I have some questions regarding the shielding of a nuclear medicine hot laboratory and an examination room. How much lead or concrete shielding thickness is required for these rooms? Allowing for extra safety margins, can we use 4 mm lead thickness or will it create another problem? To my knowledge a thickness of 1-2 mm of lead will be enough. Is there a way to calculate the required shielding exactly? What are the references?*

ANSWER: Shielding designs for nuclear medicine hot laboratories and examination rooms are prepared on a case-by-case basis. There is no magic amount of shielding that can be specified to suit every situation. I will provide you with my approach. The following basic equation calculates dose to an individual from a single source:

$$D = \frac{\Gamma \times A \times t}{d^2} \times \left(\frac{1}{2}\right)^{\frac{x}{\text{HVL}}} \times T,$$

where:

D = dose

Γ = specific gamma ray constant (dose rate from 1 mCi at 1 cm)

A = activity

d = distance between source and point of interest

x = thickness of shielding

HVL = half value layer

T = fraction of work week that any specific individual is in the area of interest

t = time

Solving for x,

$$x = \frac{\text{HVL} \times \ln\left(\frac{D \times d^2}{\Gamma \times A \times t \times T}\right)}{\ln\left(\frac{1}{2}\right)}.$$

By substituting appropriate values for each factor, the shielding thickness can be calculated. The key, of course, is entering in the right numbers. The following are things to consider.

HVL – use the broad beam HVL for a given radionuclide. Package inserts often give the HVL for radionuclides used in nuclear medicine.

D – use the maximum dose you will permit someone in the area to receive. It could be 100 mrem (1 mSv) per week. This is a radiation worker dose limit, but is not really adequate to maintain radiation doses as low as reasonably achievable. Ten percent (10%) of the dose limit is more appropriate, e.g., 10 mrem (0.1 mSv) per week for occupationally exposed workers. For members of the general public 2 mrem (0.02 mSv) per week corresponds to the U.S. Nuclear Regulatory Commission's annual dose limits for members of the public of 100 mrem (1 mSv). Some argue that one should use 25% of this value to account for a member of the public that might be exposed at more than one site. The design basis dose will also be different if one is shielding to protect undeveloped film or interference to another the gamma camera.

d – use the distance between the source and a hypothetical person on the other side of the barrier. The radiation sources move in nuclear medicine, so choosing the right distance depends on how the radioactive materials move in the room.

Γ – use the specific gamma ray constant for a given radionuclide. Package inserts often provide this information. Be careful of the units, however. Traditional units are roentgen per hour per millicurie at 1 centimeter, but other units may be given.

$A \times t$ – activity and time should be considered together. Exposure from a 50 mCi unshielded source for 1 hour is the same as that from 1 curie unshielded source for 3 minutes.

T – standard values for the occupancy factor are 1 for full occupancy, $\frac{1}{4}$ for partial occupancy, and $\frac{1}{16}$ for occasional occupancy. These are described in detail in NCRP Report 49.¹

To make matters more complicated, there is also a dose rate limit of 2 mrem (0.02 mSv) an hour for unrestricted areas, which must be considered as well. This can be exceeded when using $T = \frac{1}{16}$, when the source position is closer than the average position used, or when A is large and t is small; therefore, shielding must be calculated separately to meet this requirement as well. To determine the dose rate, simply remove time (t) and occupancy factor (T) from the equations above.

The equation above only works for a single radionuclide. If multiple radionuclides are used, as is typically the case, the dose formula becomes:

$$D = \sum_i \frac{\Gamma_i \times A_i \times t_i}{d^2} \times \left(\frac{1}{2}\right)^{\frac{x}{HVL_i}} \times T$$

And the derivation for the shielding formula is too difficult for my little mind. I would put the above formula in a computer spreadsheet and vary x until D was an appropriate number.

The use of local shielding may be considered to significantly reduce the need for shielding in walls.

I hope this provides you with the information you are seeking. There is quite a bit of professional judgment involved in determining appropriate values for shielding a nuclear medicine facility. I recommend that you have a professional health or medical physicist experienced with shielding design provide you with specific shielding designs to meet your needs or review your design.

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¹“Structural Shielding Design and Evaluation for Medical Use of X Rays and Gamma Rays of Energies up to 10 MeV” National Council on Radiation Protection and Measurements, Report No. 49, (1976) <http://www.ncrp.com/ncrprpts.html>