Isotope	Half-life
H-3	12.3 years
Mn-54	300 days
Co-58	71 days
Co-60	5.2 years
Sr-89	50.5 days
Y-90	64.8 hours
Y-91	57.5 days
MO-99	67 hours
I-151	81 days
Cs-134	2.3 years
Te-152	78 hours
I-133	20.5 hours
Cs-136	13 days
Cs-137	27 years
Ba-140	12.8 days
La-140	40.5 hours
Ce-144	290 days

Figure 6-24 Half-lives of radioisotopes present in the liquid releases from a 1,000-megawatt pressurized water nuclear reactor
Source: Data from Wright 1970.

be characteristic of most heavy metals, which currently constitute an important portion of the globe's persistent pollution level. We could find no accurate means of weighing even the current components of pollution in an assessment of the effective half-life. We therefore chose a conservative figure of 1.5 years for the assimilation half-life of persistent pollution AHL in World3 in 1970.

Having assumed a linear relationship between the assimilation half-life AHL and the index of pollution* PPOLX and having specified the magnitude of AHL in World3 in 1970, we needed only to estimate the slope β of the line relating the two. For a specific pollutant the slope could in theory be calculated from the kinetic rate constants as indicated earlier. Where a wide variety of pollutants is involved, some other basis for an estimate had to be found. Our approach was to determine the dynamic significance of β, the slope of the line relating AHL and PPOLX.

Given our assumption that AHL is a linear function of PPOLX,

$$\begin{aligned} \text{AHL} &= \text{AHL70}\,(1 + \beta \times \text{PPOLX}) \\ &= \text{AHL70}\,(1 + \beta \times \text{PPOL/PPOL70}). \end{aligned}$$

Thus:

$$\text{PPASR} = \frac{\text{PPOL}}{\text{AHL70}(1 + \beta \times \text{PPOL/PPOL70})\ (1.4)}.$$

In 1970 the assimilation rate is:

$$\text{PPASR}\,(1970) = \frac{\text{PPOL70}}{\text{AHL70}(1 + \beta)\ (1.4)} \simeq \frac{\text{PPOL70}}{\text{AHL70} \times 1.4}.$$

*It should be noted that the AHL relationship assumed for the model runs is slightly nonlinear, for AHL is assumed to be constant at 1.5 years when PPOLX is less than 1.0. The resulting behavior is indistinguishable from an assumed linear AHL relationship.

The approximation is valid since we assume that β is substantially less than 1.0.

To estimate the approximate value of β, we may compute the maximum value for the assimilation rate PPASR, which occurs when the pollution level approaches infinity. If we allow pollution to grow toward infinity ($\beta \times \text{PPOL} >> 1$), then:

$$\text{LIM}_{\text{PPOL}\to\infty}\ \text{PPASR} = \text{LIM}_{\text{PPOL}\to\infty} \frac{\text{PPOL}}{\text{AHL70}(1 + \beta \times \text{PPOL/PPOL70}\ (1.4)}$$

$$= \frac{\text{PPOL70}}{\text{AHL70}(\beta)\ (1.4)} = 1/\beta \times \text{PPASR}(1970).$$

Thus, given a linear relationship between AHL and PPOL, at very high levels of persistent pollution PPOL, pollution assimilation PPASR becomes a constant independent of PPOL and equal to the reciprocal of β times the assimilation rate observed in 1970. This is just a restatement of the limiting case for assimilation found in the simple kinetic model derived earlier in this chapter. It is thus clear that β can be evaluated by intuitively estimating the relationship between the assimilation rate in 1970 and the maximum assimilation rate that could be sustained by the global environment. We assumed that the environment could assimilate up to 25 times the amount of pollutants it rendered harmless in 1970. Thus β was set equal to 0.04 in the standard version of the World3 program. However, we tested the sensitivity of the pollution sector's behavior mode to a variety of other assumptions about the maximum possible assimilation rate. It should be noted that so long as AHL is not zero, growth in the level of persistent pollution PPOL will accompany an increasing generation rate PPGR even if the assimilation capacity of the environment is assumed to be infinite. The form of the standard relationship between PPOLX and the multiplier on the assimilation half-life in 1970 AHL70 is shown in Figure 6-25.

```
AHLM.K=TABHL(AHLMT,PPOLX.K,1,1001,250)                    145, A
AHLMT=1/11/21/31/41                                       145.1, T
    AHLM   - ASSIMILATION HALF-LIFE MULTIPLIER
             (DIMENSIONLESS)
    TABHL  - A FUNCTION WITH VALUES SPECIFIED BY A TABLE
    AHLMT  - AHLM TABLE
    PPOLX  - INDEX OF PERSISTENT POLLUTION
             (DIMENSIONLESS)

AHL.K=AHL70*AHLM.K                                        146, A
AHL70=1.5                                                 146.1, C
    AHL    - ASSIMILATION HALF-LIFE (YEARS)
    AHL70  - ASSIMILATION HALF-LIFE IN 1970 (YEARS)
    AHLM   - ASSIMILATION HALF-LIFE MULTIPLIER
             (DIMENSIONLESS)
```

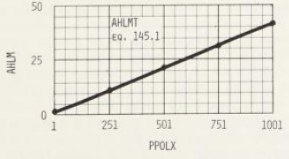

Figure 6-25 Table function of the relationship between PPOLX and the multiplier on the assimilation half-life in 1970 AHL70