UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON D.C. 20460

August 18, 1992

OFFICE OF
THE ADMINISTRATOR
SCIENCE ADVISORY BOARD

EPA-SAB-DWC-LTR-92-013

Honorable William K. Reilly
Administrator
U.S. Environmental Protection Agency
401 M Street, SW
Washington, DC 20460

Subject: Science Advisory Board Review of the Viral Transport (VIRALT) Model

Dear Mr. Reilly:

On December 6-7, 1990, the Drinking Water Committee (DWC) of the EPA Science Advisory Board (SAB) reviewed VIRALT, a modular semi-analytical and numerical model for simulating transport and fate of viruses in ground water. The stated purpose for developing the model was for use as a screening tool for assisting in the development and implementation of the forthcoming ground water disinfection rule. The Committee provided oral comment to the Agency at that public meeting. The comments which form the basis for this report were drafted following the meeting. At a subsequent meeting of the Committee on February 11-12, 1992, Agency staff requested that the Committee's advice concerning the model be formalized in a Science Advisory Board report.

The most serious deficiency of the model development is the lack of field validation. Until this field validation is completed, the model should not be used. Default values for source concentrations, adsorption coefficients and other parameters have been taken from the literature and are not well supported or documented. Furthermore, the assumptions used to develop the model must also be validated. Without these validations, VIRALT cannot be used to identify wells at risk or the disinfection levels required. A very important issue that needs to be addressed is definition of the target user group for VIRALT. The documentation states that it is intended to be used by EPA, State and local technical staff. One potential problem that this presents is the wide range of technical capabilities that would be represented within such a diverse group. The documentation is not adequate for users with a cursory knowledge of groundwater flow and transport phenomena.

The Committee was asked to: 1) make a thorough review of the appropriateness of the modeling assumptions and suggest possible revisions that might improve the predictive capabilities of the model, and discuss the limitations of the model, and 2) review the validity and utility of the model.

1. SCIENTIFIC AREAS OF REVIEW

1.1 Assumptions Underlying the VIRALT Model and Limitations thereof

VIRALT is based on two sets of assumptions: 1) those governing groundwater flow computations, and 2) those governing viral transport computations. Specific EPA questions concerning these assumptions are:

a) Are the assumptions made in the development of the code appropriate considering the intended use of the model and the limitations of the available data?

b) Are any of the assumptions oversimplified or unacceptable? If so, what steps should be taken to address concerns about assumptions?

1.1.1 Groundwater Flow Assumptions

VIRALT employs a semi-analytical flow module for performing groundwater flow computations.

a) Two Dimensional Flow - The flow module is based on two dimensional flow in a confined (or shallow unconfined) aquifer with fully penetrating wells, streams, and boundaries. This should generally produce acceptable predictions for shallow aquifers that would be most likely to be contaminated by septic tanks or leaky sewers. The vadose zone is ignored so the model would tend to produce overly conservative predictions for deep aquifers with thick unsaturated zones because flow in the vertical direction would be significant and would result in longer travel times than predicted by the model.

Partially penetrating wells or stream boundaries in relatively deep aquifers would result in significant vertical flow that, in turn, would result in higher flow velocities than the model would predict leading to non-conservative model predictions. Related issues that need to be clarified are: 1) how the model treats injection of virus into the aquifer, 2) are they mixed over the depth of the aquifer or are they assumed to be injected at the ground water surface as would most likely be the case in a real situation, and 3) what initial virus concentrations should be assumed?

b) <u>Steady State Flow Field</u> - The steady state assumption is probably reasonable for a screening model with the limited data that are available for most sites. Modifying the model to simulate transient flow conditions would require a substantial increase in computational effort and data requirements and would not be justified in most cases. The limitations of the steady state assumption should be discussed in more detail in the documentation to aid the user in understanding its implications for a particular site.

c) <u>Homogenous Isotropic Aquifer</u> - This assumption would be reasonable for situations where application of the model would be most appropriate, i.e., shallow fine grained aquifers. It is not appropriate for layered, or for Karst and fractured rock aquifers where short circuiting or channeling might occur. In these cases it would result in non-conservative predictions of flow times.

1.1.2 <u>Viral Transport Assumptions</u>

a) <u>Viral Transport Mechanism</u> - The transport equation is based on the assumption that viruses behave like dissolved solutes, but viruses are known to behave like charged colloids.

b) <u>Multiple Default Parameters</u> - The user is presented with multiple sorption and inactivation coefficients for 5 viruses with no guidance on parameter selection. Consideration should be given to selecting a standard or indicator virus, i.e. MS-2 phage.

c) Transverse Dispersion Neglected - The transport module is based on the assumption that viral transport occurs along groundwater pathlines. Dispersion perpendicular to the direction of travel is ignored and is represented in the documentation as being conservative because viral concentrations along pathlines would not be diluted by the effects of transverse dispersion. In reality, adjacent wells might be subject to viral contamination because of dispersion of the viral plume, although this is not predicted by the model.

d) Viral Adsorption - The model uses a linear adsorption isotherm that the available data do not seem to support. A more thorough study of available data should be undertaken to assess the validity of the linear isotherm approach. Non-linear or non-equilibrium sorption processes might yield higher virus concentrations at extraction wells than predicted using the linear isotherm. The model does not consider desorption that might in some cases to be important. VIRALT could be probably used to identify potential source areas, but EPA already has models with that capability (GWPATH or RESSQ with modification).

e) First Order Viral Inactivation - First order viral inactivation is not adequately justified, and the basis for temperature correction is not given. The model assumes that viral inactivation rates are the same for viruses in pore water and adsorbed on soil particles. Viruses are inactivated at different rates in adsorbed and dispersed states.

1.2 Validation and Utility of Viralt

Model Validation - The most serious deficiency is the lack of field validation and the model should not be used until this field validation is completed. Default values for source concentrations, adsorption coefficients and other parameters have been taken from the literature and are not well supported or documented. Furthermore, the assumptions used to develop the model must also be validated. Without these validations, VIRALT cannot be used to identify wells at risk or the disinfection levels required.

1.3 Other Issues

A very important issue that need to be addressed is definition of the target user group for VIRALT. The documentation states that it is intended to be used by EPA, State and local technical staff. One potential problem that this presents is the wide range of technical capabilities that would be represented by such a diverse group. The documentation is not adequate for users with a cursory knowledge of groundwater flow and transport phenomena.

Another important issue is the multiplicity of choices of viruses, soil types, aquifer characteristics, etc., with which the user is faced. U.S. EPA should consider adoption of a standard or indicator virus and collecting data for this virus over a wide range of conditions.

2. CONCLUSIONS

The following general conclusions can be made regarding the model.

2.1 Model Assumptions and Limitations

a) Steady State Assumption - Limitations of the steady state assumption need to be described in more detail to aid the user in applying the model to a particular site.

b) Fully Penetrating Wells/Boundaries - The differences of fully versus partially penetrating wells need to be described in detail for the benefit of the typical user. Another issue that needs clarification for all users is that of source injection. Is the contaminant source introduced at the groundwater surface or uniformly over the depth of the aquifer and what concentration of virus are introduced?

c) Aquifer and Virus Transport Parameters - The user's manual should provide the typical user more guidance on selection of modeling parameters. Virus transport parameters are tabulated in Appendix A, but the user is given little guidance in selecting appropriate values for specific site conditions.

d) Interpretation of Results - The typical user is left to his or her own devices in interpreting model results. No mention is made of results interpretation in the users manual.

e) Model Applicability - The model is limited to predicting viral transport in shallow homogenous aquifers.

f) Vadose Zone - VIRALT will produce overly conservative results in deep aquifers with thick un-saturated zones. Long flow times and high rates of viral sorption/inactivation will produce viral concentrations in the aquifer significantly below model predictions.

g) Homogeneous Aquifers - VIRALT is suited neither for karst nor fractured rock aquifers and will generally make non-conservative predictions of virus removal in those formations.

h) Linear Viral Adsorption Isotherm - The linear isotherm is not justified based on the available data.

2.2 Validation and Utility of VIRALT

Before a model can be considered reliable and useful, it must be validated for the conditions that it will be expected to simulate.

a) Validation - VIRALT has not been field validated to date. A field validation must be performed for aquifer systems conforming as closely as possible to the assumptions under which the model was developed.

b) Identification of High Risk Wells - VIRALT can probably be used to identify high risk wells.

c) Source Identification Capabilities - VIRALT cannot be used to reliably identify contaminant sources. EPA already has models with that capability (GWPATH or RESSQ with modification).

2.3 Documentation

The User's Manual is generally adequate for the experienced modeler who is fully aware of the limitations of the model and is experienced in selecting appropriate model coefficients and parameters. To make VIRALT useful for the inexperienced user, however, deficiencies in the User's Manual need to be resolved.

3. RECOMMENDATIONS

The following recommendations are made based on our review of VIRALT.

3.1 Validation of the Model

The model must be validated in the field before adoption for routine use. It has never been validated by comparing its predictions with field data on virus transport in groundwater. As part of the validation, the appropriateness of the assumptions that have been made and the values of the parameters assumed must be evaluated. These include:

a) Steady-state assumption

b) Fully penetrating well assumption

c) Saturated zone assumption

d) Virus adsorption and inactivation parameters

e) Initial virus concentration and means of introduction of virus to the aquifer

f) Selection of target virus assumption

3.2 Define Target User Group

The target user audience needs to be defined and the documentation revised accordingly. An experienced groundwater professional can use the model with the existing documentation with the following recommended modifications. Before inexperienced users can productively use the model, however, documentation will require extensive revision and the program made more user friendly.

a) Documentation - Deficiencies in the User's Manual need to be corrected. Some of the limitations of the model need to be described in more detail.

b) Interpretation of Results - The user should be given guidance in interpreting model results.

We appreciate the opportunity to review this model and look forward to your written response to the advice contained in this letter.

Sincerely,

Raymond C. Loehr

Dr. Raymond C. Loehr, Chair
Science Advisory Board

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