Insecticide	Quantity on the Skin That Has Lethal Effects on 50 Percent of a Population (mg/kg)		
Phorate	2.5	–	6
Demeton	8.0	–	14
Parathion	7.0	–	21
Ethion	62.0	–	245
DDT			2,510

Figure 6-13 Toxicities of DDT and four alternative insecticides
Source: SCEP 1970, p. 281.

fore, we assumed that one-tenth of one percent of the materials remains in the environment long enough to become classified as persistent pollution. For the standard model simulations the fraction of inputs in the form of persistent materials FIPM was estimated to be 0.001.

Little information was available on which to base our estimate concerning the relative toxicity of industrial and agricultural materials. The toxicity of pesticides in common use appears to be increasing. Figure 6-13 provides information on the relative toxicities of DDT and four insecticides that are being substituted for it. The substitutes exhibit from 10 to 400 times the toxicity of DDT when ranked according to the milligrams of chemical that must be applied to the skin for each kilogram of body weight to produce death in 50 percent of a population.

The greatest part of the persistent materials released through agricultural activities are not pesticides but nutrients. These substances cause damage by suppressing the activity of soil organisms, by accelerating eutrophication of fresh water (thus reducing populations of food fish), and by contaminating groundwater used for human consumption. The first effect, the suppression of soil organism activity, is described briefly in Chapter 4. The second process was studied in detail in our substudy of eutrophication (Anderson et al. 1973). Nitrates in drinking water may be converted to nitrites by bacteria in the intestines of those consuming the contaminated water (Commoner 1971, pp. 78–90)—in babies the nitrites may lead to methemoglobinemia.

While the damage caused by agricultural pollution is important, it appears to be less severe than the effects of the heavy metals and the chemicals that compose industrial pollution. Thus the toxicity index of agricultural materials was defined equal to 1.0, an order of magnitude smaller than the estimated toxicity index of industrial materials.

Persistent Pollution Appearance Rate PPAPR Industrial and agricultural activities release persistent materials directly to the environment. However, the level of persistent pollution PPOL in World3 and the index of persistent pollution PPOLX do not refer to all materials in the environment but only to those persistent materials which are located and concentrated so that they exert a negative influence on living organisms. In most instances there is a delay, which depends on the material involved and on the location and the mode of its release, between the time a persistent material is first released and the time its damaging effects are widely felt in the biosphere. The delay is associated with the chemical and physical processes that govern the transport of materials through the environment and with the biological processes that cause materials to be concentrated as they pass through successive trophic levels. To incorporate this delay in the persistent pollution sector of World3 we defined a persistent pollution appearance rate PPAPR, which is a delayed function of the persistent pollution generation rate PPGR.


```
PPAPR.KL=DELAY3(PPGR.JK,PPTD)                          141, R
PPTD=20                                                141.1, C
    PPAPR  - PERSISTENT POLLUTION APPEARANCE RATE
                (POLLUTION UNITS/YEAR)
    DELAY3 - THIRD-ORDER EXPONENTIAL MATERIAL DELAY
    PPGR   - PERSISTENT POLLUTION GENERATION RATE
                (POLLUTION UNITS/YEAR)
    PPTD   - PERSISTENT POLLUTION TRANSMISSION DELAY
                (YEARS)
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The effect of the transmission delay is to smooth and displace in time the effects on the biosphere of changes in the persistent pollution generation rate PPGR. The principal determinant of the delay's effect is the magnitude of its time constant, the persistent pollution transmission delay PPTD. This time constant is the average number of years spent by a unit of persistent pollution between the time of its generation and the time of its full impact on the biosphere. The dynamic influence of the delay function is illustrated in Figure 6-14, where hypothetical "step" and "ramp" increases and declines in the persistent pollution generation rate are related to the appearance rates they would produce. In Figure 6-14 the transmission delay is 20 years, its normal value in World3.

Even for individual materials the magnitude of the transmission delay is difficult to estimate from historical data because the lags in diffusion and concentration are generally confounded with delays in social perception and response. Case studies of mercurial poisoning in Japan and Sweden provide some information on the total length of the delays involved between the first release of mercury and the society's ultimate perception of its effects. Although these chronologies place upper limits on the transmission delay in these specific instances, they do not permit precise estimates of the length of time involved in the transmission and concentration of the mercury involved. Moreover, they only deal with instances in which the diffusion of mercury took place over small distances. Thus they include much shorter transmission delays than those existing for many globally distributed materials. The following summary of studies by Klein (1972) and Montague and Montague (1971) suggests that the mercury transmission delay in Minamata Bay was less than 3 years:

1950 Japanese factory begins discarding mercury into Minamata Bay.
1953 First case of alkylmercury poisoning, called "Minamata disease," detected.
1956 Public health authorities aware of widespread Minamata disease.