

nuclear reactors as a source of electric power illustrates this tendency. The transmission delays inherent in the diffusion of sulfur dioxide and other fossil fuel combustion products are very short. Thus the effects of these materials have already become apparent, and they are the objects of intense social concern. With the growing pressure to decrease fossil-fuel pollution, the relative importance of coal and oil in power generation will probably be substantially decreased as society increases its reliance on nuclear reactors. Reactor effluents are potentially much more dangerous, but their transmission delays are so long that the harmful consequences of reactor wastes are not yet fully perceived. Since society always prefers to shift the costs of present activities to the future, it should be expected that political processes will alter the composition of persistent materials so that the globe's average effective pollution transmission delay will increase. However, information about the strength or the relative importance of this effect was insufficient to warrant the incorporation of a secular trend in the equation defining the persistent pollution transmission delay PPTD. Therefore, we merely defined the delay as a constant and assigned it a value of 20 years in most of the World3 simulations.

Concluding this discussion, we quote from René Dubos, who writes eloquently of the potential effects of the pollution transmission delay:

The point of importance here is that the worst pathological effects of environmental pollutants will not be detected at the time of exposure; indeed they may not become evident until several decades later. In other words, society will become adjusted to levels of pollution sufficiently low not to have an immediate nuisance value, but this apparent adaptation will eventually cause much pathological damage in the adult population and create large medical and social burdens. [Dubos 1968]

Persistent Pollution PPOL and Index of Pollution PPOLX Persistent pollution PPOL at time t is defined to be equal to the level of persistent pollution present in 1900, plus the accumulated difference between the persistent pollution that has appeared and that which has been assimilated between the year 1900 and time t .

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PPOL,K=PPOL,J+(DT)*(PPAPR,JK-PPASR,JK)      142, L
PPOL=2.5E7                                     142.1, N
PPOL - PERSISTENT POLLUTION (POLLUTION UNITS)
DT - TIME INTERVAL BETWEEN CONSECUTIVE
      CALCULATIONS (YEARS)
PPAPR - PERSISTENT POLLUTION APPEARANCE RATE
      (POLLUTION UNITS/YEAR)
PPASR - PERSISTENT POLLUTION ASSIMILATION RATE
      (POLLUTION UNITS/YEAR)

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To establish the initial value of persistent pollution we assumed that the generation rate PPGR, appearance rate PPAPR, and assimilation rate PPASR were all equal in 1900.* The generation rate in 1900 PPGR(1900) can be calculated from the initial values of the other model variables:

$$\begin{aligned}
 \text{PPGR}(1900) &= (\text{PPGIO}(1900) + \text{PPGAO}(1900))(\text{PPGF}) \\
 &= (\text{PCRUM}(1900) \times \text{POP}(1900) \times \text{FRPM} \times \text{IMEF} \times \text{IMTI} \\
 &\quad + \text{AIPH}(1900) \times \text{AL}(1900) \times \text{FIPM} \times \text{AMTI}) (\text{PPGF}) \\
 &= [.17 \times 1.65 \times .02 \times .1 \times 10 + 6.6 \times .9 \times .001 \times 1] \times 1 \\
 &= 5.6 \times 10^{-6} + 5.95 \times 10^{-6} \\
 &= 1.16 \times 10^{-5} \text{ persistent pollution units per year}
 \end{aligned}$$

Since we assumed that the assimilation rate PPASR was equal to the generation rate PPGR in 1900, we could calculate the initial value of pollution PPOL in 1900. The pollution assimilation rate is equal to PPOL/(AHL \times 1.4), where AHL is the World3 computer program abbreviation for assimilation half-life and 1.4 is a numerical correction factor explained later, in the section defining PPASR. Thus PPOL equals PPASR \times 1.4 \times AHL.

$$\begin{aligned}
 \text{PPOL}(1900) &= \text{PPASR}(1900) \times 1.4 \times \text{AHL}(1900) \\
 &= 1.16 \times 10^{-5} \times 1.4 \times 1.5 \\
 &= 2.5 \times 10^{-5} \text{ persistent pollution units}
 \end{aligned}$$

The level of persistent pollution PPOL is measured in persistent pollution units, which are related to resource consumption and the application of agricultural inputs. We also defined a ratio scale for pollution which is an index of the pollution level at time t relative to its level in 1970. The influence of persistent pollution at time t on average life expectancy, soil fertility, and the assimilation half-life is expressed as a function of this index of pollution PPOLX:

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PPOLX,K=PPOL,K/PPOL70      143, A
PPOL70=1.36E8              143.1, C
PPOLX - INDEX OF PERSISTENT POLLUTION
      (DIMENSIONLESS)
PPOL - PERSISTENT POLLUTION (POLLUTION UNITS)
PPOL70 - PERSISTENT POLLUTION IN 1970 (POLLUTION
      UNITS)

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The value of PPOL70 was determined by measuring the 1970 value of PPOL in the standard run of the World3 model.

Persistent Pollution Assimilation Rate PPASR The equation for the persistent pollution assimilation rate PPASR is fully determined by one simple assumption and one definition. The assumption was derived in part from our detailed studies of the processes that cause the assimilation of DDT and mercury. On the basis of those pollution substudies we assumed that persistent materials disappear from the environment at a rate directly proportional to the total quantity of materials present. In other words, any given level of persistent materials present in the environment will decline asymptotically to zero.* All radioactive materials decay (are assimilated) exponentially. The reasons for assuming an exponential assimilation of other persis-

*We thus implicitly assumed that the level of persistent pollution PPOL was constant in the year 1900. Of course, there are essentially no data to support this or any other precise assumption about the value of the World3 pollution variables in 1900. However, the errors possibly introduced by this assumption create only a small transient, which disappears long before pollution has any significant influence on the other sectors of the model.

*However, if the persistent pollution appearance rate is greater than zero, the total amount of persistent pollution will not decline to zero. Even though each unit will ultimately disappear, new units may be added at the same rate or even faster than the old ones are assimilated.