composed of materials that would have some economic value if they were available as inputs to further production. Agricultural pollution, on the other hand, is a consequence of the deliberate dispersal of materials in the environment. Pesticides and fertilizers are useful to farmers only when they are present in sufficient concentration in specific areas of the environment. As a result, both the current causes and the future control of the two pollutant streams involve radically different procedures and incentives. We therefore separated the generation of persistent pollutants into two categories: persistent pollutants generated from industrial output PPGIO and persistent pollutants generated from agricultural output PPGAO. The persistent pollution generation rate PPGR is the sum of PPGIO and PPGAO.

```
PPGR.KL=(PPGIO.K+PPGAO.K)*(PPGF.K)                      137, R
    PPGR   - PERSISTENT POLLUTION GENERATION RATE
                (POLLUTION UNITS/YEAR)
    PPGIO  - PERSISTENT POLLUTION GENERATED BY
                INDUSTRIAL OUTPUT (POLLUTION UNITS/YEAR)
    PPGAO  - PERSISTENT POLLUTION GENERATED BY
                AGRICULTURAL OUTPUT (POLLUTIONUNITS/YEAR)
    PPGF   - PERSISTENT POLLUTION GENERATION FACTOR
                (DIMENSIONLESS)

PPGF.K=CLIP(PPGF2,PPGF1,TIME.K,PYEAR)                   138, A
PPGF1=1                                                 138.1, C
PPGF2=1                                                 138.2, C
    PPGF   - PERSISTENT POLLUTION GENERATION FACTOR
                (DIMENSIONLESS)
    CLIP   - A FUNCTION SWITCHED DURING THE RUN
    PPGF2  - PPGF, VALUE AFTER TIME=PYEAR
                (DIMENSIONLESS)
    PPGF1  - PPGF, VALUE BEFORE TIME=PYEAR
                (DIMENSIONLESS)
    TIME   - CURRENT TIME IN THE SIMULATION RUN
    PYEAR  - YEAR NEW POLICY IS IMPLEMENTED (YEAR)
```

To assist the analyst in testing the effects of alternative control policies, a persistent pollution generation factor PPGF is included in the equation for the persistent pollution generation rate PPGR. When TIME equals the chosen policy year PYEAR, the value of PPGF shifts from PPGF1 to PPGF2. Under normal circumstances both parameters will be equal to 1.0 and PPGF will not influence the behavior of the model. Reducing PPGF below 1.0 during a simulation corresponds to introducing pollution abatement procedures in industry and agriculture that do not decrease resource consumption. Thus PPGF should be decreased only to represent policies in which the normal effluent is converted to nontoxic, nonpersistent, or permanently sequestered material. A policy of capturing an effluent and recycling it into another use would reduce both the outflow and the net inflow of resources. A recycling policy should be represented by setting PPGF=1.0 and by setting NRUF<1.0 to reduce the resources used per capita.

Persistent Pollution Generated by Industrial Output PPGIO We defined the persistent pollution generated by industry PPGIO as the leakage of persistent materials into the environment from the flow of resources used in producing industrial output.

Since industrial output is consumed or invested in services and industry, persistent effluents from all three uses are included in PPGIO. For example, beryllium released to the environment through the smelting of metals (industry), mercury that escapes during the manufacture of paper (industry), mercury compounds released by medical laboratories (services), asbestos released from home insulation and brake linings (services), and insecticides consumed in home pest control (consumption) are all included in persistent pollution generated through industrial output.

The generic factors governing the rate of industrial pollution generation are:

1. The total usage rate of natural resources, that is, per capita resource usage times population (PCRUM × POP).
2. The fraction of the total resource flow that is in the form of persistent materials FRPM.
3. The fraction of the persistent material flow that is released into the environment, that is, the industrial materials emission factor IMEF.
4. The toxicity of the materials, that is, the industrial materials toxicity index IMTI.

If the product of the last three factors always equaled 1.0, we could link pollution generation directly to resource utilization. However, the persistent material fraction, the emission fraction, and the toxicity index can all vary independently from the total resource usage rate. Thus we chose not to represent the resource usage rate and the pollution generation rate as elements in a single, conserved material subsystem.

```
PPGIO.K=PCRUM.K*POP.K*FRPM*IMEF*IMTI                    139, A
FRPM=.02                                                139.1, C
IMEF=.1                                                 139.2, C
IMTI=10                                                 139.3, C
    PPGIO  - PERSISTENT POLLUTION GENERATED BY
                INDUSTRIAL OUTPUT (POLLUTION UNITS/YEAR)
    PCRUM  - PER CAPITA RESOURCE USAGE MULTIPLIER
                (RESOURCE UNITS/PERSON-YEAR)
    POP    - POPULATION (PERSONS)
    FRPM   - FRACTION OF RESOURCES AS PERSISTENT
                MATERIALS (DIMENSIONLESS)
    IMEF   - INDUSTRIAL MATERIALS EMISSION FACTOR
                (DIMENSIONLESS)
    IMTI   - INDUSTRIAL MATERIALS TOXICITY INDEX
                (POLLUTION UNITS/RESOURCE UNIT)
```

The curve relating the per capita usage rate of nonrenewable resources PCRUM to industrial output per capita IOPC is described in Chapter 5. It is reproduced for reference as Figure 6-12. Because the curve is a nonlinear function of industrial output per capita, the persistent pollution generated by industrial output PPGIO cannot be expressed solely as a function of total industrial output. This important point may be illustrated by considering two hypothetical societies. One society has 10 people, an industrial output per capita of 1000 dollars per year, and thus an annual resource consumption of 6.2 units per person-year. The second has 100 people, with an annual industrial output per capita of 100 dollars per year and a yearly resource consumption of 0.42 units per person-year. Although the GNP of both societies is 10,000 dollars, the total resource consumption of the first society is about 1.5 times that of the second. If the persistent material fractions, the emission factors,