number of tests and the maximum level of strontium-90 in the water. The time involved in the concentration of the pollutant in various life forms also adds to the total transmission delay. Because strontium-90 tends to be absorbed and eliminated very slowly from the human body, there would be an even longer delay between the date on which the greatest amount of the isotope was released into the environment and the time at which the concentration of strontium-90 would reach its maximum level in the body tissues of humans who had drunk the contaminated water.

The delay associated with movements through a food chain is illustrated by another study of persistent radioactive materials, one in which the materials are traced as they move up several trophic levels in a very confined ecosystem. In Figure 6-7 the radioactive material fed into a forest plant is shown to reach its maximum level 1.0 week after the start of the experiment. The concentration of radioactive pollutant in herbivores feeding on the plant peaks one week later, while the level of radioactivity in the predators that consume the herbivores is still rising after 6.0 weeks, five weeks after the peak in the application of the material.

Persistent chemicals exhibit transmission delays similar to those observed in radioactive materials. The authors of two studies of DDT flows have pointed to the delays inherent in the transport of that pesticide through air and water (Harrison et al. 1970, Woodwell et al. 1971). Our simulation substudies of DDT and mercury also provide information on the transmission delays associated with the movement of these materials through the global environment. Simulations of our two submodels are presented

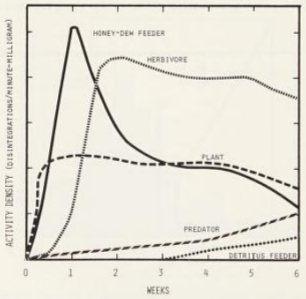

Figure 6-7 Levels of radioactivity present in different species over time after application of a radioisotope to one plant in a small ecosystem
Source: Odum 1971, p. 462.

later in this chapter to supplement the preceding information as a basis for estimating an appropriate range of transmission delays for inclusion in the world model pollution sector.

Geological and biological factors are not the only sources of delays influencing the flow of persistent materials through the global ecosystem. Social delays in identifying pollution problems, designing appropriate responses, obtaining social consensus on the need to act, and implementing decisions also influence the level of persistent pollution present at any time. Social delays are not incorporated explicitly in the standard pollution sector of World3, but they are added to the model in several of the runs of section 6.6 where we analyze the relative effectiveness of alternative pollution control policies.

Biological Concentration of Persistent Materials

The third widely observed pattern in the behavior of persistent materials is the tendency of organisms at each level in a food chain to concentrate persistent materials, so that concentrations in species at the top of the chain may be far above ambient levels. Figure 6-8 summarizes data on strontium-90 levels in various parts of a freshwater ecosystem after low-level radioactive wastes were introduced into the water of a nearby lake. After equilibrium was attained, the higher species on the food chain were found to have concentrations of strontium-90 between 1,000 and 3,900 times those found in the water. The data presented in Figure 6-9 reveal a similar behavior in the concentration of DDT.

Man occupies a comparatively high position on both aquatic and terrestrial food chains. Thus his own body load of persistent materials will generally be much greater than the ambient level. This fact is illustrated by the levels of DDT found in human adipose tissue. Various studies of human tissue have found DDT residues present in concentrations between 2.3 parts per million by weight (ppm) in Germany in 1958 and 26 ppm in India in 1964 (Wayland 1966). The latter concentration is higher than

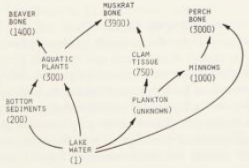

Figure 6-8 Concentrations of strontium-90 in various trophic levels of a small lake contaminated with low-level atomic wastes (average strontium-90 concentrations are expressed relative to the level of the isotope in lake water)
Source: Odum 1971, p. 460.