8. DEVELOPMENT OF TRIM.Expo

The TRIM.Expo module of TRIM is an exposure-event model that is being developed to assist in assessing health risks related to chemical exposures. The exposure assessment process consists of relating chemical concentrations in environmental media (*e.g.*, air, surface soil, root zone soil, surface water) to chemical concentrations in the exposure media with which a human population has contact. This model uses concentrations of chemicals in different environmental media over time to provide information such as the number of individuals in a population that are exposed to various levels of chemicals over various time periods of interest. The TRIM.Expo module can function as an integral part of TRIM, using the output data from TRIM.FaTE as input data, or it can function independently of TRIM, using other environmental fate models or monitoring data as input data.

8.1 PURPOSE OF DEVELOPING TRIM.Expo

The TRIM.Expo module is intended to contribute to a number of health-related assessments, including risk assessments and status and trends analyses. The TRIM.Expo module, like most exposure models, provides a key step in the analysis of the link between various chemical sources and potential human health risks. Multiple sources of environmental contamination lead to multiple contaminated media, including air, water, soil, food, and dust. When considering human exposure, it is necessary to focus on the more immediate contact or exposure media, which include the envelope of air surrounding a human receptor, the water and food ingested, and the layer of soil and/or water that contacts the skin surface. The magnitude and relative contribution of each exposure pathway must be considered to assess the total exposure of a particular chemical to humans.

> **EXPOSURE**
>
> Exposure is the contact between a target organism and a pollutant at the outer boundary of the organism, quantified as the amount of pollutant available at the boundary of the receptor organism per specified time period. As an example, inhalation exposure over a period of time may be represented by a time-dependent profile of the exposure concentrations.

Human exposures to air pollutants can result from contact with contaminated air, water, soil, and food. Such exposures may be dominated by contact with a single environmental medium or may reflect concurrent or successive contacts with multiple media. The nature and extent of such exposures depend largely on two elements: (1) human factors and (2) the concentrations of a chemical in the exposure media. Human factors include all behavioral, sociological, and physiological characteristics of an individual that directly or indirectly affect his or her contact with the substances of concern. Important factors in this regard include contact rates with food, air, water, and soil. Activity patterns, which are defined by an individual's or a group of people's allocation of time spent participating in different activities at various locations, are also significant because they directly affect the magnitude of exposures to substances present in different indoor and outdoor environments. The information on activity patterns is taken from measured data collected during field surveys of individuals' daily activities, the amount of time spent engaged in those activities, and the locations where the activities occur. Therefore, from an exposure assessment standpoint, the principal goal is to estimate or measure an individual's or group's exposure as a function of relevant human factors and the measured and/or estimated chemical concentrations in the contact or exposure media. This is a challenge due to the paucity of information regarding many of the human factors that affect exposure. Therefore, a tiered approach is being used for the initial development of TRIM.Expo. Specifically, model development is being focused on applications where the input parameters are most critical and where input data exist.

With respect to population groups, the exposure-event module within TRIM.Expo uses the concept of a cohort. Cohorts are subsets of a population grouped so that the variation of exposure within a cohort is much lower than the variation between or among cohorts. This approach is used because available data are not adequate to estimate the exposure of each individual in a population; therefore, information about people who are expected to have similar exposures is aggregated together to make more efficient use of the limited data. The cohorts are assumed to include individuals with exposures that can be characterized by the same probability distribution for key characteristics. The demographic variables used to describe a cohort are selected to minimize the differences between individuals within the cohort. The model selects an individual from the appropriate cohort and uses that individual's activity pattern data to create an exposure-event sequence for that day. Currently, TRIM.Expo accounts for variability within a cohort through multiple runs of the model for the exposure duration under study. As new statistical techniques are developed, future versions of TRIM.Expo will be modified to use the best available approaches for characterizing time/activity pattern data. At the present time, however, the current method of using cohorts is a useful technique for modeling the exposures of a large population in the absence of adequate time/activity pattern data (see the TRIM.Expo TSD for a more detailed discussion on cohorts).

The TRIM.Expo module was designed to allow flexibility in the user's ability to select a cohort's characteristics. The demographic variables (*e.g.*, age, gender, work status) that characterize a cohort can be modified by a user of TRIM.Expo providing that there are data available. Hence, the cohorts' characteristics can be chosen for individualized studies on a site-specific or case-specific basis.

Using exposure modeling approaches instead of exposure monitoring studies has several advantages: (1) direct monitoring of the exposure of humans to chemicals (*i.e.*, personal exposure monitoring) is expensive, and (2) direct monitoring of exposures resulting from large numbers of pollutants can present large logistical and analytical difficulties. Therefore, OAQPS has determined that exposure modeling, such as using TRIM.Expo, is useful for estimating exposures to air pollutants and may be used in conjunction with limited personal exposure monitoring data.

8.2 OVERVIEW OF TRIM.Expo

Emissions of chemicals to air can (depending on the characteristics of an individual chemical) lead to contamination of multiple environmental media, including ambient outdoor air, indoor air, surface and ground water, soil, food, and dust. The more immediate contact or exposure media, which include the envelope of air surrounding a receptor, the water and food ingested, and the layer of soil and/or water that contacts the skin surface, should be the main focus of an exposure assessment. Furthermore, the magnitude, duration, and frequency of exposures via each exposure route (inhalation, ingestion, or dermal contact) must be considered to assess the aggregate exposure to a particular chemical.

As shown in Figure 8-1, the TRIM exposure assessment process consists of relating chemical concentrations in environmental media (*e.g.*, air, surface soil, root zone soil, surface water, vegetation, ground water) to chemical concentrations in the immediate exposure/contact media with which a human population has direct contact (*e.g.*, personal air, tap water, foods, house dust, soil). The TRIM.Expo module simulates the movement of an individual and/or a subset of the human population (*i.e.*, a cohort) according to activity patterns, through locations (*i.e.*, microenvironments) of varying chemical concentrations, thus allowing the estimation of exposures to the various cohorts within the population.

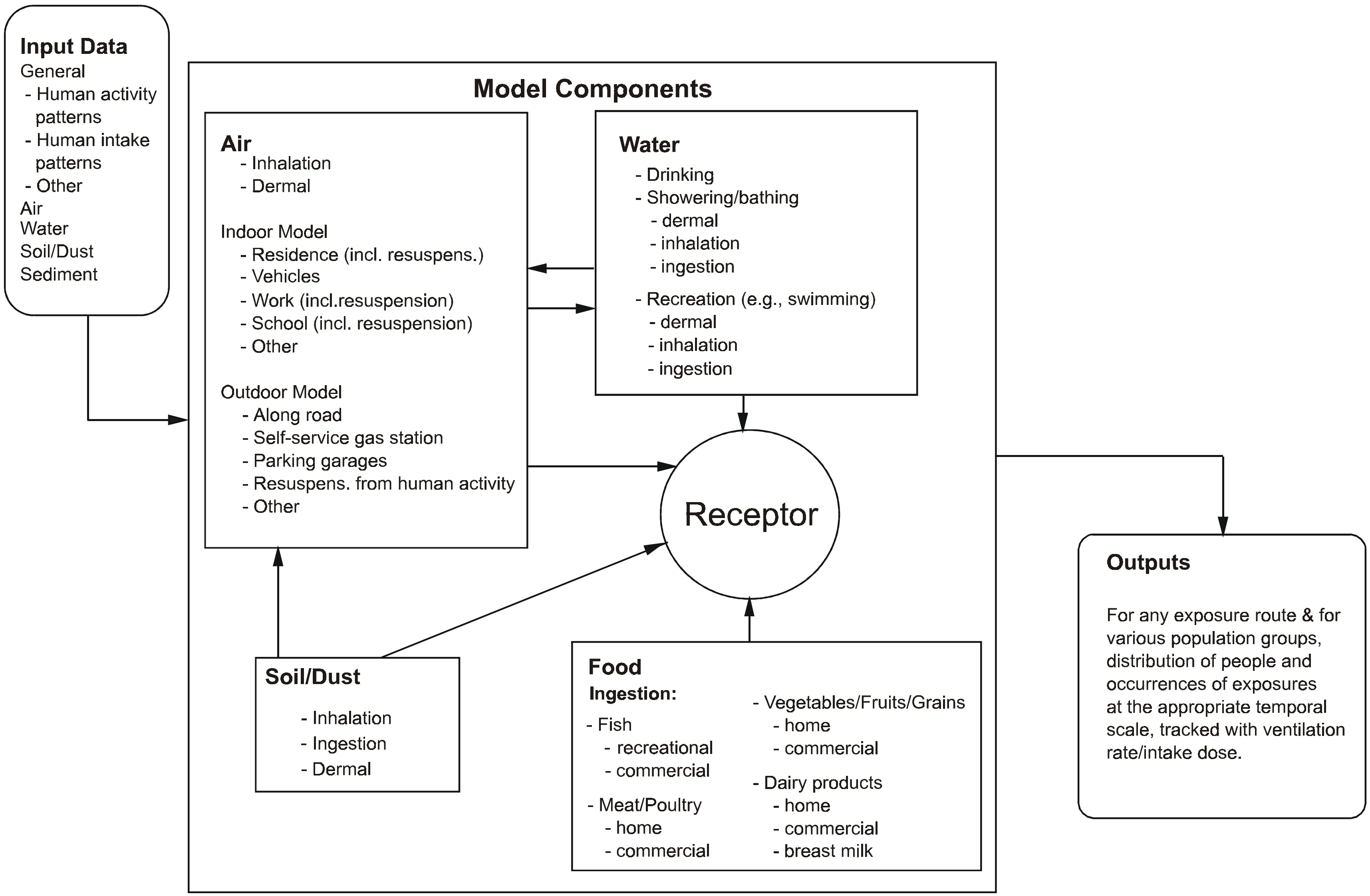
In a typical TRIM application, TRIM.FaTE data may be used to provide an inventory of chemical mass across an ecosystem for selected time steps (*e.g.*, hours, days, years), or monitoring data may be substituted for TRIM.FaTE data. Alternatively, concentration estimates from an air dispersion model may be used if inhalation is the only exposure route of interest and either (1) the chemical is not persistent, or (2) the impacts of only current emissions are of interest. The TRIM.Expo module uses these data, combined with the characteristics and movements of individuals and/or cohorts, to estimate exposures. The movements are defined through a sequence of exposure events that corresponds to the time steps modeled by TRIM.FaTE. Each exposure event places the individual or cohort in contact with one or more of the exposure media for a specified time. Besides the individual's or cohort's sequence of locations, other characteristics that relate to exposure and uptake, such as the respiration rate or the water consumption rate, are also tracked over time.

Current development of TRIM.Expo includes incorporation of the Probabilistic National Ambient Air Quality Standards Exposure Models (pNEM) (Johnson et al. 1992, Johnson et al. 1999) and Hazardous Air Pollutant Exposure Model (HAPEM4)[1] into the TRIM.Expo platform for short-term and long-term inhalation exposures, respectively; incorporation of ingestion algorithms based on the EPA Indirect Exposure Methodology (IEM)[2] (U.S. EPA 1999d) and the California Total Exposure Model for Hazardous Waste Sites (CalTOX) (McKone 1993a, McKone 1993b, McKone 1993c); and the performance of test cases for inhalation and ingestion pathways. These test cases will undergo an SAB review.

[1] The development and testing of HAPEM4 were recently completed. The developers are in the process of producing a report and accompanying Programmer and User Guides.

[2] The EPA now refers to this as Multiple Pathways of Exposure (MPE) methodology.

Figure 8-1
Conceptual Diagram of TRIM.Expo



8.3 CONCEPTUALIZATION OF TRIM.Expo

The TRIM.Expo module is built around the concept of simulating a series of exposure events. Exposure events are human activities that bring individuals in contact with a contaminated exposure medium within a specified microenvironment at a given geographic location. In TRIM.Expo, exposure of each individual or cohort is determined by a sequence of exposure events specific to the individual or cohort. The exposure-event sequence is a chronologically-ordered series of events that identifies the locations and amount of time spent in those locations. Each exposure-event sequence consists of a series of events with durations ranging from one to 60 minutes. Each exposure event assigns the cohort to a particular combination of exposure district, microenvironment, and activity (*e.g.*, cooking, playing, resting). An exposure district is a geographic location within a defined physical or political region, where there is potential contact between an organism and a pollutant, and for which environmental media concentrations have been estimated either though modeling or measurement. A microenvironment is a location defined by a specific chemical concentration where exposure may occur. The following important attributes of an exposure event are used to estimate the corresponding exposure concentrations and potential doses:

- Chemical concentration in an environmental medium (*e.g.*, ambient outdoor air, surface water, soil);
- Any significant intermedia transfer to the exposure medium (*e.g.*, from soil to house dust to air in an indoor microenvironment);
- Chemical concentration in an exposure medium (*e.g.*, personal air, tap water);
- Duration of contact with the exposure medium;
- Number of contacts with the exposure medium; and
- Time scale of interest.

The TRIM.Expo algorithms will use this information to estimate the exposure concentration at each time step to create an exposure time series or profile. By combining the exposure concentration and the breathing rate at each time step, TRIM.Expo will also create a potential dose profile. Depending upon the health effects associated with the chemical of interest, the exposure and potential dose profile may be used to derive several metrics, such as the number of person-hours of exposure to concentrations above a threshold value, the sum of the concentrations that exceed a threshold value, the average of concentrations that exceed a threshold value, or the maximum concentration corresponding to an averaging time of interest for the simulation period.

8.4 FUNCTIONAL ATTRIBUTES OF TRIM.Expo

The goal of the TRIM project is to develop a framework that is scientifically defensible, flexible, and user-friendly; that can address the broad range of risk assessments required under the various CAA programs/provisions; and that supports the regulatory decision-making process for these programs. TRIM is intended to be part of a new generation of environmental risk and exposure models for OAQPS. It will eventually be a predictive environmental model of chemical transfers to human health endpoints that is flexible and applicable to both criteria pollutants and HAPs, while incorporating multimedia, multipathway estimates of exposure and dose. To be successful, TRIM must address the wide range of spatial and temporal scales, endpoints, and pathways of interest to specific CAA programs. To meet these goals, TRIM.Expo will include the following functional attributes:

- Indoor and outdoor environments;
- Indoor and outdoor sources;
- Portable, modular, and flexible algorithms;
- Explicit treatment of uncertainty; and
- Explicit treatment of variability.

8.4.1 DIMENSIONS OF THE EXPOSURE ASSESSMENT PROBLEM

Three important dimensions of the exposure assessment problem are considered: (1) the route of exposure, (2) the time scale of an exposure event relevant to the pollutant's associated effects, and (3) dependence of exposure on the location of the exposed subject (*i.e.*, how strongly or weakly dependent is exposure on the location of the exposure subject?). Addressing these three issues has the greatest impact on the structure of the exposure model (*e.g.*, on the exposure media included, the degree of spatial resolution, and the level of temporal and spatial aggregation). For example, consider a model used to assess inhalation exposures to chemicals with health effects that depend on the number and duration of contacts above a threshold concentration. This model requires a compilation of short-term exposure events and must provide relatively detailed information on the location of the exposed individual. In contrast, an exposure model used to assess ingestion contact with a chemical that has health effects that depend primarily on the lifetime cumulative intake of that chemical would require much different temporal and spatial detail about the exposed individuals. In this case, rather than tracking the detailed time/location profile of the exposed cohort, it is more important to know the location of the exposed cohort's food or water supply and the cumulative intake of food or water from a specific supply.

The primary routes of exposure to environmental chemicals are inhalation, ingestion, and dermal contact. The primary time scales for exposure assessment models vary from short-term resolution (*e.g.*, minutes to hours and days) to long-term resolution (*e.g.*, days to months and years). Short-term resolution allows for the assessment of both cumulative intake and the number and duration of peak exposure events. Long-term resolution allows primarily for the assessment of cumulative intake. The quantitative distinction between short-term and long-term depends to some extent on the pharmacokinetics (*i.e.*, uptake and distribution) and toxicokinetics of the chemical substance. Location dependence specifies the level of detail required for the time-activity budget of an exposed individual. For example, to address inhalation exposures where chemical concentration varies significantly from among several districts in which the exposed cohort lives and differs strongly between indoor and outdoor microenvironments, location dependence is high. But, if the properties of the chemical are such that concentrations are similar in almost all microenvironments, location dependence is lower. For ingestion exposures to a chemical in ground water that is distributed throughout a region, the location of the exposed cohort is much less important than the source of the cohort's drinking water.

Three primary attributes are used to describe an exposure problem using TRIM.Expo: (1) exposure route, (2) exposure time scale, and (3) the degree of location dependence. This set of attributes gives rise to a broad set of exposure problems, such as short-term inhalation exposure with strong location dependence, long-term ingestion exposure with weak location dependence, and short-term dermal contact exposure. The general exposure-event function used in TRIM.Expo has a form that can be adapted across the broad range of problems defined by these attributes. In some situations, aggregating among two or more sets of exposure model attributes may be necessary (*i.e.*, combining long-term ingestion exposures that are weakly location dependent with short-term inhalation exposures that are strongly location dependent). The TRIM.Expo module is designed to make such aggregation possible.

8.4.2 DESIGN FEATURES OF TRIM.Expo

Although exposures to some types of exposure media, such as commercial foodstuffs, are not location or time dependent, most of the chemical exposures addressed by TRIM.Expo are associated with particular locations. Also, because of spatial and temporal differences in contamination of exposure media, tracking the locations and activities of individuals or cohorts through time and space to estimate their exposure is important. This requires methods for logging both time-activity-specific locations of individuals or cohorts and the time-specific concentrations of chemicals in relevant exposure media. The process of combining these three different types of information (*i.e.*, location, activity, and concentration) is the *exposure characterization process*. The exposure characterization process can be short-term (*i.e.*, over hours or days) or long-term (*i.e.*, over months or years). The critical issue of the exposure characterization process is to identify appropriate and transparent methods to combine concentration information with activity tracking (*i.e.*, tracking locations and activities at different times) to assess short- and long-term exposures. To develop the exposure characterization process for TRIM.Expo, the following attributes that define an exposure event were identified and ranked:

- Route of exposure;
- Time/space scale of the chemical concentration;
- Time scale of the health effects;
- Duration of the exposure event;
- Contributing environmental medium;
- Exposure medium; and
- Demographic characteristics of the exposed individual (*e.g.*, age, gender).

The route of exposure refers to the way the chemical can enter the receptor during the exposure event (*i.e.*, by inhalation, ingestion, or dermal uptake). The route of potential uptake (*i.e.*, absorption into the body) is a very important attribute of an exposure event. The health effects of an exposure may vary significantly among these three routes. Both the exposure medium and exposure-related activity are often strongly associated with a particular intake route. For example, air is associated with the inhalation route, and the inhalation rate varies significantly with activity location. Water, food, and soil are associated with the ingestion route and with eating and hand-to-mouth activities.

The time scale and spatial scale of the chemical concentration variation provide critical insight on time and space resolution needed in constructing an exposure event. If a chemical shows little spatial variation in concentration over a large region, even if the concentrations vary with time, there is little need for large numbers of geographic regions in an assessment. Similarly, for a chemical whose concentrations do not vary significantly in time, even if they show large spatial variation, using longer time steps may be possible than that needed for a chemical whose concentrations vary more quickly in time. However, the time scale of exposure associated with health effects for a particular pollutant also strongly effects the temporal resolution required of the exposure-event model. Some chemicals, such as most of the criteria air pollutants, require the estimation of the number and duration of peak exposure events. For hazardous air pollutants with acute health effects, exposures may need to be aggregated over periods as short as one hour or less. For many hazardous air pollutants, only long-term cumulative exposure may need to be characterized.

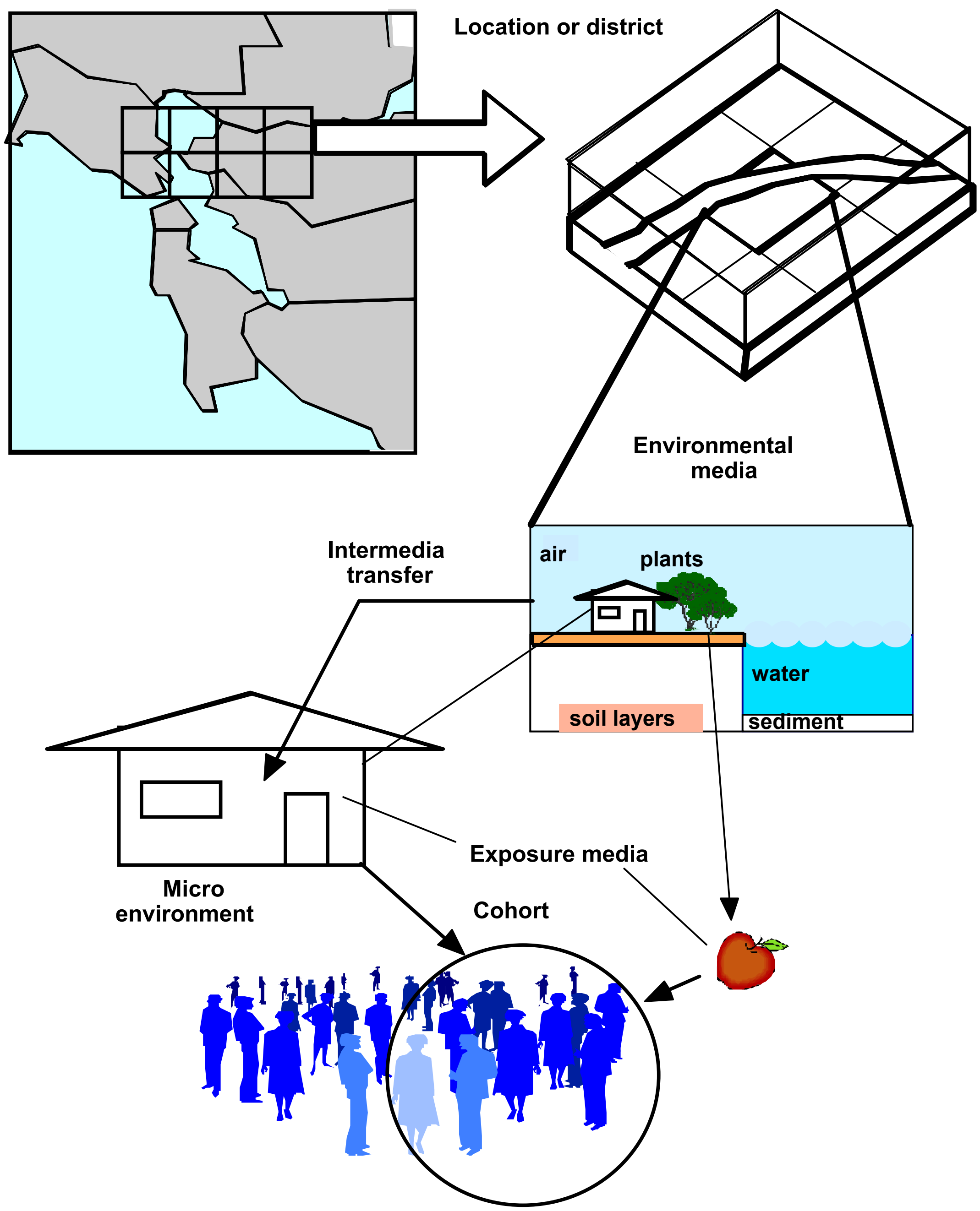
The durations of the exposure events and human activities are important considerations in the structure of the exposure-event model. Other factors that affect the structure of the exposure-event model are the demographic characteristics of an exposed individual or population group, such as age or gender, that may influence both their activity pattern and their health response to exposure. Other characteristics, such as proximity to particular emission sources or health status, also may be important. The interconnected nature of the relationships among the locations, microenvironments, environmental media, intermedia transfers, exposure media, and cohorts within TRIM.Expo is illustrated in Figure 8-2.

8.5 APPROACH USED IN DEVELOPING TRIM.Expo

The TRIM.Expo module will model exposures from the inhalation, ingestion, and dermal contact routes. For the first prototype, however, the exposure routes are limited to inhalation and ingestion. Dermal contact will be addressed as a longer-term goal of TRIM.Expo.

The TRIM.Expo TSD includes a comprehensive discussion of currently available exposure models. These models were reviewed to determine whether they would be suitable for the exposure modeling needs of OAQPS. Although no single model or set of models has been identified that meets all the requirements for the exposure modeling needs of OAQPS, many of the concepts and components developed for existing models have been used in TRIM.Expo. For the inhalation pathway, the structure from EPA's pNEM/CO (probabilistic NAAQS Exposure Model for Carbon Monoxide) and HAPEM4 models

Figure 8-2
Relationships Among Locations, Microenvironments, Environmental Media, Intermedia Transfers, Exposure Media, and Cohorts



have been adopted for short-term and long-term exposures, respectively. These constructs use activity patterns to track population groups/cohorts as they move among exposure media. The pNEM/CO model also includes a mass balance treatment of the relationship between the environmental medium (*i.e.*, outdoor air) and the exposure medium (*i.e.*, indoor air), as well as the characterization of uncertainty and variability. For the ingestion pathway, algorithms from EPA's IEM and CalTOX have been adopted. The CalTOX model can model multimedia transport and transformation of chemicals, and multipathway exposure for humans. The IEM incorporates current EPA guidance for addressing exposures via inhalation, ingestion, and dermal contact.

8.6 SUMMARY REVIEW OF EXISTING EXPOSURE MODELS AND THE UNIQUENESS OF TRIM.Expo

This section provides a brief review of currently available and emerging exposure modeling approaches. The Agency critically evaluated each of the exposure models described in this section, assessing their strengths and limitations. Based on this review, none of the models adequately meets the modeling needs of OAQPS (see Chapter 1 for a discussion of OAQPS' needs). The review in this section, however, highlights the unique features of these models that can be included in TRIM.Expo to meet the modeling needs.

8.6.1 OVERVIEW OF CURRENT MODELS

In general, the models that most closely meet the design goals for TRIM.Expo development are the focus of this section. These include models that can calculate short-term exposures (*i.e.*, one hour or shorter) and that can be adapted to evaluate long-term exposures as well. The models should also be able to explicitly treat variability and uncertainty. Other desirable model attributes meeting OAQPS' needs are the inclusion of multiple media, the use of a mass balance approach for estimating indoor air concentrations, and the ability to track exertion rates concurrent with exposure. For inhalation, this means providing estimates of the respiration rate (also called the ventilation or breathing rate) for various activities. Additional useful features include accounting for indoor air emission sources and the ability to include geographic mobility (*e.g.*, commuting) in the exposure simulation.

The development of TRIM is designed to focus on the processes that have the greatest impact on chemical fate and transport and on human exposure. To have the same scientific basis as the rest of the TRIM system, TRIM.Expo needs to incorporate the same attributes, including (1) mass conservation; (2) the ability to characterize uncertainty and variability; (3) the capability to assess multiple chemicals, multiple media, and multiple exposure pathways; and (4) the ability to perform iterative analyses at varying levels of complexity. Hence, these four design attributes are the basis for critically comparing the strengths and limitations of current exposure models and for determining the features that will be used in TRIM.Expo development.

No single model exists that can meet all of the needs of OAQPS for a multimedia, multichemical exposure model. However, several models use methodologies that can be adopted in the development of TRIM.Expo. One model that has many of the desirable attributes is the pNEM/CO (Johnson et al. 1992, Johnson et al. 1999). Although this model is for a single medium only (*i.e.*, air), it incorporates many of the features needed for the inhalation component of TRIM.Expo. The pNEM/CO benefits from having most of its input variables chosen stochastically. This stochastic approach allows both variability and uncertainty to be incorporated into the model operation. The pNEM/CO treats human exposure as a time series of the convergence of human activities occurring in a particular microenvironment and air quality in those microenvironments. The model also is designed to provide estimates of the intake dose associated with exposures. In addition to the other criteria listed above, pNEM/CO is well documented and is already being used by OAQPS as an input to regulatory decision-making. Furthermore, the pNEM/CO has undergone review.

The disadvantages of the pNEM/CO model in its current form are that it is difficult to execute and cannot be readily updated and calibrated as more data becomes available. Furthermore, the pNEM/CO model, as with all of the pNEM models, is a single pollutant, single media model.

For modeling the non-inhalation routes of exposure, the CalTOX model, developed at the Lawrence Berkeley National Laboratory, includes many features needed for estimating indirect routes of exposure (McKone 1993a, McKone 1993b, McKone 1993c). The CalTOX model can calculate multipathway exposures for organic chemicals and some metals. In addition, the model is stochastic and can quantify the variability and uncertainty in the exposure calculations. The CalTOX model consists of two main components: (1) a multimedia transport and transformation model and (2) a multipathway human exposure model. The CalTOX model has 23 exposure pathways encompassing all three routes of human exposure, which are used to estimate average daily doses within a human population near a hazardous air pollutant release site. The exposure assessment process consists of relating contaminant concentrations in the multimedia model compartments to pollutant concentrations in the media with which a human population has contact (*e.g.*, personal air, tap water, foods, house dust). This provides explicit treatment of the differentiating environmental media pollutant concentrations and the pollutant concentrations to which humans are exposed. In addition, all input variables are taken from distributions that are provided with the model.

The CalTOX model is limited in the extent of the environmental settings for which it can be applied. For example, it has limited effectiveness for settings where there is a large ratio of surface water area to land area. In addition, it was developed for a limited range of pollutants (*i.e.*, only organic chemicals). As a result, CalTOX does not provide adequate flexibility in the environmental settings nor the chemical classes it models. Also, CalTOX does not allow spatial tracking of a pollutant, hence it is not directly applicable to the TRIM approach.

The Hazardous Air Pollutant Exposure Model (previously called the Hazardous Air Pollutant Exposure Model for Mobile Sources, or HAPEM-MS) has undergone many enhancements in recent years (Johnson et al. 1993, Palma et al. 1996). The latest version of the HAPEM is designated HAPEM4. It allows exposure to population cohorts to be simulated at the census tract level. This is a much finer spatial resolution than was previously possible with the model. It also means that calculation of population exposures no longer needs to rely solely on data from fixed-site monitors. This is an important step in being able to estimate exposures to HAPs because widespread monitoring networks for these chemicals are not available.

The HAPEM4 calculates long-term average exposure concentrations in order to address exposures to pollutants with carcinogenic and other long-term effects. Thus, HAPEM4 does not preserve the time-sequence of exposure events when sampling from the time/activity database. This means that information to evaluate possible correlations in exposures to different pollutants due to activities that are related in time is not preserved. Also, the model does not include any measures of the ventilation rate associated with an activity, so that there is no ability to calculate the potential dose received when engaging in various activities.

The IEM includes fate and transport algorithms, exposure pathways, and exposure algorithms. It focuses on procedures for estimating the indirect (*i.e.*, non-inhalation) human exposures and health risks that can result from the transfer of chemicals from air to soil, vegetation, and water bodies. The IEM addresses exposures via inhalation, ingestion of food, water, and soil, and dermal contact. The methodology has undergone extensive scientific peer review.

The IEM has limitations, however, related to the design goals for TRIM. The methodology can be applied only to pollutants that are emitted to air. Another important limitation of IEM is that it does not provide a detailed time-series estimation of media concentrations and resultant exposures. Also, the methodology does not provide for the flexibility needed by OAQPS in site-specific applications or in estimating population exposures. Significant site-specific adjustments must be made to allow for spatially tracking the relationship between concentrations and exposures. Much of the focus of the methodology is on evaluating specific receptor scenarios (*e.g.*, recreational or subsistence fisher) that may be indicative of high-end or average exposures, but it does not readily allow for modeling the distribution of exposures within a population.

The models summarized in this section provide background information for some of the most commonly used exposure models currently available. More detailed information about these and the other exposure models that were evaluated can be found in the TRIM.Expo TSD.

8.6.2 RATIONALE AND NEED FOR DEVELOPING TRIM.Expo

The TRIM.Expo module is intended to contribute to a number of health-related assessments, including risk assessments and status and trends analyses. The TRIM.Expo module provides a key step in the analysis of the potential for various pollutant sources to contribute to human and ecological health risks. Multiple sources of environmental contamination can lead to multiple contaminated environmental media, including air, water, soil, food, and dust. When considering human exposure, it is necessary to focus on the more immediate contact or exposure media, which include(s) the envelope of air surrounding a human receptor, the water and food ingested, and the layer of soil and/or water that contacts the skin surface. The magnitude and relative contribution of each exposure pathway must be considered to assess the total exposure of a particular pollutant to humans.

The TRIM development is designed to focus on the processes that have the greatest impact on chemical fate and transport and on human exposure. Besides the four design attributes for TRIM.Expo (see Section 8.6.1), OAQPS determined that the model must also (1) address varying time steps (one hour or greater) and provide sufficient spatial detail at varying scales, (2) have the "transparency" needed to be practical to a large and diverse group of users, (3) be modular in design, and (4) be easily accessible.

The summary review of multimedia models presented here, and described in more detail in Chapter 3 and Appendix B of the TRIM.Expo TSD, showed that none of the currently available models offers all of the design features needed by OAQPS for multimedia exposure assessments. Although some models incorporate individual features, none of these, separately or in combination with other models, can function to provide an integrated system that meets the modeling requirements previously described. In addition, most models are limited in the type of media and environmental processes addressed. No model currently exists that addresses the broad range of chemicals and environmental fate and transport processes that are anticipated to be encountered by OAQPS and other stakeholders when evaluating the risks from the multitude of hazardous air pollutants and criteria air pollutants. Therefore, the developers of TRIM have constructed a new model framework that is distinct from the other multimedia models and unique among the current suite of EPA exposure models.

Another reason for developing TRIM.Expo is that none of the currently available exposure models that OAQPS investigated is a sufficiently integrated multimedia model that accounts for inherent "feedback" loops in the exposure continuum and that provides the temporal and spatial resolution needed for estimating human exposures. It is not known to what extent modeled exposure estimates would differ between the currently available models and a truly integrated multimedia exposure model. However, models that are not fully coupled have long been considered to lack scientific credibility. Therefore, OAQPS has determined that it is necessary to undertake efforts to develop a truly coupled multimedia exposure model.

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