Title: **Totally Rad - Radiation from a Source**

Objective: To learn how to calculate the radiation exposure from a radioactive source.

Suggested Grade Level: 8 - 12

Skills: Mathematics, problem solving

Duration: 45 minutes

Materials: Calculator

Background:
Now that we have learned about the background radiation that is part of our everyday life, we need to know about how much radiation dose we could receive from a radioactive source that is near us.

The basic formula is very simple.

Formula:

$$\text{Radiation Dose Rate at location} = \frac{\text{Effective Area of body}}{(4\pi r^2)} \times \text{Radiation Dose at surface of source}$$

To find the Radiation Dose Rate at Location -

We need:

1. The effective area of our body that is exposed to the radiation. If an outline of your body was drawn on a flat sheet of paper, it would approximately form a rectangle which includes the width of your shoulders and your total height as the length of your body. The effective area is approximately the product of the width of your body and the height, giving the area in square meters. (Area of a rectangle = Length X width.)

   For example, if an elephant is two meters wide and two meters tall, then the effective area is (2 meters x 2 meters = 4 square meters).

2. Because the radiation for the source goes equally in all directions, the fraction of the radiation that we receive is the area or our body divided by the area of a sphere (**$4\pi r^2 = 12.6 r^2$**) whose radius is the distance of our body from the radioactive source. This ratio gives the fraction of all of the radiation that is intercepted by our body.

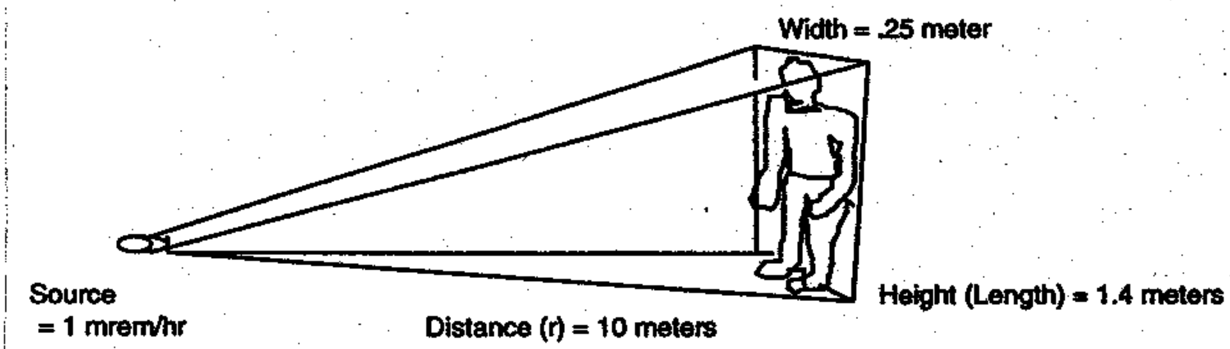
   How far are we from the center of the source (distance) is (r) the radius. We must square the radius.

   (r^2) **or** $(r \times r)$ **or** $(r) \times (r)$

   (Remember the factors for reducing radiation exposure - time, distance, shielding, and quantity.)

3. How much radiation per hour (Dose Rate) is being emitted from the surface of the source (millirem per hour).

(Remember our millirem chart - the <u>source</u> is the radioactive material.)



Example:

The effective area of our body must be in the same units as we used to measure the distance from the source to our location (for example, meters and square meters).

A small source emitting 1 millirem per hour is 10 meters away from us. Assume that we are about 1.4 meters tall and about .25 meter wide at the shoulders. We can approximate our effective areas as a rectangle.

Height = 1.4 meters

Width = 0.25 meter

1.4 X .25 = 0.35 square meters of area

Using the formula we get :

$$\text{Radiation dose rate at our location} = \frac{0.35}{(12.6)\,(100)} \times (1 \text{ millirem per hour}) = 0.0003 \text{ millirem per hour (mrem/hr)}$$

which is really a small amount per hour.

What if we are close to a dangerous source? Let us consider a source of 150 millirem per hour. This doese rate is not good. If we stay here for 15 minutes, we will have as much radiation as a dental x-ray. Let us now move a whole football field (100 meters) away from the source.

Then:

$$\text{Radiation dose rate at our location} = \frac{0.35}{(12.6)\,(100)\,(100)} \times (150 \text{ mrem/hr}) = 0.0004 \text{ millirem per hour (mrem/hr)}$$

This is very small! So, getting a large distance away from even a dangerous source will decrease the dose to very low values.

Another way to decrease the danger of a radioactive source is to put it behind or inside **shielding**.

For each source there is a thickness that reduces the dose rate by 1/2. This thickness is called a half-value layer.

If we put one half-value layer around our source, the dose rate would be 1/2 (150 millirem per hour) or 75 millirem per hour.

If we put 2 half-value layers around our source, it would be reduced by 2 again, and the dose rate would be 1/2 (75 mrem/hr) or 37.5 mrem/hr.

Let us now put 7 half-value layers around the source. Now the dose rate will be

$$(1/2) \times (1/2) \times (1/2) \times (1/2) \times (1/2) \times (1/2) \times (1/2) \times (150 \text{ mrem/hr})$$
$$= (1/128) \times (150 \text{ mrem/hr})$$
$$= (150/128)$$
$$= 1.171875$$
$$= 1.2 \text{ mrem/hr.}$$ rounded to the nearest significant number.

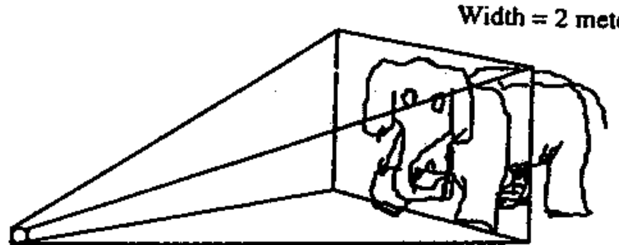
Shielding can make a dangerous source so much less dangerous.

Is it possible, with shielding, to make the dose rate exactly zero?

Trucks carrying radioactive cargo usually have shielding so the radiation dose rate at the truck's surface is about 1 millirem per hour.

If such a truck is parked 10 meters from our pet elephant who is 2 meters tall and 2 meters wide, and if the dose rate at the truck is 1 mrem/hr, what is the dose rate for our elephant?

Answer:



$$\text{Radiation dose rate at the elephant} = \frac{2 \times 2}{(12.6)\,(10 \times 10)} \times (1 \text{ mrem/hr}) = 0.0003 \text{ mrem/hr.}$$

It would take 1000 hours for our elephant to get a dose of 3 millirem at this distance.

The following table is taken from a reference called BEIR V, which stands for the "Biological Effects of Ionizing Radiation 5." This reference summarizes the experience of the world's scientific community with the immediate effects of radiation. It does not indicate the small effects on the possible state of cancer later in life. The effects of low levels of radiation for causing cancer in a lifetime are given by a small number for each millirem of exposure. This number is about 1.2 per 10 million for every millirem. We will not be using this number here, but have included it for completeness.

According to BEIR V

Biological Effects of Ionizing Radiation	
Amount of exposure	Effect
5000 mrem (5 rem)	No detectable injury or symptoms
100,000 mrem (100 rem)	May cause nausea and vomiting for 1-2 days and temporary drop in production of new blood cells
350,000 mrem (350 rem)	Nausea and vomiting initially, followed by a period of apparent wellness. At 3-4 weeks there is a potential for infections and bleeding due to a profusion of white blood cells and platelets. Medical care is required.
Higher levels of exposure can be fatal.	

Procedure:

1. Read the sample problem below and identify all information needed to solve the problem. Use the example below as a guide.

   A person who is 1.5 meters tall and 1/3 meter wide is standing 20 meters away from a source with a dose rate of 5 millirem per hour. What is the dose rate absorbed by this person?

   Answer:

   $$\text{Dose rate at this location} = \frac{(1.5)\,(1/3)}{(12.6)\,(20)\,(20)} \times (5\ \text{mrem/hr})$$

1.5 x (1/3) The effective area of our body	**divided by the product of**	(12.6) (20) (20) Area of a sphere $(4\pi r^2)$ (r squared is the distance squared)	**multiplied by**	5 millirem per hour Radiation dose at the source

The dose rate at this location = .0005 millirem per hour

The same person is now standing only 1 meter away from the 5 millirem per hour source. What is the dose rate now?

$$\text{The dose rate} = \frac{(1.5)\,(1/3)}{(12.6)\,(1)\,(1)} \times (5\ \text{mrem/hr}) = 0.2\ \text{mrem/hr.}$$

2. Use the formula for finding radiation dose from a source to solve the three problems below.

   (1) A person who is 2 meters tall and 1/2 meter wide stands 15 meters away from a radioactive source with a dose rate of 10 millirems per hour. What is the dose rate absorbed by this person?

   (2) If the person in problem #1 moves to a distance of 30 meters from the source, what is the dose rate absorbed?

   (3) Joe is 1.5 meters tall and 1/2 meter wide. He stands 30 meters from a radioactive source with a dose rate of 8 millirems per hour. Mary is 2 meters tall and 1/3 meter wide. She stands 20 meters from a radioactive source with a dose rate of 5 millirems per hour. Who absorbs radiation at a higher rate?

   Answers:
   (1) 0.0035 mrem/hr
   (2) 0.00088 mrem/hr
   (3) Joe = 0.00052 mrem/hr
   Mary = 0.00066 mrem/hr
   Mary absorbs radiation at a higher dose in this situation

Discussion Questions:

1. How does increasing the distance away from a radioactive source change the dose rate?

2. If the distance to a source is increased by a factor of 10, how much does the dose rate change?

3. Can any number of half-value layer of shielding make the dose rate of a source equal to zero?

4. What are the three things a person can change to decrease the amount of radiation absorbed by our body because of a source?

Assessment Evaluation:

Students' performances could be assessed based on each student's calculations and understanding of the problem solving. Participation in class or group discussion may also be assessed.

Extensions:

Students may be interested in collecting some actual data and creating their own problems to be solved. Perhaps getting some information from a local scientist could be a resource for creating a set of problems for the class to work on.

Resources:

Berger M., Byrd, Bill, West, C. M. (HAP), Ricks, R. C., Transport of Radioactive Materials Q&A About Incident Response Reacts Medical Sciences Division, Oak Ridge Associated Universities, 1992

Environmental Restoration and Waste Management (EM) Fact Sheets U.S. Department of Energy, November 1991