available, and comprehensive cross-sectional data are nonexistent, the dynamic effects of persistent materials in the world system appear to be similar in several important ways:

1. Each is released through industrial or agricultural activity.
2. The impact of each material on man or the ecosystem has already been proved adverse in local areas.
3. Each material has been dispersed around the globe.
4. Each persists long enough to influence the components of the biosphere for years or decades once it is released into the environment.

The impact of persistent, man-made pollutants on the global biosphere will depend on both the pollutants' total level and the changing chemical composition of that level over time. The future mix of pollutants may be changed relatively rapidly in response to factors not explicitly represented in World3. It is certainly impossible to predict that mix in advance, especially since society has not yet identified all the components of the present stream of effluents that are persistent material pollutants—new ones are frequently discovered. Because the mix of pollutants is so indeterminate, the pollution sector is restricted to an aggregated representation of the globe's persistent pollution burden. We did not differentiate among specific materials but constructed the model to represent one generalized persistent pollution level. Our inability to make any precise statements about the composition of pollutants over the long term and the scarcity of comprehensive data on the long-term effects of persistent materials decidedly lessened the number of meaningful assumptions that could be incorporated in the pollution sector. Thus this sector of World3 is much less complex than the sectors representing global population, agriculture, and industrial and service output.

An aggregated model of pollution cannot be used to make precise forecasts of the levels and impacts of specific materials, nor is it useful in describing the current "quality" of the environment. Instead, the purpose of the persistent pollution sector is to represent in general terms the dynamic characteristics of the physical processes governing the generation, transportation, concentration, and assimilation of persistent, harmful materials that are released through agricultural and industrial activities. Our primary objective was to provide a conceptual dynamic structure that could capture the qualitative behavior of persistent pollutants in the world system.

Even as a very general model, the pollution sector addresses several important questions:

1. If material output and population continue to grow, what could be the global impact of future persistent material burdens on the behavior of other sectors in the world system?
2. Can technological programs, initiated in response to perceived pollution levels, be implemented in time to avoid substantial damage from the presence of persistent materials?
3. What effects on the ultimate global pollution level might be caused by various delays in society's efforts to stop the increase in the generation of persistent pollutants after the level has passed some critical threshhold?

4. What could happen to pollution levels if the natural pollution absorption mechanisms of the ecosystem were themselves degraded by pollution?
5. How sensitive is any estimate of future relative pollution levels to errors in assumptions about the magnitude of important delays and coefficients in the persistent pollution sector?

The answers to these questions depend both on the underlying geological and biological characteristics of the global ecosystem and on the nature of future social goals, decisions, and technological achievements. Although they are not yet fully understood, the physical characteristics do, in theory, lend themselves to prediction. But there is no possibility of predicting long-term social responses with great accuracy. Heightened social concern, more stringent legislation, and improved technologies can be expected to influence the future location, level, and composition of persistent pollution. Technological change may alleviate or exacerbate future pollution problems in ways that cannot currently be anticipated. Thus we represented the physical determinants of pollutant flows endogenously in the pollution sector and tested the future effects of conceivable changes in social and technical policies through exogenous changes in the model's structure and coefficients. As a consequence of omitting explicit assumptions about changes in society's response to pollution, none of the outputs of this sector can be used as the basis for a prediction of what *will* happen. The model can only lead to such statements as, "*If* these values, policies, and technologies are adopted, the most likely behavior of the system will be. . . ." Although the sector as modeled cannot be used to identify optimal pollution policies, it can indicate many policies that will not have the desired effects.

In this chapter we first present empirical data illustrating the observed behavior modes of persistent pollutants in the world system (section 6.2). We then provide a set of basic concepts that define persistent pollutants and the determinants of their dynamic behavior (section 6.3). The precise causal relationships of the World3 persistent pollution sector are then expressed graphically and in equation form in sections 6.4 and 6.5. In section 6.6 we present eighteen computer runs of the pollution sector with exogenous changes in its structure and coefficients. Simulations of the equations in this sector are presented to illustrate the behavior of the World3 pollution sector in response to different patterns of economic activity and population growth. Since the range of plausible values for each parameter is so large; sensitivity analyses are particularly important in the pollution sector. The influence of each parameter on the sector's behavior is thus tested to identify the most critical areas for further research. Finally we test the effectiveness of alternative policy responses to rising pollution and the damage it produces.

6.2 HISTORICAL BEHAVIOR MODES

Four dynamic attributes appear to characterize nearly all known persistent pollutants:

1. They are generated at increasing rates by industry and agriculture.
2. Their accumulated level in the global environment is increasing.