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Modeling Pesticide Movement in Soils

Technical report of an international conference organized by Embrapa Environment
Campinas (SP), Brazil, March 15th, 2001.

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Claudio A. Spadotto

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Preface

The **International Conference on Modeling Pesticide Movement in Soils** was the first conference on this issue with emphasis on tropical and subtropical environmental sets, especially to Brazilian soil and weather conditions. It was organized by **Embrapa Environment** as part of a collaborative effort among **Embrapa**, **University of Florida**, **Oklahoma State University** and **CSIRO-Australia**, with support from **Embrapa Secretariat for International Cooperation**, **Embrapa Labex, Embrapa Information Technology**, **Inter-American Institute for Cooperation on Agriculture**, and **Herbicide in the Environment Committee – Brazilian Weed Science Society.** The conference provided a forum for agricultural and environmental related professionals to discuss on general principles, as well as on specific aspects of modeling pesticide movement in soils stimulated by invited lectures and paper presentations.

This publication is the conference proceedings and contains a report based on annotations from organizing committee members and contributors, as well as abstracts from the presentations by invited participants. About forty scientists and dignitaries from several Brazilian institutes, universities, pesticide registrant scientists, and state research agencies, as well as international scientists from Australia, Germany, Spain, and the United States attended the conference. Attendance and interest were very good and judging by interactions with conference participants presentations were useful or educational for all participants. The audience participated actively by asking questions to the speakers and offering thoughts on various related topics based on their experience and knowledge.

I am very grateful for all of the effort put forth by many people at Embrapa Environment, Embrapa Secretariat for International Cooperation, Embrapa Labex, Embrapa Information Technology, Inter-American Institute for Cooperation on Agriculture, and Herbicide in the Environment Committee of the Brazilian Weed Science Society. I would like to extend my thanks to the participants for their valuable contributions, especially to Drs. Bernardo van Raij, Arthur Hornsby, David Nofziger, Rai Kookana, Arquimedes Lavorenti, Mara de Andrea, Rubem Oliveira Jr., Jussara Regitano, Maria Conceição Pessoa, Diego de Barreda Ferraz, Antonio Moniz, João Baptista da Silva, and Harris Vereecken.

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Introduction

The conference began with an opening presentation by Dr. Bernardo van Raij, who provided an overview of pesticide use and issues in Brazil. The Brazilian pesticide market was some 3-4 times the Australian market and that herbicides constituted nearly 50% of pesticide market in 1999. Soybean herbicide use clearly constituted the major slice of the herbicide component. Dr. van Raij gave the following three useful definitions of a model. A model is (1) a small imitation of the real thing, (2) a system of postulates, data, and inferences presented as a mathematical description of a system of interest, and (3) a technique to organize knowledge on a subject.

Dr. Claudio Spadotto provided an overview of types of models and an introduction to six mathematical models dealing with pesticide transport and fate. Definition and purposes of modeling were presented, as well as nature and structure of models, criteria for model classification and selection, and possibilities for model application were discussed.

Dr. Arthur Hornsby presented an introduction to processes controlling environmental fate of pesticides drawing from his extensive experience not only as a researcher but an extension specialist. Dr. Hornsby also provided an overview of important processes responsible for movement and degradation of pesticides in soils. He emphasized that pesticides move by advection and diffusion, they move with soil water, and the sorption process by which they interact with solid material is a dynamic process that retards the movement of pesticides.

Following this, Dr. David L. Nofziger provided an overview of the CMLS management model for pesticide transport and fate, explaining the fundamental parts of the model, presenting the sensitivity analysis and its limitations. Dr. Nofziger illustrated uses for it, described processes incorporated into it, simplifications made in it, data requirements of it, and methods of dealing with uncertain model parameters such as unknown future weather at a site and spatial variability in soil properties.

Discussions during the question time following these talks demonstrated that the participants appreciated the complexity of the processes and assessed the applicability of CMLS under the Brazilian conditions. Considerable discussion centered around the issues such as conditions under which CMLS can be applied and *vice-versa*.

Dr. Rai Kookana presented Australian experience in pesticide modeling showing case studies where simple modeling tools such as AF index, PIRI index, CMLS and other models have been used to identify chemicals with greater risk of migration to groundwater and surface water, vulnerability assessment and identifying pesticides for inclusion in monitoring program. Dr. Kookana showed some results of experiments involving transport and fate and the ability of different models to describe the measurements. In those cases, CMLS performed as well as other models in predicting the location of the chemical and its amount. However, since CMLS does not provide concentration distributions other models may be needed to answer certain questions. His presentation illustrated that models with good quality data can provide useful information for managing pesticides and protecting human and natural resources. Dr. Kookana also highlighted the similarities between the Australian and Brazilian soils, the difficulty in extrapolation of data from temperate to tropical regions. Substantial discussion ensued on relative suitability of models, data quality and methodology for environmental fate data.

In the panel session, an array of Brazilian scientists presented environmental fate data on pesticides in Brazilian soils. This included sorption, degradation, and modeling studies aspects including sorption versus pH modeling. Pesticide sorption and, particularly, the importance of pH for sorption of ionizable compounds was highlighted in talks of Drs. Claudio Spadotto, Arquimedes Lavorenti, Jussara Regitano, and Rubem Oliveira. Mineralization rates and formation of bound residue was the topic of talk of Dr. Mara de Andrea. Experiences with CMLS applications for Brazilian soils were presented by Dr. Maria Conceição Pessoa. It became clear from the discussions that pH of the soil not only affects the chemical nature of the pesticide molecule, but also the sorbent characteristics. While the effect of pH on charge distribution on variable charge surface is often appreciated, the impact of soil pH on soil organic matter configuration was highlighted for the first time by Dr. Spadotto.

The conference concluded with closing remarks by several eminent participants, Drs. Harris Vereecken, Diego G. de Barreda Ferraz, Antonio C. Moniz, João Baptista da Silva, and a final plea for team approach by Dr. Bernardo van Raij.

Abstracts

Lecture Session

(Invited Speakers)

Remarks on Pesticide Use in Brazil

Bernardo van Raij – Former Director at Embrapa Environment, Brazil

Brazil is an important consumer of pesticides, with a total expenditure of 2.2 billion dollars in 1997, compared with the figure of 30 billion dollars for the whole world. The number has more than doubled during the last decade. In 1999, 49% was used with herbicides, 27% with insecticides, 18% with fungicides and 4% with acaricides. Most of it is used for soybean (35%), with the second crop, sugarcane requiring 8% of the expenditure. Corn, coffee, citrus, cotton, beans and potato are the other important crops for pesticide use. São Paulo state, with its extremely diversified agriculture, uses 23% of the pesticides, followed by Paraná, with 20%. Other important consumers are Rio Grande do Sul, Mato Grosso, Minas Gerais and Mato Grosso do Sul. Some crops require large quantities of active ingredients of pesticides on area basis, especially tomatoes, with 39.5 kg/ha, potato (21.8 kg/ha) and citrus (12.2%). Extensive field crops use less, for example, sugarcane (1.6 kg/ha) and soybean (0.9 kg/ha). These figures, provided by the pesticide industry (SINDAG) and organized by Spadotto et al. (1998), inform in which crops and regions the problems are important. But specific pesticides have to be treated individually and considering the variety of molecules available, this is a formidable task, reinforcing the need for scientific approaches than can aid to the understanding and prediction of pesticide behavior in the environment. A model is often considered a small imitation of the real thing, a definition that suits well objects. But in this case of modeling pesticide movement in soils we are dealing with mathematical models to describe and to organize knowledge, using variables that we can easily measure or belong to the physical chemistry properties of compounds.

Introduction to Pesticide Modeling

Claudio A. Spadotto – Embrapa Environment, Brazil

A model is a representation of an actual system or phenomena that takes into consideration single or multi processes. Just as a physical model, a mathematic model has some level of simplification and abstraction, and the modeling work has many steps. Initially the purpose of the model will condition the modeling work and it is needed explicitly to define the problem and objectives, as well as the spatial and time scales. The required information has to be specified and a survey of existent models is strongly recommended. If no existent model is suitable to the study purpose, a conceptual modeling has to be done, which is based on theory and information available. At this step the approach is chosen, depth of consideration of basic processes and, consequently, the assumptions, degree of complexity, and limitations of the model to be developed are defined. Following this, experimental data are used to adjust and calibrate the model proposed. During the calibration step adjusting of parameters to achieve accurate simulation is done, and a set of criteria for determining model accuracy is selected. At the verification phase the calibrated model is used to simulate data set not utilized in calibration. Other step is the sensitivity analysis when selected parameters are varied and the ranges of output values are compared. There are two basic approaches in modeling: mechanistic and functional. The mechanistic modeling incorporates the most fundamental mechanisms and defines the change rate of water content and solute concentration. Research models are examples of mechanistic models that deal with knowledge seeking better understanding of processes, and provide insights to develop simplified, more practical models. They are useful to identify information gaps and areas of needed research, and researchers concepts may raise questions based on using this type of models. Research models can also be used in coordinating multidisciplinary work. In turn, functional modeling incorporates simplified treatments of solute and water flow, defines changes in amounts of solute and water content, uses capacity factors and is oriented to management or decision-making. Decision-making models deal with information and are generally easy and economical to use. Models can also be deterministic or stochastic. Deterministic models can simulate the system response to a single set of assumed conditions, thus a given set of events leads to a uniquely definable outcome. Stochastic models are structured to account for the uncertainty and take into account the variability of both input conditions and model predictions.

Principles of Pesticide Movement in Soils

Arthur G. Hornsby – University of Florida, USA

Understanding the basic properties of pesticides and interactions with soils and climatic conditions is requisite to achieve efficacy in pest control, economy in food production, and protection of drinking water quality and aquatic ecosystems. Pesticide properties, such as solubility, volatility, sorptivity, and biological and chemical degradation rates affect the fate of pesticides used in agricultural and industrial applications as well as for human health. Soil properties and management are also important determinants of the movement of pesticides in soil either as surface runoff or leaching to groundwater. Soil properties important in pesticide movement include organic mater, clay content and mineralogy, hydraulic properties, and soil biota. Climatic inputs such as temperature and precipitation may play key roles in the environmental fate of pesticides and contribute to significant uncertainty in research and monitoring programs. A summary of databases needed for assessing pesticide movement in soils was presented.

Chemical Movement in Layered Soils (CMLS) Model

David L. Nofziger – Oklahoma State University, USA

The CMLS model was written to serve as a management tool and a decision aid for the application of pesticides to soils. CMLS can be used to estimate the movement of these chemicals in soils in response to downward movement of water. The model also estimates the degradation of the chemical and the amount remaining in the soil profile. CMLS was specifically formulated for ease of use. All of the soil parameters required by the model are relatively easily obtained. CMLS includes routines to estimate daily infiltration and evapotranspiration values from historical weather records. The model incorporates methods to assess uncertainty in leaching estimates due to unknown future weather at a site, spatial variability of soils, and uncertainty in chemical properties. This provides the decision-maker with insight into the range of leaching expected or the probability of leaching more than a specified amount of chemical past some critical depth. Many types of graphs and tables are provided to view results. Extensive data entry and editing capabilities are also provided. As with all models, CMLS incorporates numerous simplifications of the flow and transport system. These arise from time scale of interest, the need to make the data requirements manageable, and the level of complexity considered in other portions of the groundwater system. The nature of these simplifications and their significance to model users were presented. The model was developed as an MS-DOS application. It is now being rewritten in Java for use in the Windows and Internet environments.

Modeling Pesticide Movement in Australian Soils

Rai S. Kookana – CSIRO, Australia

The use of simulation models to predict pesticide behaviour is an attractive way of evaluating solutions to pesticide management problems. A large number of models are available in the literature and a number of these have been used under Australian conditions with varying degree of success. Several screening models have been developed and used in Australia, mainly to carry out vulnerability assessment of groundwater to pesticide contamination. This is because groundwater is an important source of drinking water in several parts of Australia. For example, in the metropolitan Perth (Western Australia) some two thirds of potable water is extracted form groundwater. Several other rural and urban water supplies depend upon ground water sources. In most of the cases, the modeling of pesticide fate under Australian conditions was marred by the lack of locally developed input parameters, e.g. even the simple sorption and degradation parameters. Therefore, it is difficult to objectively comment on the performance of any model. None of the models used is likely to be perfect and all of these are potentially useful. The choice of a model need to be made on the basis of the objective of the study, and availability of input data keeping in mind the strength and weaknesses of the model. Under conditions where the reliable input data is not available, complex models may not be able to provide any more accurate results than those from the simpler models. Clearly it is important to match the availability of input data and model requirements, once a suitable model has been chosen to fulfil the main objective of the study.

Abstracts

Panel Session

Soil Temperature and pH Effects on Pesticide Behavior in Soils

Claudio A. Spadotto – Embrapa Environment, Brazil

Pesticides interact in complex ways with soil components in determining persistence and mobility of organic chemicals. Pesticide movement has been shown to be inversely proportional to the degree of sorption. Several researchers also have suggested that sorption processes tend to limit the biodegradation rate of organic pesticides. Therefore, sorption has a profound impact on pesticide spatial distribution, bioavailability, and persistence in the environment. Extensively mobile pesticides may move into deeper soil layers where microbiological activity is often lower than that in topsoil layers, and this may have important implications with respect to persistence of residues. Degradation rate is also known to be affected exponentially by temperature that decreases with soil depth. Temperature regime is very different in temperate and tropical regions. The term sorption is used to include a variety of possible associations between chemicals and solid phases. Multiple mechanisms of sorption may be involved in the association of a particular chemical with a given heterogeneous system such as soil. Extensive research has been conducted on sorption of pesticides in soils, and several reviews on this topic have been published. Various soil properties have been identified as affecting the mechanism and degree of pesticide sorption. The predominance of nonionic organic-compound sorption on soil organic matter has been extensively documented. While soil organic matter appears to dominate the sorption of most nonionized pesticides, this cannot be assumed for ionizable or highly polar compounds. Many pesticides are weak acids or bases, so one factor that can have a particularly marked influence on the sorption of ionizable pesticides is pH. This is because the extent of sorption can differ greatly for the ionic and neutral forms of such compounds. Although most soils have a net negative charge due to the relative abundance of negative charges on crystalline alumino-silicates and organic matter, some soils in tropical and subtropical agricultural regions of the world, which are composed principally of amorphous alumino-silicates or oxides (hydroxides, oxyhydroxides) of iron and aluminum, may have a net positive charge at low pH.

Influence of Organic Matter in Sorption and Desorption of Glyphosate in Soil

Arquimedes Lavorenti – ESALQ/USP, Brazil

The aim of this study was to evaluate the effects of soil organic matter on the sorption and desorption of glyphosate in three Brazilian soils with different mineralogical attributes. The experiments were carried out at the Laboratório de Ecotoxicologia of the Centro de Energia Nuclear na Agricultura (CENA/USP), Piracicaba, SP. The soils were classified as: Rhodic Kandiudalf (NVef), Xanthic Anionic Acrudox (LAw) and Typic Humaquept (G). In order to evaluate the influence of organic matter on the ghyphosate sorption, the soils were oxidized with H_2O_2 (30 %). The design was completely randomized with a 2X3 factorial experiment. For the sorption experiment, five gliphosate solutions were employed with concentrations of 0.42, 0.84, 1.68, 3.36 and 6.72 mg L^{-1} and radioactivity of 0.233 kBq mL^{-1}. The desorption experiments were performed at concentration of 0.84 mg L^{-1}. The results showed that glyphosate was extremely sorbed to all soils, independently of the presence of organic matter. The glyphosate sorption was related mainly to the mineral fraction of the soils, i.e., to the Fe and Al oxides, however, the organic fraction only played secondary role. It was not observed glyphosate desorption, mostly forming soil bound residues.

Imazaquin Mobility in Tropical Soils

Jussara B. Regitano – CENA/USP, Brazil

This research studied the influence of soil dryness and incubation time before rain (hereafter referred as rainfall timing) on the mobility of imazaquin in two highly weathered soils. Imazaquin mobility will affect the herbicide effectiveness and the potential to contaminate the water table. The soils were classified as Rhodic Kandiudalf (Nvef) clay and Anionic Xanthic Acrudox (Law) sandy clay. They were packed in glass columns (40 x 5 cm) and treated initially at three different moisture contents (saturated, air-dried, moist). Then, applied imazaquin (150 g ai ha^{-1}) was incubated for three different periods (0, 1, and 30 days, respectively) before rainfall simulation began. Imazaquin leaching was not a potential problem in the clay soil (Nvef), but it was a potential problem in the sandy clay soil (Law). For both soils, imazaquin mobility was at maximum when rainfall occurred soon after imazaquin application in moist soils. Soil dryness and rainfall timing affected sorption and consequently imazaquin mobility, mainly in Nvef. The potential of imazaquin to contaminate the water table will be significantly higher when applied to coarse-textured tropical soils and rainfall occurs soon after application. The potential of imazaquin to cause residue problems will be much higher when applied to fine-textured tropical soils and rainfall is delayed following application. Therefore, soil type and weather patterns or irrigation timing must be considered before imazaquin application to achieve maximum herbicide effectiveness and to avoid costly damage caused by residues. Imazaquin leaching from these soils was not in agreement with imazaquin soil sorption data as measured in batch equilibrium experiments. Consequently, batch equilibrium data alone can not be used to predict leaching of anionic organic molecules, such as imazaquin, in tropical soils.

Behaviour of Pesticides in Brazilian Soils

Mara M. de Andrea – Instituto Biológico, Brazil

The studies on the behaviour of pesticides in Brazilian soils begun in 1974 after a joint with the International Atomic Energy Agency – IAEA and Brazilian funding agencies with the Centro de Radioisótopos, today called Laboratório de Ecologia de Agroquímicos. Since then, the researchers have been trained in this subject by the IAEA training courses and specialized by post-graduation courses. Results obtained cover different classes and chemical groups of pesticides, as well as different soil types, and now it is possible to draw some trends on the behaviour of pesticides in Brazilian soils. For example, although organochlorine compounds have been reported as faster degraded in tropical conditions, it did not happen here neither with aldrin, lindane, DDT nor DDE. The main pointed reason seems to be related with the Brazilian soil acidic pH. On the other hand, increase of temperature together with the acidic pH were the reasons for predominance of chemical process for degradation of atrazine, which, in turn, is not very mobile in Brazilian soils. The adsorption of various pesticides – including insecticides, herbicides and fungicides – was related mainly with the soil organic matter and clay content, as detected everywhere. In general terms, the soil organic matter was also found as the main factor for pesticide retention, and consequently, smaller movement in the soil profile. The persistence of the insecticides malathion, carbaryl, parathion, lindane, DDT, some metabolites of disulfoton, as well as the fungicides carbendazin, metalaxyl, and the herbicides 2,4-D, diuron and trifluralin was smaller in soils with larger organic matter contents. The bound residues were detected in smaller amounts for the organochlorine compounds and in larger amounts in soils richer in organic matter. The enhanced degradation of the insecticide parathion and the fungicide metalaxyl was also studied and related with the biological activity of some soils. The effects of different pesticides on some soil biological parameters resulted mainly in stimulation of the dehydrogenase activity and inhibition of iron reduction which measure, respectively, the soil oxidative and anaerobic processes. Although the effects of pesticides on the soil biological parameters were clear, they were transient, indicating the need to maintain favorable conditions for continuous activity of microorganisms, which will act on short-lived effects of pesticide applications.

Sorption and Leaching Potential of Herbicides on Brazilian Soils

Rubem S. Oliveira Jr. – UEM, Brazil

Sorption of the herbicides alachlor, atrazine, dicamba, hexazinone, imazethapyr, metsulfuron-methyl, nicosulfuron, simazine, and sulfometuron-methyl was characterized on six Brazilian soils, using the batch equilibration method. In general, weak acid herbicides (dicamba, imazethapyr, metsulfuron-methyl, nicosulfuron and sulfometuron-methyl) were the least sorbed, whereas weak bases such as triazines and non-polar, non-ionic herbicides (alachlor) were the most sorbed. The Kd values found showed a significant correlation with soil organic carbon content (OC) for all herbicides except imazethapyr and nicosulfuron. Koc values showed a smaller variation among soils than Kd. To estimate the leaching potential, Koc and the Groundwater Ubiquity Score (GUS) were used to calculate half-lives (t1/2) that would rank these herbicides as leachers. The evaluation of leaching potential demonstrated that sulfonylureas and hexazinone are leachers in all soils, alachlor is transitional, and atrazine, simazine and dicamba are leachers or transitional, depending on soil type. Results provide background to prioritize herbicides or chemical groups that should be evaluated in field conditions with regard to their leaching potential to groundwater.

Simulation of Pesticide Movement in Brazilian Soil using CMLS

Maria Conceição P.Y. Pessoa – Embrapa Environment, Brazil

CMLS-94 has been used to simulate the movement of pesticides applied in different kinds of cultures cropped under risk areas to water resources. In the special case of the Espraiado stream watershed, Ribeirão Preto/SP, Brazil, the Guarani Aquifer is present under a great area cropped with sugar cane. Some pesticides, like tebuthiuron, have been intensively applied there, increasing the vulnerability to introduce groundwater contamination. Brazilian Oxisol (Dusky Latosol = "Latossolo Roxo") properties, found in the Espraiado stream watershed, change on different sample points in the same stain of that soil type. The original CMLS-94 version concept checks automatically the relation of total porosity with bulk density and particle density, where particle density (dp) is assumed by CMLS-94 as a fixed default value of 2.65 $Mg.m^{-3}$ (in accordance with US conditions). This automatic checking cause problems to evaluate some Bazilian soils using CMLS-94, because some Oxisol and Vertisol could reach values greater than 2.65 $Mg.m^{-3}$ at some horizons and could not be inserted in the CMLS-94 soil database. Another problem is that due to the absence of published values of organic carbon partition coefficient (Koc) and degradation half life (t½) for the pesticides in Brazilian soil conditions, the mean values of those pesticides characteristics (available in the CMLS-94 Pesticide database) are used to evaluate Brazilian groundwater contamination risk tendencies. As result some problems could be reached because pesticides characteristics like Koc and t ½ was very influenced by temperature and other natural factors inherent to the site of study and varies on a large range of values. Mean value uses could affect the result of the Brazilian groundwater contamination evaluation. Informed by Embrapa Environment about the problem of checking commented above, Dr. Nofziger and Dr. Hornsby provided Embrapa Environment with a modified version of CMLS-94 where the checking was removed. The present work showed results obtained on simulated scenarios using CMLS-94 original and modified considering the same basic scenario: tebuthiuron (dose: 1.10 kg/ha) applied in the first year of simulation (period: 4 years) on sugar cane crop in Ribeirão Preto/SP weather conditions. Scenario 1 evaluated Oxisol without total porosity check incompatibility and scenario 2 evaluated Oxisol with total porosity check. Both scenarios considered on the evaluation values of Koc and t ½ available in CMLS-94 database (default) and those reached by tebuthiuron on Oxisol with sugar cane on Brazilian environment. CMLS94 modified allows inserting in the soil database some particular properties of Oxisols found in Brazilian regions, as well as properties of Vertisols, and it also allows observing the movement of tebuthiuron in Oxisol which could not be evaluated by the original CMLS94. Results presented show the movement of tebuthiuron to deep layers of soil reached in soil analysed by the modified CMLS94, where after 2 years tebuthiuron reaches values highest than 4.0 meters (5.27 evaluated and 4.41 default). Koc and t½ values influence the results reached and consequently the analysis of groundwater contamination risk.

Concluding Remarks

The meeting on modeling pesticides in soils dealt with the problems of using mathematical models to predict the fate of pesticides in tropical soils found in Brazil. The workshop brought together scientists to discuss the possibilities of using models to predict the fate of pesticides in Brazilian soils.

Based on the presentations given by the various authors, there seems to be an urgent need to test various models in their capability to describe the fate of pesticides in these soils. Many of the models presented were developed for regions outside the tropics. These models therefore do not take into account important phenomena and processes such as: specific climate conditions and high rainfall intensities, the specific tropical crops, the variably charged soil surfaces, the preferential flow phenomena and surface runoff. Moreover there is no quantitative information available on the performance of these models in comparison to measured data. Mainly because there are no datasets available which allow for such comparison. There is therefore a need to establish good quality datasets for model evaluation and comparison in tropical regions. Brazil and especially Embrapa could take here a worldwide leading role. Such an effort would allow identifying the extent and nature of processes which need to present in models predicting the fate of pesticides.

The databases should comprise information at mainly two scales: the lysimeter and field scale. The lysimeter scale provides a unique way to test models because it allows measuring the most important fluxes (drainage, volatilization, actual evapotranspiration) and state variables and this under optimal and controlled conditions. It also allows for a detailed monitoring of the crop such as dry matter production and leaf area index. At the field scale the importance of spatial variability of properties and field scale specific processes like erosion can be taken into account. Such a two-scaled approach may also provide valuable information for the registration of pesticides and the conservation of natural resources. Combining these tested models with geographic information systems would allow gaining insight the regional aspects of pesticide application.

Harris Vereecken
ICG, Germany

This International Conference on Modeling Pesticide Movement in Soils is a timely event, considering the preoccupation of the fate of pesticides in the environment. Most pesticides applied reach the soil and several can leach through it. Thus predicting the fate of pesticides into the environment is necessary to anticipate and minimize their adverse effect away from the point of application.

This publication handles the subject from different perspectives. Dr. Spadotto introduced the subject, with the definition and purposes of modeling. Dr. Hornsby discussed the basic principles of pesticide interactions with soils. Dr. Kookana went to the heart of the subject, the use of simulation models. And Dr. Nofziger explained how the models can be used as management tools and decision aids.

My feeling is that this publication will be of high importance for Brazilian agriculture. As a soil scientist that has tackled the subject of variable charges of tropical soils, with their amphoteric behavior and strong ligand exchange properties on their oxidic surfaces of the soil particles, I am sure that the research stimulated by the concepts given in this publication will produce some exciting new knowledge and ideas on the behavior of pesticides in soils.

Bernardo van Raij
Former Director at Embrapa Environment
Brazil

Much work has been done on pesticide movement in soils, which has had either an emphasis on agricultural purposes or environmental concerns. Pesticides interact in complex ways with soil components in determining their fate and behavior in the environment. The Conference dealt with movement modeling of pesticides, particularly in soil and weather conditions, and data availability in Brazil.

The presentations stimulated numerous discussions including:

* How models deal with pH and compacted layers in soils.

* Brazilian soils interact with pesticides in complex ways and require lots of data to describe. What is the current state of data in Brazil?

* Pesticide sorption and degradation in tropical and subtropical soils.

* Soil sorption and movement of ionizable pesticides.

* How deeply or carefully models consider microbiological activities.

* A wider range of pesticides is used in Brazil than in Australia. Will the Australian approach be useful in Brazil?

* How close physical and mathematical models can come to describing field situations.

A model can be defined as a mathematical representation of water flow and transport of its constituents on some part of the land surface or subsurface environment. By using models we can better understand or explain natural phenomena and under some conditions make predictions in a deterministic or probabilistic sense. Models can also be utilized as planning tools for determining management practices that minimize pollutant loading from an agricultural activity to water resources. The results obtained depend on a good representation of the environment through which water flows.

Many participants expressed appreciation for the conference and the opportunity to become acquainted with other scientists researching pesticide fate issues. The most important aspect of it was likely the opening of communication lines between scientists working in different locations and for different agencies. Many expressed the desire to continue cooperative work in the future saying that Brazil has scientists who can make a major impact upon our understanding of pesticide fate and transport in the tropics and subtropics and throughout the world, especially by working cooperatively. Overall it was most interactive meeting of scientific exchange and the conference laid the foundation for an effective coordinated approach to deal with pesticide issues in Brazilian environment.

Claudio A. Spadotto
Embrapa Environment, Brazil

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Selected references on issues discussed during the Conference are listed below.

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