December 31, 1998

EPA-SAB-EC-ADV-99-003

Honorable Carol M. Browner
Administrator
U.S. Environmental Protection Agency
401 M. Street, SW
Washington, DC 20460

Subject: Advisory on the Total Risk Integrated Methodology (TRIM)

Dear Ms. Browner:

The Environmental Models Subcommittee (EMS) of the Executive Committee (EC) of the Science Advisory Board (SAB) met in Washington DC May 5 and 6, 1998 to review the Total Risk Integrated Methodology (TRIM), and in particular to review the TRIM.FaTE module. TRIM is being developed by the Office of Air Quality Planning and Standards (OAQPS) of the Office of Air and Radiation (OAR). It is an overall modeling framework intended to provide a flexible method for integrating the release(s) of pollutants from single or multiple sources to their multimedia, multipathway movement in order to predict exposure to pollutants and to estimate human health and ecological risks.

The Subcommittee appreciates the opportunity to provide an early review and early advice to the Agency on the TRIM methodology and on the TRIM.FaTE module in particular. Overall, we found the development of TRIM and the TRIM.FaTE module to be conceptually sound and scientifically based. EPA has gone beyond the current available modeling to create an integrated framework for dealing with multimedia transfers in a more self-consistent, and, hopefully, more useful fashion. It is a very complex model in terms of interconnections, so care needs to be taken to insure that it is applied appropriately and produces realistic results.

There were six charge questions before the EMS. As a result of the public review meeting to evaluate the TRIM.FaTE module in light of the charge questions, and subsequent writing activities by the Subcommittee, this letter and the accompanying report have been prepared. The letter summarizes EMS' key findings and recommendations. The attached report provides a more complete description of the Subcommittee's advice. In response to requests from OAQPS, the Subcommittee expects to conduct additional advisory reviews of the other TRIM modules (i.e., exposure, uptake, biokinetics, dose/response, and risk characterization) over the next few years.

1. Is the overall conceptual TRIM approach appropriate?

The conceptual approach for TRIM appears to be technically defensible. The Subcommittee notes that the most important challenge facing the TRIM modeling enterprise is the lack of available data for fate, transport, exposure and risk processes. The Subcommittee, therefore, recommends that the Agency identify and acquire significant additional field data to estimate modeling parameters and to "validate" the model components and other aspects of the modeling system.

2. Is the spatial compartmental mass-balance approach commensurate with quantifying uncertainty and variability in a scientifically defensible manner?

The Subcommittee accepts that at present the TRIM.FaTE development team has yet to enter into substantial work on the analysis of sensitivity and uncertainty, as it appears that thus far only a local sensitivity analysis has been implemented under prototypical, test-case conditions. The Subcommittee recommends that the literature on sensitivity and uncertainty analysis be reviewed thoroughly prior to making firm choices on the specific forms for incorporating sensitivity and uncertainty analysis into TRIM and that the TRIM developers take the necessary time to reflect on what value the analysis of uncertainty and sensitivity will add to their work and the resulting framework for modeling. The Subcommittee endorses the notion of incorporating checks and balances into the model framework and software in order to guard against future users making inconsistent or illogical choices for numerical parameterization of the model and its uncertainty analysis.

3. Is the overall conceptual approach represented in the TRIM.FaTE Module appropriate?

There are several strengths to the TRIM.FaTE methodology. The Subcommittee finds that the TRIM.FaTE module is conceptually sound and aims at an appropriate level of complexity. The challenge ahead will be in developing and implementing the details beyond the linear algorithms incorporated in the prototype version. OAQPS' emphasis on the steady state distribution of contaminants may prove to be an important limitation. The Subcommittee recommends that the Agency develop a users guide that includes a description of the strengths and the limitations of the TRIM.FaTE module as it is currently constructed or envisioned.

4. The TRIM approach is designed to be flexible and to allow for a tiered approach, to function as a hierarchy of models.

4a. As implemented at this time, is the TRIM.FaTE Module appropriate from a scientific perspective?

TRIM.FaTE is an ambitious attempt to model fate and transport of air pollutants through all aspects of an ecosystem. By design it is very broad and encompasses the different media, pollutant transformations and exchanges. Although the model predicts the accumulation of released air pollutants in target organisms throughout the food chain, there are few data sets that exist to compare with the overall model predictions. TRIM.FaTE consists of a series of connected hypotheses to simulate the complexities inherent in a multi-media environment. It is these hypotheses that can be scientifically tested to elucidate the efficacy and the limitations of the overall model.

The Subcommittee finds that TRIM.FaTE as currently presented and configured has not been checked against a detailed set of observed, spatially varying real world environmental concentration data. The Subcommittee recommends that the module be constructed in a fashion that will permit the component results to be disaggregated and studied to build confidence in the overall prediction of the model.

4b. Is the TRIM.FaTE Module, as designed, an appropriate tool, when run either at a screening level or for a more refined analysis, for use in providing information for regulatory decision-making?

The Subcommittee, absent additional testing and evaluation, cannot provide an assessment or recommendation regarding the appropriateness of the module as a decision-making tool. At this point in its development, the module seems to hold promise as a screening tool.

5. Does the TRIM.FaTE Module, as it has been conceptualized, address some of the limitations associated with other models?

The Subcommittee finds that the TRIM.FaTE module has the excellent feature of conserving mass for chemicals undergoing first-order linear mass transfer and transformation processes. It is, however, uncertain at this time as to how the proposed methods can be adapted for chemicals subject to non-linear higher-order processes. The Subcommittee recommends that the Agency consider providing additional methods and guidance to assist users in selecting the appropriate level of spatial and temporal resolution necessary to obtain adequate precision and accuracy in the results.

6. Does the TRIM.FaTE Module, as it has been conceptualized and demonstrated to date, facilitate future integration with appropriate data sources and applications?

The Subcommittee finds that the TRIM.FaTE module could conveniently and effectively be integrated with data sources such as GIS, provided the spatial scales in the GIS are congruent with those of TRIM.FaTE. However, coupling TRIM.FaTE with other more complex models which generate continuous spatial gradients may be problematic.

In addition to the above, the subcommittee recommends that EPA seek input from users before and after the TRIM.FaTE methodology is developed to maximize its utility, to know how it is being used, and to guard against inappropriate uses; to provide documentation of recommended and inappropriate applications; to provide training for users; to test the model and its subcomponents against current data and models to evaluate its ability to provide realistic results; and to apply terminology consistently.

We congratulate EPA for its initial effort, and look forward to conducting additional reviews of other TRIM modules over the next few years. We look forward to the response from the Assistant Administrator for the Office of Air and Radiation.

Sincerely,

/signed/
Dr. Ishwar P. Murarka, Chair
Environmental Models Subcommittee
Science Advisory Board

/signed/
Dr. Joan M. Daisey, Chair
Science Advisory Board

NOTICE

This report has been written as part of the activities of the Science Advisory Board, a public advisory group providing extramural scientific information and advice to the Administrator and other officials of the Environmental Protection Agency. The Board is structured to provide balanced, expert assessment of scientific matters related to problems facing the Agency. This report has not been reviewed for approval by the Agency and, hence, the contents of this report do not necessarily represent the views and policies of the Environmental Protection Agency, nor of other agencies in the Executive Branch of the Federal government, nor does mention of trade names or commercial products constitute a recommendation for use.

ABSTRACT

The Environmental Models Subcommittee (EMS) of the Executive Committee (EC) of the Science Advisory Board (SAB) reviewed the TRIM.FaTE Module of the Total Risk Integrated Methodology (TRIM) being developed by the Office of Air Quality Planning and Standards (OAQPS) in the Office of Air and Radiation (OAR). TRIM is designed to provide a method for integrating multimedia, multipathway sources of pollutants to more accurately estimate exposure to pollutants and effects from environmental releases. The Subcommittee found the development of TRIM and the TRIM.FaTE module to be conceptually sound and scientifically based. It is a very complex model in terms of interconnections, so care needs to be taken to insure that it is applied appropriately and produces realistic results. Recommendations are made to seek input from users before and after the methodology is developed to maximize its utility, to know how it is being used, and to guard against inappropriate uses; to provide documentation of recommended and inappropriate applications; to provide training for users; to test the model and its subcomponents against current data and models to evaluate its ability to provide realistic results; and to apply terminology consistently.

Keywords: TRIM, TRIM.FaTE, Environmental Models

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1. EXECUTIVE SUMMARY

The Environmental Models Subcommittee (EMS) of the Executive Committee (EC) of the Science Advisory Board (SAB) reviewed the TRIM.FaTE Module of the Total Risk Integrated Methodology (TRIM) being developed by the Office of Air Quality Planning and Standards (OAQPS) in the Office of Air and Radiation (OAR). TRIM is designed to provide a method for integrating multimedia, multipathway sources of pollutants to more accurately estimate exposure to pollutants and effects from environmental releases. The Subcommittee addressed six charge questions:

Charge Question 1: Is the overall conceptual TRIM approach appropriate, given the underlying science, EPA policy, and regulatory needs (i.e., what are the strengths and the weaknesses)?

The conceptual approach for TRIM appears to be technically defensible. The prospect of using TRIM for screening level as well as for more refined analyses offers an appropriate way to use science to inform regulatory decision-making. However, because the approach is still evolving, and subject to change, it is understandably unclear as to how the overall methodology will operate for addressing the spectrum of regulatory questions. For example, one of the strengths of model design is that it can be expanded or simplified as appropriate for a particular application. At the same time, the very flexibility of the system means that care must be taken to guard against developing unnecessarily complex or site-specific modeling applications that can lead to inconsistency or unnecessary delays in the implementation of regulatory policy. In light of this, the Subcommittee recommends that utmost care be exercised to guard against developing unnecessarily complex or inconsistent modeling applications.

The Subcommittee notes that the most important challenge facing the TRIM modeling enterprise is the lack of available data for fate, transport, exposure and risk processes. This lack of data will limit the ability to estimate the parameters for many of the chemicals being modeled. Insufficient data also hinder validation efforts. The Subcommittee, therefore, recommends that the Agency identify and acquire significant additional field data to estimate modeling parameters and to “validate” the model components and other aspects of the modeling system.

Charge Question 2: The TRIM approach is designed for the explicit treatment of uncertainty and variability, including both model uncertainty and parameter uncertainty. Is the spatial compartmental mass-balance approach commensurate with quantifying uncertainty and variability in a scientifically defensible manner?

In principle, there is no reason why an analysis of uncertainty could not be conducted at this stage. However, it is not possible to ascertain whether the spatial compartmentalization will be a significant source of uncertainty in generating predictions. It is apparent that choosing a coarse compartmentalization could introduce significant errors. Another important source of uncertainty is the use of linear models for physical, chemical, and biological processes. Model uncertainty and parameter uncertainty will depend a great deal on the extent and quality of the data available for the modeling effort.

The Subcommittee accepts that at present the TRIM.FaTE development team has yet to enter into substantial work on the analysis of sensitivity and uncertainty, as it appears that thus far only a local sensitivity analysis has been implemented under prototypical, test-case conditions. The Subcommittee recommends that the literature on sensitivity and uncertainty analysis be reviewed thoroughly prior to making firm choices on the specific forms for incorporating sensitivity and uncertainty analysis into TRIM. Agency mandates and other considerations notwithstanding, the Subcommittee recommends that the TRIM developers take the necessary time to reflect on what value the analysis of uncertainty and sensitivity will add to their work and the resulting framework for modeling. The Subcommittee endorses the notion of incorporating checks and balances into the model framework and software in order to guard against future users making inconsistent or illogical choices for numerical parameterization of the model and its uncertainty analysis.

The Subcommittee views the issue of “validation” of TRIM to be an intractable issue because TRIM will never be capable of (in)validation in the classical sense. However, the Subcommittee recommends that the history matching and qualitative peer review should not be set aside, and that the Agency watch for novel methods for quantitatively assuring the quality of models as tools for fulfilling specified predictive tasks. The Subcommittee endorses the incorporation of checks and balances into the TRIM software/framework to guard against future inconsistent or illogical choices for numerical parameterization.

Charge Question 3: The TRIM.FaTE Module is the environmental fate, transport, and exposure component of TRIM. Is the overall conceptual approach represented in the TRIM.FaTE Module appropriate, given the underlying science, EPA policy, and regulatory needs (i.e., what are the strengths and weaknesses of the approach)?

The Subcommittee finds that the TRIM.FaTE module is conceptually sound and aims at an appropriate level of complexity. However, the terminology used to describe the model structure and components is sometimes confusing and contradictory. Chemical transformation algorithms are not clearly characterized. Since this module is still under development, the Subcommittee hopes the developers will pay close attention to resolving this confusion. The Subcommittee further notes that it is difficult to understand the difference between application of the module in a screening capacity versus its application in a more in-depth analysis mode, further examples and clarification are required.

The Subcommittee finds that the TRIM.FaTE module has several strengths. It meets the requirements of scientific and technical defensibility. It is flexible in application to different exposure scenarios, and it is able to address exposures relevant to human health and ecological risk assessment. Further it is user friendly. The challenge ahead will be in developing and implementing the details beyond the linear algorithms incorporated in the prototype version. OAQPS' emphasis on the steady state distribution of contaminants may prove to be an important limitation. The Subcommittee understands that the Agency is fully aware of the bounds and limitations of the methodology. The challenge that remains is to establish how accurate and precise the model results have to be in order to effectively enable human health and ecological risk assessments to inform regulatory decision-making.

The Subcommittee recommends that the Agency develop a users guide that includes a description of the strengths and the limitations of the TRIM.FaTE module as it is currently constructed or envisioned.

Charge Question 4: The TRIM approach is designed to be flexible and to allow for a tiered approach, to function as a hierarchy of models, from simple to complex, as needed.

4a. As implemented at this time, is the TRIM.FaTE Module, with its 3-dimensional, spatial compartmental mass-conserving approach to predicting the movement of pollutant mass over time, appropriate from a scientific perspective?

TRIM.FaTE is an ambitious attempt to model fate and transport of air pollutants through all aspects of an ecosystem. By design it is very broad and encompasses the different media, pollutant transformations and exchanges. The Subcommittee finds that TRIM.FaTE, as currently presented and configured, has not been checked against a detailed set of observed, spatially varying real world environmental concentration data. Furthermore, with its highly aggregate representation of environmental compartments, it is unlikely that it can be effectively used to address fully variable 3-dimensional spatial analysis. Structurally, intermedia mass transfer capabilities have been articulated, but their scientific “validity” awaits bench-marking against observational data and other media-specific models. TRIM.FaTE consists of a series of hypotheses that are connected to simulate the complexities inherent in a multimedia environment. It is these hypotheses that need to be scientifically tested to elucidate the efficacy and the limitations of the overall model. A number of other process-based models for air, surface water or ground water systems (e.g., MODFLOW for 2- and 3-dimensional groundwater flow, Chesapeake Bay Water Quality Model) may offer greater value for certain applications than does the TRIM.FaTE module, particularly when transport and concentration gradients within the particular medium dominate the fate and exposure outcome.

The Subcommittee recommends that the module be constructed in a fashion that will permit the component results to be disaggregated and studied to build confidence in the overall prediction of the model. The model needs to include an internal tracking and accounting system that will permit scrutiny of smaller segments or sub-components. The Subcommittee identified several important issues that may limit the applicability and credibility of the current prototype of the module, including the omission of dispersion phenomena throughout the model, especially turbulent diffusion in air. Neglecting horizontal diffusion as an intercompartmental transport mechanism in the prototype appears to be a serious limitation, especially for short-term simulations. The effect of this assumption is clearly apparent in the results with constant meteorology, and it also affects the results for the case with variable meteorology. Such limitations will be particularly important when chemical properties and site-specific conditions result in significant local concentration gradients and/or temperature effects.

4b. Is the TRIM.FaTE Module, as designed, an appropriate tool, when run either at a screening level or for a more refined analysis, for use in providing information for regulatory decision-making? Given the module design (i.e., the potentially large number of parameters and associated uncertainty and variability), is TRIM.FaTE suitable to support regulatory decisions?

The Subcommittee, absent additional testing and evaluation, cannot provide an assessment or recommendation regarding the appropriateness of the module as a decision-making tool. At this point in its development, the module seems to hold promise as a screening tool providing results to inform decision-making.

Charge Question 5: Does the TRIM.FaTE Module, as it has been conceptualized, address some of the limitations associated with other models (e.g., non-conservation of mass, steady state approach, inability to quantify uncertainty and variability, limited range of receptors and processes considered)? Are there other limitations that the TRIM.FaTE model should address?

The Subcommittee finds that the TRIM.FaTE module has the excellent feature of conserving mass for chemicals undergoing first-order linear mass transfer and transformation processes. It is however, uncertain at this time as to how the proposed methods can be adapted for chemicals subject to non-linear higher-order processes. Since TRIM.FaTE is a compartmental model, there are no explicit vertical or horizontal dimensions, though these may be added by including additional compartments for a given medium. The Subcommittee recommends that the Agency consider providing additional methods and guidance to assist users in selecting the appropriate level of spatial and temporal resolution necessary to obtain adequate precision and accuracy in the results.

The flow model for air transport is highly simplified. The Subcommittee recommends that the Agency carry out additional evaluation of available air models and make the appropriate selection of additional process modules or components for incorporation in the TRIM.FaTE module. In particular, incorporation of turbulent diffusion processes will be important for chemicals where atmospheric concentrations vary significantly from source-release to exposure locations.

The predictive capability of the module is limited because of the gross transfer of mass between sources, receptors and sinks. The Subcommittee recommends that results from TRIM.FaTE be compared with results obtained from the existing "single-media linked models" to establish the advantages and limitations of the TRIM multi-media transport and fate model.

The Subcommittee observes that given the stage of its development, TRIM.FaTE has yet to be substantially tested and exercised using methods for the analysis of sensitivity and uncertainty. The Subcommittee recommends that the literature on sensitivity and uncertainty analysis be reviewed and examined thoroughly by the developers prior to making choices on the specific forms of parametric and model-structure sensitivity and uncertainty analysis.

Charge Question 6: Does the TRIM.FaTE Module, as it has been conceptualized and demonstrated to date, facilitate future integration with appropriate data sources (e.g., GIS) and applications (e.g., multipathway exposure assessment for humans)?

The Subcommittee finds that the TRIM.FaTE module could conveniently and effectively be integrated with data sources such as GIS, provided the spatial scales in the GIS are congruent with those of TRIM.FaTE. However, coupling TRIM.FaTE with other more complex models which generate continuous spatial gradients may be problematic.

The linkage between the TRIM.FaTE module and the Exposure Event Module has not yet been established. The results produced are not directly useable for human exposure assessment, because TRIM.FaTE does not generate distributions of indoor air pollutants, which are the most important input for the Exposure Event Module. The Subcommittee expects that the Agency will be conducting further work to produce distributions of pollutants in all major microenvironments and media so that a full, integrated and reliable exposure assessment for humans becomes possible.

Overall, the Subcommittee found the development of TRIM and the TRIM.FaTE module to be conceptually sound and scientifically based. It is a very complex model in terms of interconnections, so care needs to be taken to insure that it is applied appropriately and produces realistic results. Recommendations are made to seek input from users before and after the methodology is developed to maximize its utility, to know how it is being used, and to guard against inappropriate uses; to provide documentation of recommended and inappropriate applications; to provide training for users; to test the model and its subcomponents against current data and models to evaluate its ability to provide realistic results; and to apply terminology consistently.

2. INTRODUCTION

The Environmental Models Subcommittee (EMS) of the Executive Committee (EC) of the Science Advisory Board (SAB) met on May 5-6, 1998 to review the TRIM.FaTE Module of the Total Risk Integrated Methodology (TRIM). TRIM is being developed by the Office of Air Quality Planning and Standards (OAQPS) in the Office of Air and Radiation (OAR) to provide a method for integrating multimedia, multipathway sources of pollutants to more accurately estimate exposure to pollutants and effects from environmental releases.

This initial review of TRIM, which focuses on TRIM.FaTE, the environmental distribution and fate component of the model, is considered an SAB Advisory since it provides peer review of an Agency work-in-progress. The goal of an SAB Advisory is to provide suggestions to the Agency for mid-course adjustments that will refine the ultimate product. In this case, the intent of an early SAB review of the TRIM.FaTE module is to facilitate the completion of the TRIM multimedia, multipathway computer methodology. The Subcommittee expects to conduct Advisory reviews of the other TRIM modules (i.e., exposure, uptake, biokinetics, dose/response, and risk characterization) over the next few years.

The materials provided to the SAB for review consisted of:

a) the Total Risk Integrated Methodology: Implementation of the TRIM Conceptual Design through the TRIM.FaTE Module, and;

b) the Total Risk Integrated Methodology: Technical Support Document for the TRIM.FaTE Module

The charge to the Subcommittee (Attachment A) contained six questions focusing on the overall conceptual TRIM approach, the treatment of uncertainty and variability, the appropriateness of the overall conceptual approach represented in the TRIM.FaTE module, the appropriateness of the approach to predict the movement of pollutant mass over time, the suitability of TRIM.FaTE to support regulatory decisions, the extent to which the TRIM.FaTE module addresses some of the limitations associated with other models, and the ability of the TRIM.FaTE module to facilitate future integration with appropriate data sources (e.g., GIS) and applications (e.g., multi-pathway exposure assessment for humans).

3. OVERVIEW COMMENTS AND OBSERVATIONS

The general conceptual approach of TRIM is consistent with the state-of-the-art of multimedia pollutant fate and transport models. The use of a compartmental mass-conserving approach to predict the movement of pollutant mass over time is appropriate from a scientific perspective. The idea of using the model in a hierarchical mode first for screening and subsequently for more refined analyses is appropriate to inform regulatory decision-making. The TRIM concept represents a complex and comprehensive set of interconnections. EPA has gone beyond the current available modeling to create an integrated framework for dealing with multimedia transfers in a more self-consistent, and, hopefully, more useful fashion.

The major concerns regarding TRIM.FaTE at this point center around the extent to which it:

a) represents reality and is scientifically verified

b) can provide defensible information for decision-making

c) is user-friendly

4. RESPONSE TO CHARGE

Charge Question 1: Is the overall conceptual TRIM approach appropriate, given the underlying science, EPA policy, and regulatory needs (i.e., what are the strengths and the weaknesses)?

The conceptual approach for TRIM appears to be technically defensible. However, because the approach is still evolving, and subject to change, it is unclear how the overall TRIM methodology will operate. TRIM's strength is its multimedia, multiexposure pathway design that for atmospheric releases will allow consideration of the exposure pathways, other than direct inhalation, that are critical for the assessment of likely ecological or human health risks.

The focus of the TRIM.FaTE conceptual approach is on the impact of atmospheric releases of persistent chemicals. Currently, the system is being developed to allow the assessment of organic and inorganic chemicals, specifically air pollutants; EPA is currently developing model parameters for mercury, arsenic, benzo(a)pyrene and phenanthrene. A technical strength of the approach is the explicit and full accounting of the distribution of the mass of the chemicals across the environment. This is important when accounting for the cycling of chemicals in the environment that may result in ecological or human health risk via a variety of exposure pathways. A further strength of the TRIM approach is the flexibility accorded by its open architecture. The modular design allows assessment of different temporal and spatial scales, and of different human and ecological endpoints. It allows the system to be expanded or simplified as appropriate for a particular application. At the same time, the very flexibility of the system means that care must be taken to guard against developing unnecessarily complex or site-specific modeling applications that can lead to inconsistency or unnecessary delays in the implementation of regulatory policy. It is important to remember that TRIM's utility is for practical applications; not for research. Still, the flexible architecture should be utilized to test and incorporate new research findings as they evolve for the overall improvement of the module and the regulatory decisions that are informed by it.

TRIM.FaTE aims at an intermediate level of complexity. It does this by expressing the physical system being modeled as a series of linked compartments, a simplifying approach, but then adds to it considerable complexity in the form of pollutant-specific reactions, uptake, and intermedia mass transfer and transport (advective and diffusive) between compartments. It is doubtful that a box-type compartment model of this type could become much more complex, the next level being models which incorporate precise physical boundary sizes and shapes, and generate continuous concentration gradients within model domains.

For most of the hazardous chemicals for which TRIM.FaTE is intended, the complex and often uncertain mechanisms which control partitioning and transformation among multiple environmental media are such that only order-of-magnitude accuracy is possible for predictions of environmental concentrations, at best within a factor of two. For this type of assessment, completely mixed compartment models are wholly appropriate. Furthermore, the insights needed for many environmental fate and transport applications are either insensitive to the exact locations and shapes of boundaries, or the users are relatively unconcerned with the time a certain concentration of a contaminant reaches an exact location. (There are site-specific applications where the location and shapes of boundaries, or the need for computing intradomain continuous gradients may be important, for example oil spills, sea water intrusion into groundwater, estuaries with significant tidal fluxes, etc.) Thus, although from a mathematical point of view environmental fate and transport is a boundary value problem, the use of completely mixed volumes of generally accurate size (boxes), but inexact dimensions, allows the greatly simplifying step to be taken of expressing pollutant mass balances as a series of coupled ordinary differential equations instead of partial differential equations. This is certainly acceptable, as long as the limitations of the TRIM approach are matched against the desired uses in practice.

Although the basic approach of TRIM.FaTE is reasonably clear from the Status Report, in particular the figures and examples, the terminology used to describe the module is sometimes confusing and, in some cases, contradictory. This may be important as the TRIM program continues to unfold and new participants and users are added, and as eventual users external to the EPA attempt to understand its basis. Chapter three introduces a hierarchical set of terms (volume element, domain, domain type, domain instance, cell, link, etc.) which are used throughout, but other sections sometimes use these terms differently, and borrow terms from related areas (for example thermodynamics, systems theory, and numerical methods and programming) that are used either without definition, or with definitions that seem to vary.

On p. 3-13: the construction and usage of “sinks” in the current prototype of the TRIM.FaTE module is not really consistent with the use of this terminology in general environmental modeling. It is clear that there is a need to develop a capability to track the decomposition products of reactive contaminants, particularly if these products are more toxic than the “parent” compounds. However, simply partitioning these compounds into a “box” of degradation products might help to maintain mass-balance but miss the point in constructing relevant exposure scenarios for risk assessment. It is important to clearly define all terms and use them consistently. A given individual from an allied but different background may not be comfortable with the definitions, but at least he/she will know what is meant within the context of the TRIM effort.

The model is consistent with the Agency’s Ecological Risk Assessment and Human Health Risk Assessment Guidelines, but one challenge facing the TRIM modeling enterprise is the lack of data needed to assess ecological and human health risk outcomes to accurately inform EPA’s environmental decision-making. There are two aspects to this. First, there are insufficient data to define the parameters relating to the chemicals to be modeled (i.e., there are 188 hazardous air pollutants that are subject to regulation, none of which is sufficiently well-characterized). Secondly, there are insufficient data available to carry out model “validation” efforts. A major effort is needed to meet these data needs. This problem is not unique to the TRIM approach. It is very important that data sets other than those used to develop the models be sought to test the models. It is recommended that a number of “validation” data sets be identified so that different components and aspects of the system can be tested thoroughly. This activity should not be confined to the developmental stages and early application, but should occur on an ongoing basis.

Further, the model does not specify how to develop the mass transport coefficients for these configurations for surface waters. The model cannot handle 2-D horizontal and full 3-D spatial configurations. Kinetic processes in the water column are very limited as well. While the overall structure and formulation of TRIM.FaTE is scientifically sound, particular mass transport and chemical transformation terms within the system are not clearly characterized. The extent to which these are included, and the particular representations used, need to be carefully evaluated and supported. To support regulatory needs, the configured module must be “validated” by site-specific data. The TRIM document does not currently address this issue.

Sufficient data are unlikely to be available for any chemical or set of chemicals to “validate” all aspects of TRIM.FaTE simultaneously. As such, validation of TRIM.FaTE may only be possible on a piecemeal basis, component by component. This could, of course, be viewed as a flaw in the module's design. Yet TRIM.FaTE is no different in this respect from any other large, complex model being used today as a tool for supporting policy development, screening analyses, and pragmatic, decision support analyses. There is in general a growing realization that the issue of determining the trustworthiness and utility of such models is not a closed-form problem with a simple “yes” or “no” answer. This is not to say that TRIM.FaTE can not therefore be used with confidence. Rather, the challenge is for alternative, supplementary, more appropriate methodological frameworks to be developed and applied for evaluating the legitimacy of such policy-forecasting models (as further discussed under Charge 2 below). In this respect, the Subcommittee notes, in particular, previous Agency experience in coming to terms with this problem, in evaluating models of the fate of lead in the environment (Oreskes, 1998).

The Subcommittee strongly recommends that substantial guidance and training be provided to users of TRIM to ensure its efficient and appropriate application and to facilitate its wide acceptance. Detailed guidance should be provided on the applicability of the complete mixing assumption, and on the selection of appropriate time steps and compartmental volumes. The selection of time steps and spatial resolution also needs to be carefully matched to the available data and parameter values. The prototype application assumes equilibrium for most processes, but for some processes this assumption may not be justified. Therefore, detailed guidance is needed on when equilibrium assumptions are appropriate, and/or when sensitivity analysis may be needed to evaluate errors associated with neglecting transient effects.

The Subcommittee also recommends that the EPA provide a clear articulation of the tasks to be accomplished by TRIM to help ensure its appropriate use and applications. The SAB recommends that TRIM be designed with self-diagnostic features to assist the user during its application. Careful consideration should also be given to the method used for visualization of the results as well as their uncertainties. This should be designed with consideration of the specific assessment goal for each application, since it will impact the interpretation of the results and how well they inform the decisions reached.

Besides its use at EPA for evaluating hazardous air pollutants, TRIM may find utility in a number of other scientific assessment or educational applications. Examples include evaluations of fate, transport, exposure and risk for ranking or comparing chemical emissions for product design/life cycle assessments, and teaching graduate level classes on fate and transport modeling. We expect such uses to be facilitated, because the model is intended to be operated on a PC and to be user-friendly.

Charge Question 2: The TRIM approach is designed for the explicit treatment of uncertainty and variability, including both model uncertainty and parameter uncertainty. Is the spatial compartmental mass-balance approach commensurate with quantifying uncertainty and variability in a scientifically defensible manner?

In responding to this question the Subcommittee adopted two working definitions:

a) **Uncertainty** is the term used to acknowledge the fact that the "true" value of a quantity (or variable) is not available; there are only a number of observed or estimated values available and the spread of these reflects, in some sense, the uncertainty associated with the “true” value.

b) **Variability** captures the familiar idea that a quantity (or variable) may have different "true" values at different instants in time, at different locations in space, and/or from one individual to the next. Variability is an intrinsic characteristic of a quantity; unlike uncertainty, it is not reduced by better knowledge and further study, only better characterized.

The Agency has acknowledged the need for TRIM.FaTE to account explicitly for uncertainty and variability and has apparently built this into the software framework for the module. The Subcommittee did not see a demonstration, or any output from an analysis of model uncertainty.

The ability to comment on the reliability, uncertainty and applicability of an assessment determines the extent to which an assessment can provide useful decision support for decision-making. While uncertainty and sensitivity analysis are part of the overall system, it is not clear how this analysis will be incorporated and how it will be presented as part of the overall assessment. This needs to be clearly defined.

The Subcommittee accepts that at present the TRIM.FaTE development team has yet to enter into substantial work on the analysis of sensitivity and uncertainty, as it appears that thus far only a local sensitivity analysis has been implemented under prototypical, test-case conditions. Thus, the Subcommittee strongly recommends that the literature on sensitivity and uncertainty analysis be reviewed thoroughly prior to making strategic choices on the specific forms of such analysis to be incorporated within TRIM. We say this because this literature is widely dispersed and, perhaps more importantly, has grown substantially over the past three or four years. In particular, the *Second International Symposium on Sensitivity Analysis of Model Output* was held April, 1998 in Venice, Italy. Its proceedings provide a fairly comprehensive survey of what is a rapidly evolving field, notably in the area of novel techniques for *global* sensitivity analysis, especially as applied in the areas of industrial management systems, reliability engineering, and assessments of the storage of nuclear waste materials.

In addition, the Subcommittee is concerned about the issue of correlation among sources of uncertainty, notably among the errors associated with model parameter (coefficient) estimates. Consideration of correlated errors is important for two reasons. First, during calibration of the model, an error in the estimate of one parameter may cancel out the effects of that parameter on another, with the model user being unaware of this potential source of uncertainty. The Subcommittee is concerned that the transfer coefficients in TRIM.FaTE, which are understood to be, in fact, linear sums of several other coefficients, may be especially prone to this kind of error. Second, when the model is used for the purposes of forecasting, the consequences of accounting for the effects of correlated errors can be significant, possibly markedly changing the level of uncertainty associated with the forecast states.

While calibration of a model is usually understood as serving the purpose of generating estimates of the unknown (or imprecisely known) parameters in a model, it can also be viewed as a means of reducing the uncertainty attaching to the model, prior to calibration. When viewed in this light, it is easy to appreciate how good quality data for calibration, i.e., field observations with low uncertainty, can lead to lower residual uncertainty in the model after calibration, which, in turn, should facilitate the generation of forecasts with lower levels of uncertainty.

Where EPA makes comments in anticipation of the analysis of uncertainty/ sensitivity in the development of TRIM, they suggest that incorporating such analysis will improve the science upon which the models are based. Because uncertainty analysis often results in extensive numerical output, its use may imply a more advanced, sophisticated representation of the problem. While sensitivity analysis can help to identify where further data and research can be most beneficial in filling critical knowledge gaps, it does not provide a more advanced scientific representation *per se*, it only characterizes the current state of the scientific knowledge. The role and limitations of sensitivity and uncertainty analysis should be clearly recognized and acknowledged by TRIM developers and users.

Mention is made in several places regarding or alluding to "validation" of the modules of TRIM. In line with the comments made earlier in response to this charge question, the Subcommittee would like to point out that models such as TRIM will (arguably) never be capable of (in)validation in the classical sense, of having been shown to match observed behavior in the past with, at the same time, a unique and well defined set of estimates for the model's parameters. This issue has been dealt with at some length in the paper of Beck *et al.* (1997). While the Subcommittee notes that there may not yet be consensus on this, we believe that with respect to the use of science to inform policy, the notion of model “validation” should not be seen as a matter of classical scientific prediction -- of making statements about future behavior that subsequent observation may reveal to be true (or false) -- but instead as a matter of designing a tool appropriate for the given (predictive) task.

The Subcommittee does not suggest that history matching and (qualitative) “validation” efforts should be put aside; rather, following developmental work with one of the Agency's multi-media models, we suggest that novel methodologies may become available for quantitatively assuring the quality of models as tools for fulfilling specified predictive tasks (e.g., Chen and Beck, 1998). Indeed, given the novelty, and therefore somewhat speculative character, of this shift in outlook on the notion of quality assurance of policy and regulatory models, it may be appropriate to consider convening a small workshop to assess the prospects for its success (there is also a growing interest in this matter within the European Environment Agency). The authors of the *Status Report* on TRIM.FaTE appear to be well aware of the problems of and new trends in model validation, since they identify model-intercomparison as an essential component of model confirmation and sensitivity/uncertainty analysis.

The Subcommittee notes the importance of accounting for the errors of model structure in uncertainty/sensitivity analysis. In a number of disciplines, interest has deepened beyond only accounting for the uncertainty arising from erroneous estimates of parameters in a *given* (uncontested) conceptual structure for the model. There are now efforts to attempt to quantify and account for the effects of uncertainty in this structure (i.e., uncertainty about whether the number of state variables in the model and the mathematical nature of their interactions have been correctly expressed). However, widely accepted methods have not yet emerged and accounting for the consequences of this structural error is far from being resolved.

In principle, there is no reason why an analysis of uncertainty could not be conducted with TRIM.FaTE. At this stage, however, it is not possible to indicate whether the "spatial compartmentalization" of the model (i.e., this specific choice for the structure of the model itself) will be a significant source of uncertainty in generating predictions. It is obvious that choosing a coarse compartmentalization of the model's structure could introduce significant errors into its predictions. However, if a more refined scale of spatial differentiation were to be adopted, there would then be an accompanying obligation to specify in much greater detail the spatial distributions of the model's parameters, but with limited or often no field data by which to do so (thus introducing other sources of uncertainty). The literature on the analysis of uncertainty in modeling surface water quality, for example, suggests that little work has been published on the consequences of such spatial approximation for predictive uncertainty.

Although the Subcommittee has been charged with considering the specific implications of spatial compartmentalization for the analysis of uncertainty and variability, there is a need for this issue to be kept in perspective, relative to other potential sources of error. For example, in a given application of TRIM.FaTE it could be that a more important limitation of the model's structure may be its use (to date) of merely *linear* chemical/biological interactions (see page 3-14 of the *Status Report*).

Model uncertainty and parameter uncertainty depend a great deal on the extent and quality of the data that supports the modeling effort. If site-specific data are available to independently derive the key model parameters, then the parameter uncertainty and prediction uncertainty would be reduced. There is no mention about using site-specific data to develop key model parameters in the documentation of TRIM.

The Subcommittee endorses the stated intention of the TRIM development team to incorporate checks and balances into the software/framework in order to guard against the future user community making inconsistent or illogical choices for numerical parameterization of the software for analyzing uncertainty.

Charge Question 3: The TRIM.FaTE Module is the environmental fate, transport, and exposure component of TRIM. Is the overall conceptual approach represented in the TRIM.FaTE Module appropriate, given the underlying science, EPA policy, and regulatory needs (i.e., what are the strengths and weaknesses of the approach)?

There are several strengths to the TRIM.FaTE methodology. It appears, at least conceptually, to meet the requirements of scientific and technical defensibility, flexibility in application to different exposure scenarios (i.e., prototypes), ability to address exposures relevant to human health and ecological risk assessment, and accessibility for use by the regulatory user community.

The modular structure and process flow of TRIM.FaTE (e.g., Figure 3-4 of the TRIM.FATE Status Report Document) recommends this approach and appears as a powerful framework for developing the integrated exposure assessment capabilities required to support human health and ecological risk assessment. Clearly, the challenge will be in adding the appropriate level of detail to the overall methodology.

The potential weaknesses of the TRIM.FaTE approach are mainly in the mechanics and not the overall concept of an integrated environmental fate model. There appears to be a predisposition toward first order, linear "algorithms" in implementing the module, despite a considerable technical literature on modeling that identifies complex and nonlinear relationships for a number of the component processes that determine the transport, distribution, and fate of contaminants in air, soils, surface waters, groundwater, sediments, and, particularly, in biota. The inability to incorporate growth of organisms in the characterization of bioaccumulation of contaminants appears to be a limitation in the current prototype. There needs to be some guidelines to warn the user when linear algorithms might lead to exposure estimates that are unrealistic or simply incorrect.

TRIM.FaTE is a broad-based multi-media and multi-path model, but because it lacks spatial dimensionality within compartments, it does not have the ability to handle many processes. For example, while TRIM.FaTE can handle velocity in any direction, it can not handle diffusive/dispersive transfer perpendicular to the longitudinal direction, and it has a very limited configuration for mass transport in lakes which are inherently multidimensional.

The subcommittee recommends that consideration be given to implementing TRIM.FaTE with more powerful (and standardized) programming languages. Even though commercial spreadsheets (e.g., Excel) have become increasingly sophisticated and powerful, the user remains constrained to machines and operating systems that support Excel. In addition, there is computational (i.e., memory, disk space, calculations) overhead in using Excel or other such software. For complex, multi-media risk assessments of the kind that tend to justify the TRIM.FaTE, there may be requirements for computing power that exceeds the capacity of personal computers and MS-DOS or Windows. The TRIM.FaTE should be programmed into a "stand-alone" and portable higher level language (e.g., C++, Fortran-90).

While the overall approach of TRIM.FaTE is appropriate, the module is not yet ready for regulatory use. Regulating contaminants in each of the three environmental media requires much more information and data than are currently available. Proper use of the module is also an important issue. More specifically, the accuracy and representation of numerical estimates for module input parameters and coefficients for the specific site is equally important as the model code. For example, derivation of the BOD deoxygenation rate (or contaminant biodegradation rate) from the field data is essential. For toxic metals, determination of the partition coefficient is another key question often raised by regulatory staff. The TRIM.FaTE module has no apparent information on this.

It remains questionable whether the common risk assessments, either for human health or ecological impacts, will require fully integrated, multi-media fate and transport models. This all-encompassing approach, while justifiable from a certain perspective, might indirectly result in the eventual loss or deemphasis of a considerable amount of research and development that has produced a reliable set of transport and fate models for different media and chemical classes (e.g., Jorgensen, 1994). One possible alternative to the TRIM.FaTE approach would be to construct a distributed system of environmental fate models with an intelligent user-interface to select the appropriate model or models depending on the needs of the assessment (e.g., EPA IMES). However, having made the decision to move toward a fully specified, multi-media model, the TRIM.FaTE seems a reasonable approach.

A minor point to note is that the review of contaminant fate modeling in the TRIM.FaTE documentation is rather incomplete and ignores many important environmental models that provide useful exposure scenarios for risk assessment (e.g., EXAMS). TRIM also seems to ignore previous efforts aimed at identifying and organizing the available fate and exposure models into a useful framework for application in risk assessment (e.g., EPA IMES).

Other limitations are adequately outlined on p. 6-8. The challenge remains to address these weaknesses and importantly determine how accurate and precise the model results have to be in order to effectively support human health and ecological risk assessment.

Charge Question 4: The TRIM approach is designed to be flexible and to allow for a tiered approach, to function as a hierarchy of models, from simple to complex, as needed.

The word “tiered” should be removed from any reference to human health or ecological risk assessment. This is a term that applies properly to architecture, not risk assessment. In most instances in the status report, “tiered” really refers to a <u>sequence</u> of increasingly detailed computations.

An overview of the applicability of the TRIM system for different chemicals, and for various scientific and policy issues, needs to be provided. For example, for relatively non-reactive chemicals that distribute themselves in a relatively uniform manner within each media of the environment, the current framework and assumptions probably would provide a reasonable assessment of pollutant fate and transport. For other highly reactive chemicals that exhibit significant spatial gradients within a medium, it may not. It would be useful to develop a “users guide” to the problem area limitations, as well as the strengths of the system as it is currently constructed or envisioned.

The multimedia environmental system represented by TRIM.FaTE is very complex. This complexity is necessary for the level of comprehensiveness achieved by the model, though much effort is needed and should continue to be placed on making the system as accessible and user-friendly as possible. In particular, clear direction and support is needed for users to help them understand the difference between application of the model in a screening capacity versus in a more in-depth analysis. This needs to be more clearly presented in the supporting documentation and case study applications. The degree to which TRIM is truly user-friendly depends upon the ease of use of the computer code and the clarity of the supporting documentation.

4a. As implemented at this time, is the TRIM.FaTE Module, with its 3-dimensional, spatial compartmental mass-conserving approach to predicting the movement of pollutant mass over time, appropriate from a scientific perspective?

As noted above, TRIM.FaTE is a zero-dimensional and not a 3-dimensional model. Since spatial variability is not included in the coupled governing equations, TRIM.FaTE is a compartment (completely mixed) model, and there are no explicit vertical or horizontal dimensions in the cell used to represent the various shapes of the environment. Spatial variability is implicitly incorporated in the time step selected. Therefore, the selection of the time step will have a significant impact on the results due to variabilities in both spatial and temporal dimensions. Thus, all environmental fate and transport problems which are particularly sensitive to true 3-dimensional geometries should be modeled with great care using TRIM.FaTE. The report recommends that a carefully chosen automated method be developed to evaluate the spatial and temporal resolutions, and provide guidance to users on the appropriateness of TRIM for specific applications.

Structurally, the mass transfer capabilities of the model are articulated, but the scientific validity of the approach awaits benchmarking against observational data and other explicit, media-specific, models. From a scientific perspective the appropriateness of TRIM.FaTE hinges on its capacity to be evaluated and tested. TRIM.FaTE is an ambitious attempt to model fate and transport of air pollutants through all aspects of an ecosystem. By design it is very broad and encompasses the different media, pollutant transformations and exchanges. Although the module predicts the accumulation of released air pollutants in target organisms throughout the food chain, there are few data sets that exist to compare with the overall model predictions.

TRIM.FaTE consists of a series of connected hypotheses to simulate the complexities inherent in a multi-media environment. It is these hypotheses that can be scientifically tested to elucidate the efficacy and the limitations of the overall model. While TRIM.FaTE breaks new ground in its scope, TRIM.FaTE is not unique in the processes modeled. A host of existing, narrowly focused models are key resources for evaluating TRIM.FaTE (e.g., MODFLOW for 2- and 3-dimensional groundwater flow, LEACHN for water and solute movement transformations, and plant uptake and chemical reactions in the unsaturated zone, AGNPS for modeling agricultural nonpoint-source pollution in a watershed).

The Subcommittee recommends that the model be constructed in a fashion that will permit the results to be separated into modules that can be individually verified to build confidence in the overall model. As implemented at this time, the TRIM.FaTE module is not constructed to permit sub-component evaluations.

Tracking and accounting within the TRIM.FaTE module is needed to isolate its predictions and to permit benchmark comparison with data sets and other models that have been widely evaluated and that are inherently better for particular modeling applications. The components of the module need to be evaluated against data and models that have been developed over a range of settings and spatial and temporal scales. This will permit scrutiny of TRIM.FaTE transformation algorithms and the parameters that are used within this component of the TRIM model. Reporting subsets of the model results will permit evaluations of the efficacy of particular predictions in response to the varying levels of aggregation of both the processes that compose a particular transfer function and the input parameters.

As examples, there are considerable data and models to evaluate such internal sub-component predictions as:

a) Estimates of sediment transport and overland flow between land parcels and between the watershed and receiving waters at different time intervals. The Subcommittee recommends that the TRIM.FaTE results be compared (benchmarked) against results from well-tested site-specific watershed models and that the comparison include data sets at much finer spatial resolution than are currently proposed for TRIM.FaTE.

b) The relationship between contaminant loading to a receiving water body and the mass of the contaminant within phases of the aquatic environment (i.e., sediment vs. water).

c) The prediction of partitioning between the sediments and the water column.

d) The prediction of the concentrations of specific pollutants within plants, fish and wildlife that result from exposure to the mass of contaminant within the aquatic and/or terrestrial setting.

The Subcommittee identified several important simplifications within the current prototype of the model that will limit its applicability to a number of localized air pollutant problems and that could hinder its scientific acceptance, including omission of dispersion phenomena throughout the model, especially turbulent diffusion in air. Neglecting horizontal diffusion as an intercompartmental transport mechanism in the prototype appears to be a serious limitation, especially for short-term simulations. The effect of this assumption is clearly apparent in the results with constant meteorology, and it also affects the results for the case with variable meteorology.

4b. Is the TRIM.FATE Module, as designed, an appropriate tool, when run either at a screening level or for a more refined analysis, for use in providing information for regulatory decision-making? Given the module design (i.e., the potentially large number of parameters and associated uncertainty and variability), is TRIM.FaTE suitable to support regulatory decisions?

Although theoretically applicable for both screening and "refined" site-specific analyses, the module appears most suited to screening analyses for idealized cases with simple flows (e.g., absent wind shear or complex terrain) and simple geometry. For more complicated situations, the need for many compartments to represent a given medium and the fact that the volume elements are not addressed by spatial coordinates within a compartment may prove excessively cumbersome.

In the absence of additional testing and evaluation, the Subcommittee cannot provide an assessment or recommendation regarding the appropriateness of the module as a decision-making tool. Clearly, science informs decisions, but many other factors shape policies. At this point in its development, the module seems to hold promise as a screening tool. With increased testing and evaluation, EPA will gain insight into the acceptable types of applications along with the limitations and situations where the module is unsuitable for use.

Charge Question 5: Does the TRIM.FaTE Module, as it has been conceptualized, address some of the limitations associated with other models (e.g., non-conservation of mass, steady state approach, inability to quantify uncertainty and variability, limited range of receptors and processes considered)? Are there other limitations that the TRIM.FaTE model should address?

The TRIM.FaTE module is noteworthy for its dynamic design systems, with flexibility to simulate a range of temporal scales from hours to several years.

TRIM.FaTE has the excellent feature of ensuring conservation of mass. This feature is possible for both dynamic and steady-state calculations for chemicals with first-order linear processes since the approach used is not based on linking different models for different compartments or domain instances (the entire system is presented as a single informational structure, i.e., one matrix). It is however, uncertain at this point as to how the proposed methods can be expanded for higher-order non-linear processes, particularly for the steady state matrix solution procedure.

The system of intercompartmental linkages is one of the most critical components of the model. These linkages are specified by the users. While this feature provides flexibility, it also requires a trained user. The development and inclusion of an expert system is recommended to provide guidance to users. Guidelines for specifying linkages may be based on physicochemical properties of the chemicals (which control transfer and transformation processes), and/or characteristics of the specified environmental landscape and ecosystems. This suggestion is applicable to all the other flexible features in the model that require specification as shown in Figure 2-4 of the TRIM.FaTE documentation.

Because only gross transfer of pollutants between sources, receptors, and sinks is considered, the predictive capability of the module is limited. It is recommended that results from TRIM.FaTE be compared with those from existing linked systems for single-media cases, to evaluate the impact of this more aggregate, simplified simple approach.

Charge Question 6: Does the TRIM.FaTE Module, as it has been conceptualized and demonstrated to date, facilitate future integration with appropriate data sources (e.g., GIS) and applications (e.g., multipathway exposure assessment for humans)?

TRIM.FaTE is conveniently structured to use spatially arranged data sources such as GIS, provided the spatial scales are congruent with those of TRIM.FaTE. However, coupling TRIM.FaTE with other more complex models which generate continuous spatial gradients may be problematic. Such might be the case, for example, for the use of output data from an air transport model, which would require some degree of spatial averaging before being input to TRIM.FaTE. This raises a somewhat larger issue regarding model uncertainty. It appears that most of the thought on uncertainty for TRIM.FaTE revolves around the following factors: inherent parameter uncertainty, the sensitivity of the output to various parameters, and the sensitivity of the output to variations in input. These are certainly valid concerns. However, less obvious are uncertainties associated with the averaging process itself. For example, might the level of uncertainty vary with the overall size of the area to be studied and with the number of volumes used to represent the system? This issue, in turn, is related to issues of “validation” and calibration, and the availability of data from actual sites against which to compare TRIM.FaTE output.

As to the application of the results of the TRIM.FaTE module to the Exposure-Event module, the link between the two has not been established yet. The inhalation route has only been coarsely integrated into the TRIM.FaTE module. The key point is that the TRIM.FaTE module, as it is currently described, will provide a concentration of pollutants (chemicals) in ambient air (outdoors). Thus, to realistically address the inhalation route it will be important to ensure that the Exposure Event module accounts for the differences in air pollutant concentration in the microenvironments where inhalation occurs. Distributions of indoor air pollutants, which are critical for the assessment of human exposure to air contaminants, are not now provided by the TRIM.FaTE module. Further work is needed to produce temporal and spatial distributions of pollutants in various microenvironments and media, so that an integrated exposure assessment for humans is possible. This will likely entail estimating exposures to air pollutants in a cohort of humans by performing exposure monitoring (e.g., office, living room, bedroom, car) coupled with specific activity patterns (e.g., working, watching TV, sleeping, driving). Currently, the TRIM.FaTE module does not produce concentration data for locations where people spend 90% of their time.

5. CONCLUSION

The Subcommittee found the development of TRIM and the TRIM.FaTE module to be conceptually sound and scientifically based. It is a very complex model in terms of interconnections, so care needs to be taken to insure that it is applied appropriately and produces realistic results. The Subcommittee recommends that the Agency seek input from users before and after the methodology is developed to maximize its utility, to know how it is being used, and to guard against inappropriate uses; to provide documentation of recommended and inappropriate applications; to provide training for users; to test the model and its subcomponents against current data and models to evaluate its ability to provide realistic results; and to apply terminology more consistently.

The Subcommittee commends the Agency on its efforts and looks forward to reviewing the other TRIM modules.

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EPA-SAB-EC-ADV-99-003
December 1998
www.epa.gov/sab

AN SAB ADVISORY ON THE TRIM.FaTE MODULE OF THE TOTAL RISK INTEGRATED METHODOLOGY (TRIM)

CONDUCTED BY THE ENVIRONMENTAL MODELS SUBCOMMITTEE OF THE SCIENCE ADVISORY BOARD