HAZARDS OF SOME ISOTOPES IN SPENT FUEL COMPARED TO THE HAZARD OF URANIUM ORE

Purpose:

This lesson will enable students to compare the hazard of spent fuel to the hazard of uranium ore, over a range of years. Students will determine at approximately what year the hazard of given isotopes in spent fuel is the same as the hazard of uranium ore. Students will also associate times related to spent fuel decay to events they are familiar with. Logarithmic scale is explained.

Concepts:

1. Spent fuel becomes less hazardous over a period of time covering tens of thousands of years.
2. The period of time over which spent fuel decays is analogous to periods of time in the history of the Earth.
3. Ultimately spent fuel will present no more hazard than naturally occurring uranium ore.
4. Logarithmic scales enable us to represent very long periods of time in a graph.

Duration of lesson:

One 50-minute class period

Objectives:

As a result of participation in this lesson, the learner will be able to:

1. read a graph that uses logarithmic scale;
2. state approximately how long it takes for some specific isotopes in spent fuel to decay to the point that they present the same hazard as uranium ore;
3. state approximately how long it takes for the isotopes in spent fuel considered as a single entity to decay to the point that they present the same hazard as uranium ore; and
4. make comparisons between time of spent fuel storage and time in the past.

Skills:

Drawing conclusions, reading and interpreting a graph

Vocabulary:

Accessible environment, axis, exponent, hazard, isolation, isotope, linear scale, logarithmic scale, primate hominid, relative hazard

Materials:

Activity Sheets

Hazards of Some Isotopes in Spent Fuel Compared to the Hazard of Uranium Ore, p. 153

Graph Entitled Hazards of Some Isotopes in Spent Fuel Compared to the Hazard of Uranium Ore, p. 155

Transparencies

Hazards of Some Isotopes in Spent Fuel Compared to the Hazard of Uranium Ore, p. 151

Background Notes

Hazards of Some Isotopes in Spent Fuel Compared to the Hazard of Uranium Ore, p. 77
The Logarithmic Scale, p. 78

Suggested Procedure:

1. This lesson requires students to read the graph entitled *Hazards of Some Isotopes in Spent Fuel Compared to the Hazard of Uranium Ore*. Students are accustomed to reading graphs that use the linear scale, but this graph uses a logarithmic scale. Introduce logarithmic scale by having students complete Part I of the activity entitled *Hazards of Some Isotopes in Spent Fuel Compared to the Hazard of Uranium Ore*. Part I orients the students to the graph and requires them to identify the information represented by the x axis and the y axis. It may be helpful to do Part I as a class. Ask students why they are comparing these radioisotopes to uranium ore. (Uranium ore is naturally occurring.)
2. When students have completed Part I, they can complete Part II or skip to Part III. Part II will require students to recall what they learned in charting the steps in the decay series (Unit 2 Enrichment) and in charting some of the transitions in spent fuel. This section may be completed on an individual basis, in small groups, or as a class.
3. Part III can be completed on an individual basis, in small groups, or as a class. This section will give some perspective about the long periods of time involved in spent fuel disposal. One point that may be made as a result of this perspective is that while the time involved in spent fuel storage is long in relation to the lifespan of an individual human, the time is not that long in relation to events that geologists study.

   One problem students may have in completing the section is in the reversal of the timeline across the top of the graph which enables the student to see similar periods of time in both the past and future.
4. Advanced groups may also discuss the concept of using dilutions to express relative hazard as explained in the Background Notes for the lesson.

Teacher Evaluation of Learner Performance:

Student participation in class discussion and completion of the activities entitled *The Logarithmic Scale* and *Hazards of Some Isotopes in Spent Fuel Compared to the Hazard of Uranium Ore* will indicate understanding.

Enrichment:

Students might enjoy making a timeline using a linear scale where each year is represented by one/fourth or one/eighth of an inch to show all the years in the logarithmic scale in the graph. However, it will be too tedious to use a ruler to make the timeline and interested students should convert the scale they select to feet before attempting the project. A timeline would reinforce the very long period of time that is involved and would also demonstrate the utility of using logarithmic scale.

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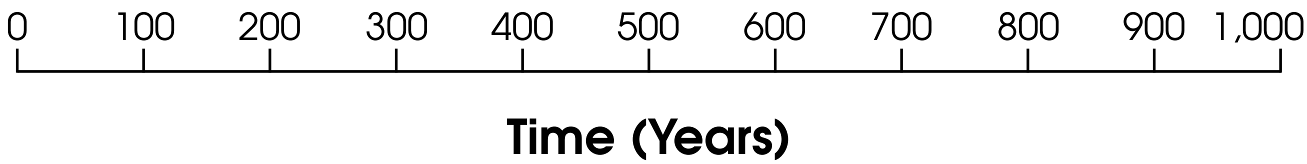
All drinking water contains trace quantities of naturally occurring radioisotopes. Researchers have determined what concentrations of radioisotopes in water are safe to drink. Hence, the volume of water required to dilute a given amount of a radioactive material to a safe level (i.e., safe to drink) is often used as a measure of the material's hazard; the more water required, the more hazardous the material.

In the graph, the hazards of the radioisotopes in spent fuel are expressed in terms of the volume of water required to dilute them to a safe level compared to the volume of water required to dilute, to a safe level, the uranium ore from which the fuel was prepared. For example, diluting the activity of Cs-137 initially present in the spent fuel requires about 100 times as much water as would be required for the uranium ore.

(Note: The dilutions referred to are hypothetical measurements. The spent fuel is a solid, not a liquid.)

The Logarithmic Scale

If we want to plot something that changes with time and the time period is relatively short, we often use a linear scale. Thus if we were considering 1,000 years, the linear scale might look like this:



Each tick mark represents 100 years and each subdivision of the scale would be the same length.

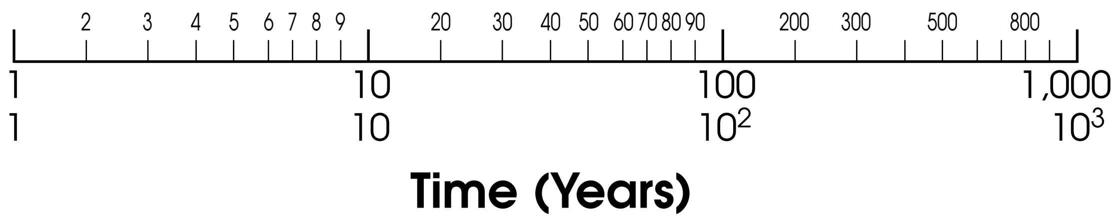
When we consider the many thousands of years it will be necessary to store nuclear waste in a geologic repository, it would not be possible to represent the decay on a linear time scale. Hence, we resort to a convenient device called the logarithmic scale for plotting large numbers.

In the logarithmic scale the only line segments that are equal are those that represent multiples of

10. Thus, 1,000 years on a simple logarithmic scale that showed only the broad divisions would appear thus:

As you can see, such a scale can plot a great many more years than is possible on a linear scale, but its use would be limited by its lack of detail.

However, if we were to divide each broad segment into nine segments and let the ticks represent



the years from 1 to 10, 10 to 100, and 100 to 1,000, the scale would look like this and would be much more useful:

Note that each broad segment is subdivided in the same way. Each tick within a broad segment represents a multiple of 10 over the corresponding tick in the previous segment. For example, in segment 10^0-10^1 the first mark equals 2. In the segment 10^1-10^2, the first mark equals 20, and in the segment 10^2-10^3, the first mark equals 200.

Note also that the subsections within each broad segment are unequal. The divisions become smaller and represent the years from 1 to 10, or 10 to 100, or 100 to 1,000.