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EXPRES: AN EXPERT SYSTEM FOR ASSESSING THE POTENTIAL FOR GROUNDWATER CONTAMINATION DUE TO PESTICIDES

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EXPRES: AN EXPERT SYSTEM FOR ASSESSING THE POTENTIAL FOR GROUNDWATER CONTAMINATION DUE TO PESTICIDES

by

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MANAGEMENT PERSPECTIVE

The Pesticide Division of the Commercial Chemicals Branch, Environment Canada, is required to assess the environmental hazards associated with a pesticide and its transformation products before it is approved for public use. One specific concern of the Pesticide Division is the potential for a pesticide to contaminate groundwater resources. Although a number of models currently exist that can predict the transport and transformation of pesticides in the subsurface, generally, regulatory personnel do not have the expertise required to accurately utilize these models. The Groundwater Contamination Project, NWRI, was approached by the Pesticide Division to develope an expert system that can be used to aid in the assessment of the potential for groundwater contamination by pesticides. This expert system, known as EXPRES (EXpert system for Pesticide Regulatory Evaluation and Simulation) can be used for the identification of agricultural development which may or may not be sustainable. This paper outlines the design, development and operation of the expert system, and also provides the reader with a brief overview of expert systems.

PERSPECTIVE-GESTION

La Division des pesticides de la Direction des produits chimiques commerciaux d'Environnement Canada doit évaluer les risques environnementaux que constituent un pesticide et ses produits de transformation, avant d'approuver son utilisation par le grand public. Le risque de contamination des eaux souterraines est un point auquel s'intéresse particulièrement la Division des pesticides. Il existe actuellement un certain nombre de modèles permettant de simuler le transport et la transformation des pesticides dans le sous-sol, mais les personnes chargées de la réglementation ne possèdent pas, en général, les compétences nécessaires pour utiliser ces modèles avec précision. La Division des pesticides a communiqué avec les responsables du Projet d'étude de la contamination des eaux souterraines, à L'INRE, en vue d'élaborer un système expert qui facilitera l'évaluation du risque de contamination des eaux souterraines par les pesticides. Ce système expert, appelé EXPRES (sigle correspondant à EXpert system for Pesticide Regulatory Evaluation and Simulation), peut être utilisé pour identifier les cas où le développement agricole est soutenable. Cette communication décrit la conception, l'élaboration et l'utilisation du système expert; de plus, elle décrit brièvement les systèmes experts.

ABSTRACT

An expert system, known as EXPRES (EXpert system for Pesticide Regulatory Evaluation Simulations), is being developed to provide regulatory personnel with a tool that will aid in their assessment of the fate of pesticides in the unsaturated zone as they migrate to the water table in order to identify potential groundwater problems. EXPRES is basically a knowledge-based system that incorporates two existing pesticide models. The inclusion of two mathematically-based models, a research model (LEACHM) and a management model (PRZM) will allow different scenarios to be run depending upon the objectives of the simulation and the availability of data. The models are used to predict the migration rates and the concentration profiles of pesticides and daughter products in the unsaturated zone and the amount of pesticide reaching the water table, with respect to both time and depth. The expert system will provide the user with the encoded expertise required to undertake a simulation with the pesticide transport models and to interprete the results of a simulation. The encoded expertise consists of (1) information required by a pesticide model to characterize the physical, meteorological, hydrogeological, pedological and agricultural settings of regions across Canada, (2) rules for choosing a model, (3) rules for ensuring accuracy and consistency of input data, and (4) rules for interpretating the results of a simulation. EXPRES is designed to be used as a management tool to aid in policy decisions. Thus, the primary purpose of EXPRES is to provide an assessment of the potential hazards posed by a new pesticide in order to identify if further study is warranted before approval of the pesticide is granted.

RÉSUMÉ

Un système expert, appelé EXPRES (sigle correspondant à EXpert system for Pesticide Regulatory Evaluation and Simulation), est actuellement en cours d'élaboration, en vue de fournir au personnel chargé de la réglementation un outil qui les aidera à déterminer le devenir des pesticides dans la zone d'aération au fur et à mesure de leur déplacement vers la nappe souterraine libre, afin d'identifier les risques qu'ils peuvent constituer pour les eaux souterraines. Le système EXPRES est essentiellement un système basé sur les connaissances; il comporte deux modèles existants qui permettent de simuler le comportement des pesticides. L'incorporation de deux modèles mathématiques, un modèle de recherche (LEACHM) et un modèle de gestion (PRZM), permettra d'examiner différents scénarios selon les objectifs de la simulation et la disponibilité des données. Les modèles permettent de prévoir les vitesses de migration et les profils de concentration des pesticides et de leurs produits de transformation dans la zone d'aération, ainsi que la quantité de pesticide qui atteint la nappe souterraine libre, en tenant compte à la fois de la profondeur et du temps de migration. Le système expert fournira à l'utilisateur les composants de codage nécessaires pour entreprendre une simulation avec les modèles de transport des pesticides et pour interpréter les résultats d'une simulation. Les composants de codage comprennent (1) les données qu'il faut inclure dans le modèle de transport des pesticides pour caractériser les milieux physiques, météorologiques, hydrogéologiques, pédologiques et agricoles des différentes régions au Canada, (2) les règles régissant le choix d'un modèle, (3) les règles permettant de s'assurer que les données

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INTRODUCTION

Pesticides are, by design, poisons which are introduced into our environment in order to kill target species of plants or organisms. Although pesticides will enhance the production and quality of crops through the control of pests, environmental risks are associated with their usage. For example, studies focusing upon the fate of the pesticide aldicarb (Zaki et al., 1982; Jones, 1985; Harkin et al., 1986; Jones and Marquardt, 1987; Jones et al., 1987; Priddle et al., 1989) within the subsurface provide strong evidence that pesticides have the potential to cause serious contamination of shallow aquifers even if the recommended application procedures are followed. All pesticides

used in Canada undergo extensive scrutiny to ensure that they and their degradation products present minimal risks to the environment before being registered for public use (Agriculture Canada, 1987; Crowe and Mutch, 1990). Because of the potential for contamination of groundwater by pesticides, regulatory personnel must have the means of assessing the potential for pesticides to reach the water table before the pesticide is approved for general use. Numerous models currently exist for predicting the distribution and concentration of pesticides in the subsurface (eg. PESTAN (Enfield et al., 1982), SESOIL (Bonazountas and Wager, 1984), PRZM (Carsel et al., 1984; 1985), LEACHM (Wagenet and Hutson, 1986; 1987), CMIS/CMLS (Nofziger and Hornsby, 1986, 1987), GLEAMS (Leonard et al., 1987) and VULPEST (Villeneuve et al., 1987)). However, the application of these models in a regulatory framework is limited because, (1) the theoretical framework upon which the models are based is quite complex and typically they can only be operated by a trained modeller, (2) the models require considerable physical and chemical field data to undertake a simulation, and (3) there is no means of ensuring that the input data and calculated results are meaningful and accurate. Therefore, even though regulatory personnel who are assigned the task of assessing the effects of the pesticide on the quality of the groundwater require these sophisticated models, the models can not readily be used by regulatory personnel.

An expert system, known as EXPRES (EXpert system for Pesticide Regulatory Evaluation Simulations), is being developed by the Groundwater Contamination Section of the National Water Research Institute to provide regulatory personnel with a tool that will aid in their assessment of the fate of pesticides (i.e. includes the mobility, attenuation, persistence, transformation and degradation of the pesticide and daughter products) as they move through the unsaturated zone to the water table. EXPRES will be used to identify potential groundwater problems before a pesticide is approved for general use and to identify if further field or laboratory study is warranted. Specifically, EXPRES is designed to provide regulatory personnel with the expertise for predicting, firstly, the migration rates and concentrations of pesticides in the unsaturated zone with respect to both time and depth, and secondly, the concentrations of pesticide reaching the water table and time required to reach the water table. This expertise consists of (1) information required by a pesticide model to characterize the physical, meteorological, hydrogeological, pedological and farm management practices of agricultural regions across Canada, (2) the computing and modelling expertise required to use the simulation models, (3) rules for choosing a pesticide model, (4) rules for ensuring accuracy and consistency of input data, and (5) rules for interpreting the results of a simulation.

THE EXPRES EXPERT SYSTEM

The expert system is designed as a management tool to be used as an aid in making policy decisions regarding the benefits and risks of a proposed pesticide. Thus, although EXPRES can be used to provide insight into the processes that control the fate of pesticides in porous media, its primary application is to provide a quick and general assessment of the potential hazards to the shallow groundwater regime associated with the use of a particular pesticide and to identify if further field or laboratory testing is warranted before approval of the pesticide is granted.

The main component of EXPRES is the inference engine which effects the general control of the expert system. The inference engine controls the reasoning strategy required to compose an input data set characterizing the physical setting, climatic conditions and agricultural practices of a particular site for the simulation model, and it also controls the evaluation of the results produced by the simulation model. In addition, it performs internal consistency checks on, and evaluates the plausibility of, all values entered. Modifications and additions to the data bases are done through the inference engine.

The second component of the expert system, the user-system interface, is an interactive program that guides the user through the entry of data required by the pesticide transport model and provides assistance on interpreting the results obtained from the model. The user-system interface prompts the user for information pertaining to the chemical characteristics of a pesticide and its application procedures. All data characterizing the physical, climatic, hydrogeological and farm management practices of typical agricultural zones across Canada are contained within a data base and the appropriate information is recalled by EXPRES to test the environmental effects of applying the pesticide in the agricultural zones selected. The user will then have the option to modify these data. Should the user be unfamiliar with any of the requested information, EXPRES will provide an explanation about the required data and/or recommend values which may be used. A second feature of the user-system interface is that it provides both quantitative and qualitative output from the simulation model. Graphical output is used to help visualize trends, anomalies and relationships among variables. Also,to help users understand the critical output from the model, EXPRES provides interpretations and evaluations of these results. The user-system interface takes the form of screens. Screens present a user-friendly environment for displaying, entering and modifying information ("fill-in-the blanks") and contains pull-down menus describing the operation of EXPRES and offering assistance to the user.

The third component of the expert system is the three information data bases, which essentially form the "expert's" contribution to the system. The facts data base is comprised of detailed information that describes the physical, climatic, hydrogeological and agricultural setting of typical agricultural zones across Canada (e.g. a wheat field in southern Saskatchewan). The characterization of the typical agricultural zones are hypothetical to the extent that the basic model

parameters are not derived from a particular field or orchard. Rather, the choice of parameters used to define the typical agricultural zones is guided by experience from a variety of field studies undertaken within a particular zone. Because there is considerable variation in the physical, hydrogeological, climatic and agricultural settings on a local scale, the values assigned to a typical agricultural zone may not adequately represent all potential sites within the zone. Therefore, the expert system is designed such that the parameters comprising a typical agricultural zone can easily be modified by the user for a particular simulation.

Information stored in the explanation base consists of encoded explanations, definitions, examples and recommended values which may be accessed to help the user understand the question or requested information during input by offering choices of values, explanations or definitions. The information in the explanation base will also allow the user to follow the expert system's reasoning strategy and will check the entered values for consistency with previously entered information. Finally, this information will aid the user in understanding the system's conclusions and recommendations.

The knowledge base contains the production rules, semantic nets and frames (encoded expertise), which describes the domain and reasoning methodology that guides a user through a simulation. This base provides two functions. Firstly, it is accessed to guide the user through the choice of parameters and options for undertaking a pesticide transport and transformation simulation, as well as providing an interpretation of the results of a simulation. Secondly, production rules are used for internal checks and for the interpretation of the modelling results through the interpretation module.

An integral component of the knowledge base of EXPRES consists of the models that are used to predict the migration and persistence of pesticides in the unsaturated zone. In order to accurately simulate the fate of pesticides in the subsurface, the mathematical framework of these models must be based on the accepted scientific principles that govern the important biological, chemical and physical processes that control the transport, attenuation, degradation and transformation of a pesticide and its daughter products.

A review of existing models (Mutch and Crowe, 1989) indicated that the model best suited for use in EXPRES is the management model PRZM (Carsel et al., 1984, 1985). A research model, LEACHM (Waganet and Hutson, 1986, 1987), is also included because the simulation of the processes involved in the transport and transformation of pesticides in the unsaturated zone would make the research model more preferable to a management model when a detailed evaluation of the transport or transformation processes is desired. Both the management and research models can be used for regulatory guidance. However, because of the detail in which the processes affecting the pesticide are simulated, the management model should be used for general site assessment where as the research model can be used for a detailed site investigate and also to

determine the relative influence of the parameters controlling the major processes. The models simulate the transport of a pesticide through the unsaturated zone only, which can be represented as a layered soil. The models account for the major physical, chemical and biological processes affecting the transport and degradation of pesticides in the unsaturated zone, such as advection, dispersion, chemical speciation, first-order degradation, adsorption (linear, reversible and instantaneous local equilibrium) and plant uptake (as a function of the rate of transpiration). PRZM uses a lumped parameter approach to the downward movement of water. LEACHM simulates flow with a more realistic mathematical representation. The models require input data from four general areas; climatic conditions, soil parameters, chemical characteristics of the pesticide and farm management practices.

CONCLUSIONS

An expert system, known as EXPRES (EXpert system for Pesticide Regulatory Evaluation Simulations), is being developed to provide regulatory personnel with a tool that will aid in their assessment of the contamination of groundwater by pesticides. EXPRES is basically a knowledge-based system that incorporates two existing pesticide models. EXPRES is designed to be used as a management tool to aid in an assessment of the potential hazards posed by a new pesticide in order to identify if further study is warranted before approval of the pesticide is granted. The inclusion of two mathematically-based models, a research model (LEACHM) and a management model (PRZM) allows different scenarios to be run depending upon the objectives of the simulation and the availability of data. With EXPRES, the user can predict the migration rates and the concentration profiles of pesticides and daughter products in the unsaturated zone with respect to both time and depth, as well as the amount and timing of the pesticide reaching the water table.

An expert system approach for regulatory personnel to evaluate the potential for pesticides to contaminate groundwater offers several advantages over the approach of contracting an outside expert to undertake this work or undertaking the task in-house by someone who does not have the expertise to ensure the accuracy of the results. Advantages of an expert system include (1) complex modelling codes can be used by those not familiar with this technology, (2) reduced costs and time associated with not having to contract an outside consultant, (3) a built-in test of the accuracy and consistency of user-supplied data, (4) identification and/or suggestions for missing values, recommendations of what or if further data are required, (5) an evaluation and interpretation of critical output from the simulation model, (6) a systematic evaluation of the potential for a pesticide to contaminant groundwater through a sensitivity analysis of parameters affecting the fate of pesticides in the unsaturated zone, (7) data bases containing information characterizing field sites and pesticides can be stored for future reference and (8) it can be used as an educational tool for teaching basic concepts about pesticide transport and transformation.

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BACKGROUND

- groundwater is an important source of drinking water in Canada

  26% of Canadian population
  38% of municipalities
  82% of rural population

(Hess, 1986)

BACKGROUND

Pesticides are, by design, poisons which are introduced into our environment in order to kill targeted species.

- used to enhance crop production and quality
- potential health & environmental risks associated with use

BACKGROUND

- all new pesticides are tested to ensure minimal risks to our environment
- concerned with the fate of pesticides in the subsurface:
  - mobility
  - persistence
  - accumulation
  - transformation / degradation
  - toxicity

INTRODUCTION

- several models are available which can be used to study the fate of pesticides in the subsurface
- models not "user-friendly" to regulatory personnel
- regulatory personnel need the accuracy of these sophisticated models
- these requirements lead to the development of an EXPERT SYSTEM

EXPRES

EXpert system for Pesticide Regulatory Evaluation Simulations

THE PESTICIDE EXPERT SYSTEM

- EXPRES is actually a knowledge-based system coupled to a pesticide transport and transformation code

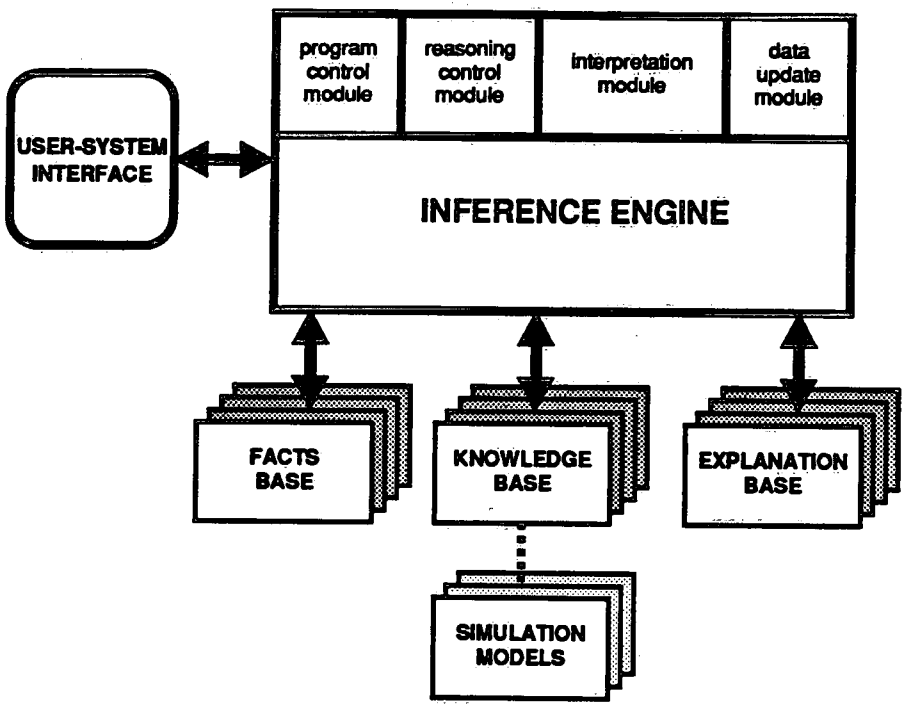
PURPOSE:

- provide regulatory personnel with a tool to aid in their evaluation of the fate of pesticides in the subsurface, and specifically, to ensure that the quality of the groundwater in agricultural areas is not impaired

THE PESTICIDE EXPERT SYSTEM

SPECIFIC OBJECTIVES:

- identify potential groundwater problems
- identify if further field or laboratory study is warranted
- provide geological, hydrogeological and modelling information for pesticide assessment simulations
- predict migration rates and concentrations of pesticides in the unsaturated zone with time and depth
- determine concentrations of pesticide reaching the water table and time required for it to reach the water table
- be easy to use by non-modellers



THE INFERENCE ENGINE

- controls execution of expert system, links all operations and searches data bases in response to input from user
- parts of the inference engine include:
  - (1) PROGRAM CONTROL MODULE
  - (2) REASONING CONTROL MODULE
  - (3) INTERPRETATION MODULE
  - (4) DATA UPDATE MODULE

USER - SYSTEM INTERFACE

- interactive guide through data entry
- data from four main areas:
  - (1) chemical characteristics
  - (2) soil and hydrogeological data
  - (3) farm management practices
  - (4) climatic information
- provides assistance when required
- aids with interpretation of results

THE DATA BASES

KNOWLEDGE DATA BASE:

- rules, nets and frames used to relate facts and concepts describing a domain or a reasoning methodology
- used to guide user through a simulation and its output
- also includes the simulation models

FACTS DATA BASE:

- data describing the physical, climatic, hydrogeological characteristics and agricultural practices of a site
- chemical characteristic of pesticides

EXPLANATION DATA BASE:

- explanations & definitions to help user understand prompts follow the reasoning strategy, test data for consistency

HYPOTHETICAL AGRICULTURAL ZONES

- zones are hypothetical to the extent that parameters are not derived from a particular site, but rather are based on experience from many studies undertaken within a zone

  (1) an orchard in central British Columbia
  (2) a berry in the Fraser River Delta, B.C.
  (3) a grain field in the Peace River district of Alberta
  (4) a sugar beet field in southern Alberta
  (5) a wheat field in southern Saskatchewan
  (6) a grape vineyard in the Niagara region of Ontario
  (7) a corn field in Ontario
  (8) a potato field in Quebec
  (9) a potato field in P.E.I.
  (10) a forest zone in New Brunswick
  (11) an orchard in central Nova Scotia

- parameters comprising a zone can easily be modified

THE SIMULATION UNIT

- mathematical model or models that does actual simulations or predictions of pesticide transport and transformation in the unsaturated zone

- mathematical framework of the model is based on accepted scientific principals that describe important biological, chemical and physical processes:

  (1) transport of dissolved pesticide:
  - advection, dispersion, surface runoff losses, flux at surface

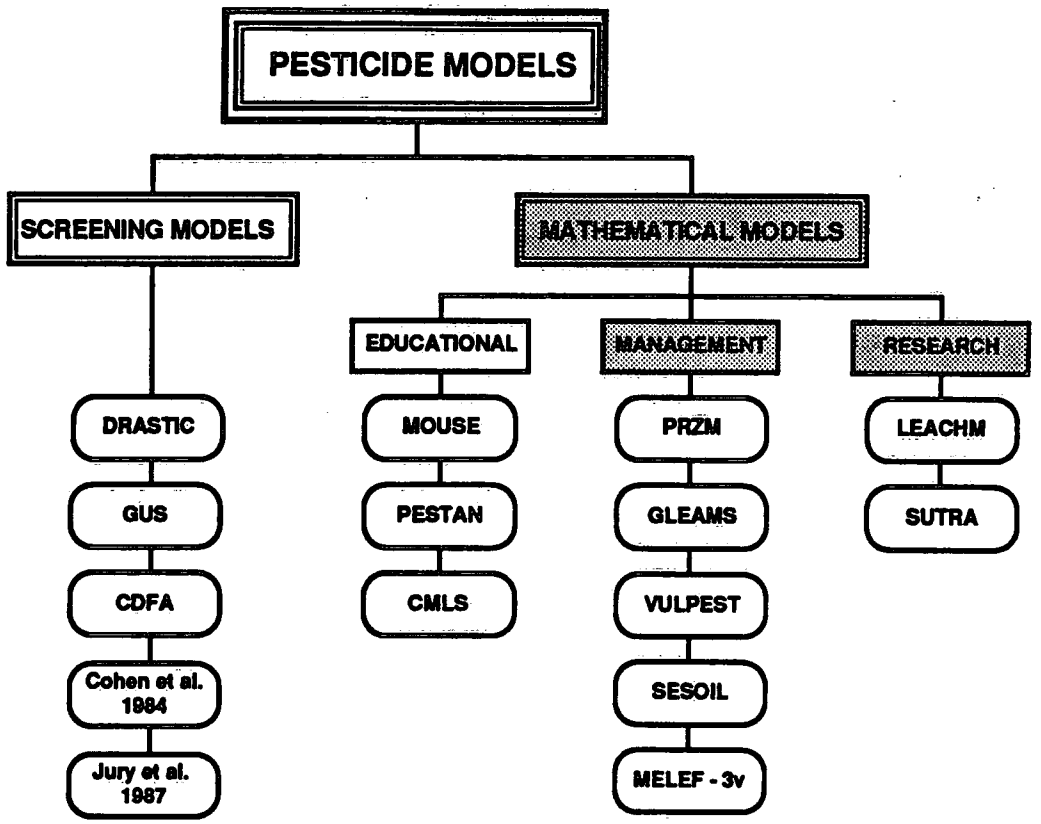
  (2) changes to chemical character of the pesticide:
  - chemical speciation, adsorption, degradation, volatilization

PESTICIDE MODELS

- use existing models
- reduces time required to arrive at the final product and ensures that the model is verified through previous use
- criteria used to choose model, the model must:
  (1) simulate the transport, and predict concentrations, of the parent pesticide and degradation products
  (2) predict migration rates and concentrations in the unsaturated zone with time and depth
  (3) determine concentrations at, and time required to reach, the water table
  (4) be based on accepted scientific principals that govern pesticide transport and transformation
  (5) be a widely accepted and verified computer code
  (6) be programmed so that modification can be made easily
  (7) be compatible with the U.S. EPA models

PESTICIDE MODELS

- many existing models available for assessing the potential for groundwater contamination by pesticides
- models vary in the:
  - number of processes described
  - detail of the description
  - intended use



MANAGEMENT MODELS

- processes described in more detail than screening and educational models
- simulation includes layered soils, transient conditions, etc.
- input data requirements not restrictive
- provide semi-quantitative results
- presentation of results allows for quick interpretation

RESEARCH MODELS

- process described in detail with complex mathematical equations that represent all processes affecting pesticides
  e.g. flow described by Richard's equation
- results are more quantitatively accurate
- use of models is more cumbersome
  e.g. input data sets are more difficult to formulate,
  execution times are lengthy, etc.

PESTICIDE MODELS

- both models simulate 1-D flow under transient conditions
- based on advective - dispersive equation

<u>PRZM (Carsel et al., 1984):</u>

- lumped parameter representation of flow
- management model
- processes not modeled in detail
- relatively short execution times

<u>LEACHM (Wagenet and Hutson, 1987):</u>

- finite difference solution to flow equation
- research model
- detailed representation of processes
- relatively lengthy execution times

PRZM

ADVANTAGES:

- execution times are short
- input data required not excessive and available from existing data bases
- surface runoff and erosion considered

DISADVANTAGES:

- simplified water flow representation
- simulations are restricted to one species
- dispersion is not directly simulated

LEACHM

ADVANTAGES:

- research model - most detailed
- flow based on Richard's equation
- considers chemical speciation (parent pesticide and two daughter products

DISADVANTAGES:

- lengthy execution times
- surface runoff and erosion not included
- large input data set - difficult to formulate

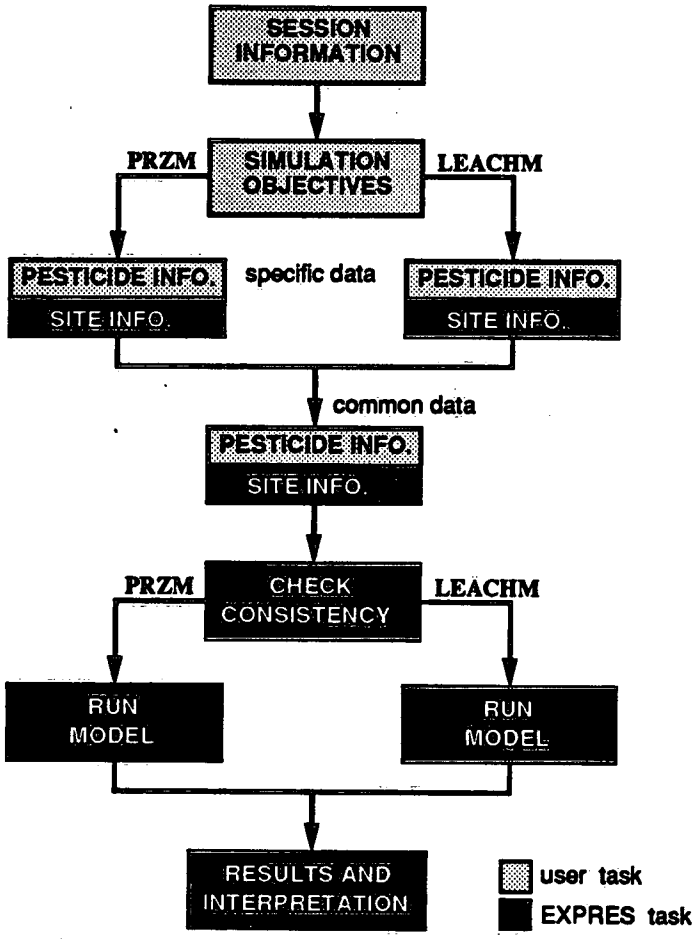
DEVELOPMENT OF EXPRES

Hardware: 80286 - based PC
80286 math co-processor
20MB hard drive
monochrome monitor
640KB RAM
CGA graphics card

DEVELOPMENT OF EXPRES

Software:

operating system	-	DOS 3.31
simulation models	-	FORTRAN
user-system interface	-	MICROSOFT C
inference engine	-	MICROSOFT C
data bases	-	ASCII files



SCREENS

- mode for user - system interface
- presents a user - friendly environment
- shows information required for a simulation
  - simulation objectives
  - "fill-in-the-blanks" for user supplied data
  - values displayed for EXPRES supplied data
- includes pull-down menus for operating EXPRES, help, etc.

Next-Scrn Previous-Scrn Default-Data Run Exit-EXPRES Help Instructions

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EXPRES

SESSION INFORMATION

INTRODUCTION

[ ] Discuss Instructions
[ ] Overview of EXPRES
[♦] Example Session
[ ] Screen Setup

FILES

[ ] Create a New File
[ ] Load an Existing File
[ ] Session Notes

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EXPRES

SIMULATION OBJECTIONS

SPECIFIC OBJECTIVES

[ ] Run a Scenario
[♦] Sensitivity Analysis

NEED RESULTS

[♦] Quickly (i.e. < 1 hour)
[ ] No Preference

DAUGHTER PRODUCTS

[♦] Simulated
[ ] Not Simulated

COMPUTER

[♦] 80286
[ ] 80386

Approximate Simulation Length (Days):

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GENERAL INFORMATION

UNITS

[♦] Metric

[ ] Imperial / US

SIMULATION DATES
(ddmmyy)

Starting

Ending

SIMULATION PARAMETERS

User Supplied Parameters
(User must supply all these data)

[ ] Agricultural Zone

[ ] Pesticide Parameters

[♦] Output Parameters

Default Parameters
(View data and change if desired)

[ ] Soil Parameters

[ ] Crop Parameters

[ ] Meteorological Parameters

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SOIL PARAMETERS

Number of Soil Parameters: 5

Depth to Water Table (m): 2.5

Horizon Number	Horizon Thickness (cm)	Surface (S) or Root (R) or Below Root (B)	Bulk Density (gm/cm^3)	Organic Carbon (%)
1	10.0	S	1.32	0.70
2	20.0	R	1.23	4.40
3	40.0	R	1.62	0.50
4	60.0	B	1.67	0.10
5	120.0	B	1.86	0.01

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PESTICIDE PARAMETERS

PESTICIDE SPECIES
Number of Pesticides and Transformation Products to Simulate (Maximum of 4):

Pesticide Number	Pesticide Name	Solubility (mg/L)	Koc (L/kg)	Parent (P) or Daughter (D)
1				
2				
3				
4				

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EXPRES

DEFINITION

EXPLANATION

USER SUPPLIED

PESTICIDE PARAMETERS

PESTICID

4

Koc - Organic Carbon Partition coefficient

The transport of pesticides in the unsaturated zone may be attenuated by the adsorption of pesticide molecules to, and desorption from, clay particles or organic matter within the soil. The concentration of a pesticide sorbed to the soil (Cs) is often assumed to be linearly related to the dissloved pesticide concentration (Cw) by a partition or distribution coefficient (Kd).

$Cs = Kd \cdot Cw$

It is also assumed that an instantaneous and reversible equilibrium exist between the amount of pesticide being absorbed and the

MORE:<Pg↓>

Chem Numl				ent (P) or ghter (D)
1				
2				
3				
4				

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EXPRES

DEFINITION

EXPLANATION

USER SUPPLIED

PESTICIDE PARAMETERS

PESTICID

Number of

4

Koc - Organic Carbon Partition coefficient

Enter any additional information that you may want to record about this variable. It will be stored in a "KOC.USR" file. The line length should not exceed 65 characters. There is no limit to the length of the file.

END OF FILE

Chem Num				ent (P) or ghter (D)
1				
2				
3				
4				

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METEOROLOGICAL DATA (cont)

CLIMATIC DATA

[♦] Actual Data

[ ] 20 Year Average

CHANGE CLIMATIC DATA

[ ] No Change

[♦] Percent Change

[ ] Change by a Factor

Note: Percent Change. The climatic data will be modified by the percentage entered below. (i.e. Entering a value of 10.0 or -10.0 will increase or decrease the actual value by 10%, respectively.

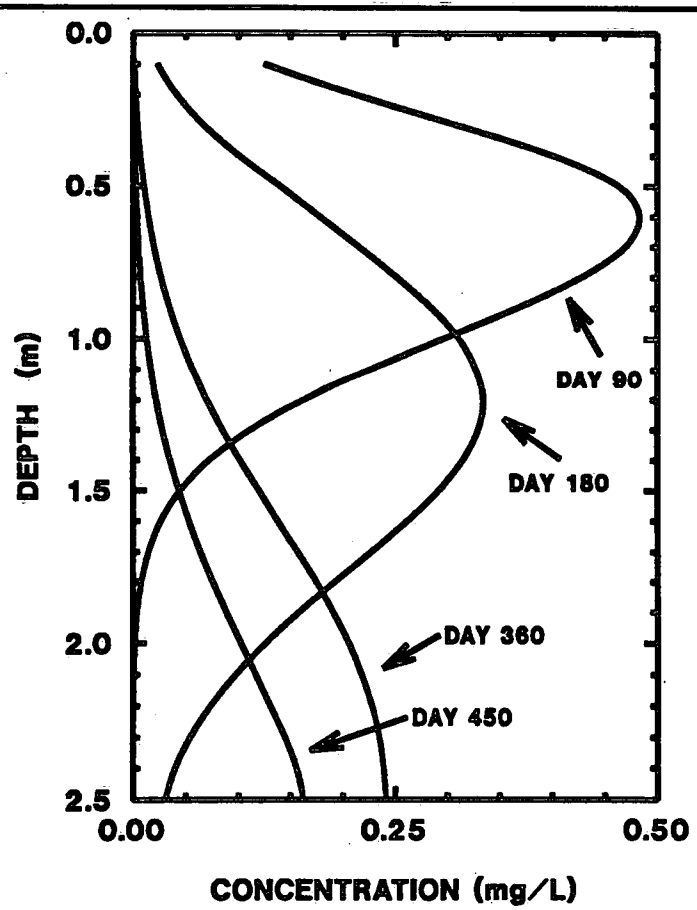
Precipitation 0.0

Temperature -5.0

OUTPUT

CONCENTRATION PROFILES:

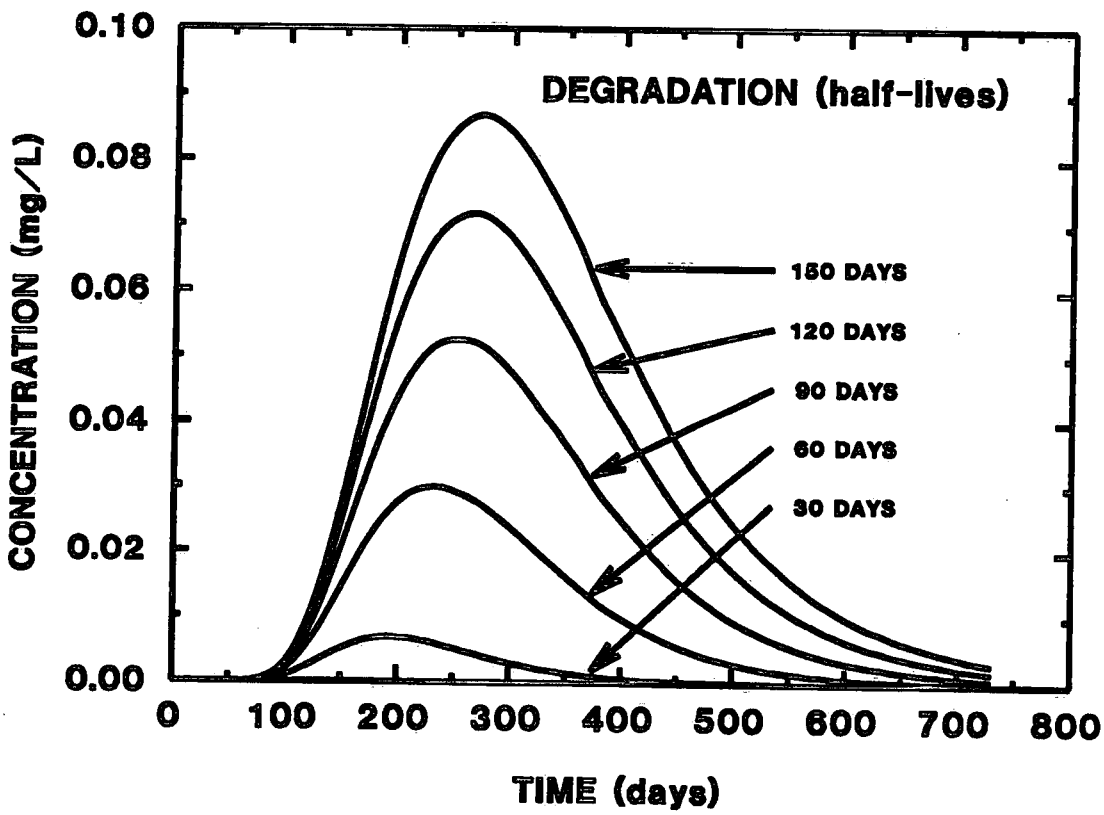
- pesticide concentrations in soil profile at specific times
- shows: - downward migration of pesticide
  - concentrations at any depth
  - decrease and spreading of pesticide



OUTPUT

SUMMARY FILES:

- time-series plot of pesticide concentrations at water table
- shows:
  - time for initial pesticide to reach the water table
  - time for peak concentration to reach water table
  - time for the pesticide to completely pass through the unsaturated zone



APPLICATION OF MODELS

MANAGEMENT MODELS:

- day - to - day operational guidance
- general site assessments
- regulatory guidance

RESEARCH MODELS:

- detailed investigation of the influence of parameters controlling themajor processes
- sensitivity analyses
- more detailed site assessments
- regulatory guidance

CONCLUSIONS

- regulatory personnel must have a means of assessing the potential for pesticides to contaminate groundwater
- pesticide transport and transformation models are available, however, they are typical too complex for non-experts to use
- our expert system (EXPRES) will provide the necessary means of supplying the expertise to run these models and interpret their results

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Pensez à Recycling!