CHERPAC (Chalk River Environmental Research Pathways Analysis Code)

Presentation for IAEA Environmental Modelling for Radiation Safety (EMRAS-II), Technical Meeting, Environmental Sensitivity Working Group, Agricultural Environment, Vienna

Sohan Chouhan
Atomic Energy of Canada Limited
Chalk River, Ontario, Canada
ChouhanS@aecl.ca

2010 January 26

AECL EACL

Introduction of CHERPAC

- CHERPAC is a time-dependent food-chain model.
- Calculates stochastic ingestion, inhalation, immersion and groundshine doses for twenty-five radionuclides released to the atmosphere in accidental situations
- Developed for participating in international model intercomparison scenarios after Chernobyl fallout data
- Some models and parameter values were originally taken from the routine-release dose calculation model CSA N288.1 and adapted into this accidental release model

Model Description

- CHERPAC uses Latin Hypercube Sampling (LHS) of distributions of parameter values to generate input for the multiple runs
- Predicts best estimates, means, and 2.5% and 97.5% confidence limits of the output distributions
- For terrestrial pathways, starts with the daily values of either (1) ground-level air concentrations and rainfall, or (2) measured depositions
- Outputs human body burden and concentrations in soil, forage, leafy and non-leafy vegetables, potatoes, other root crops, fruit, winter and spring grains, wild berries and mushrooms, milk, cheese, beef, pork, eggs, poultry, small game and big game

Model Description (continued)

- CHERPAC takes concentrations of ^{137}Cs in freshwater and saltwater fish as input and predicts human dose and body burden
- Handles accident occurring at any time of the year, and delays between harvest or production and ingestion of beef, pork, eggs, chicken, cheese, root crops, potatoes and grain.
- Calculates losses due to food processing for all foods
- Parameter values (e.g., diet, growing season, yield, animal diets and concentration ratios) in CHERPAC are Canadian, Ontario, specific
- Radionuclides: ^{51}Cr, ^{54}Mn, ^{59}Fe, ^{58}Co, ^{60}Co, ^{65}Zn, ^{89}Sr, ^{90}Sr, ^{95}Zr, ^{95}Nb, ^{99}Mo, ^{103}Ru, ^{106}Ru, ^{132}Te, ^{131}I, ^{132}I, ^{133}I, ^{134}I, ^{135}I, ^{134}Cs, ^{136}Cs, ^{137}Cs, ^{140}Ba, ^{141}Ce and ^{144}Ce

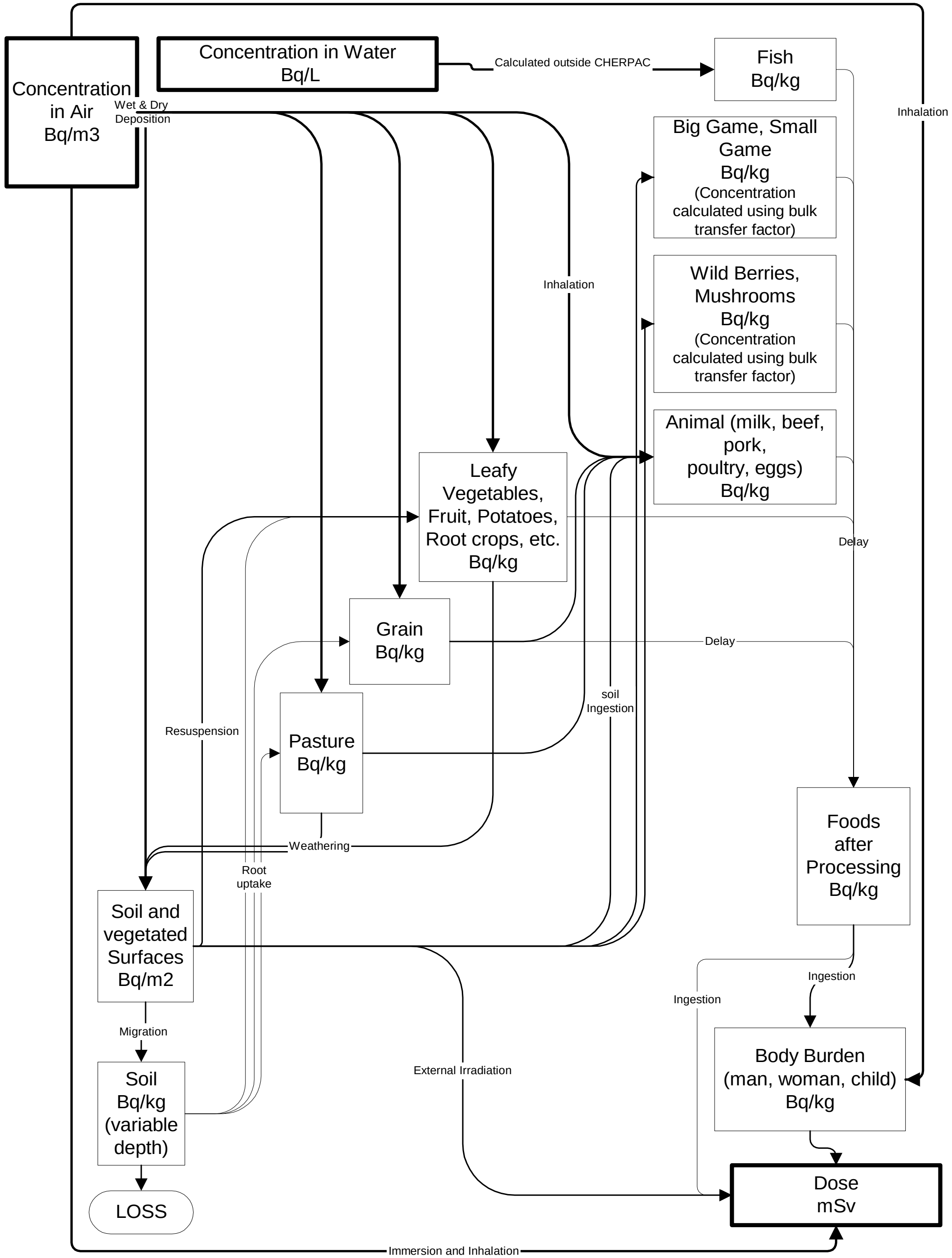

Figure 1. Simplified structure of CHERPAC

Mathematical Description

Deposition:

$$D = C_a \ (v_g * 86400 + w * I * R_w / 1000) = D_d + D_w$$

Leafy vegetable plant concentration :

$$C_v = D \exp(-\lambda_{w,r} * d\,t) / Y + C_s * (B_v + adhr) / S_w$$

Fruit, potato or root vegetables concentration :

$$C_{trans} = (D_r * T) + (C_s * (B_v + adhr) / S_w)$$

Mathematical Description (continued)

Grain concentration:

$$C_g = \{D_{pg}\,(t_i)\ 9.8E\text{-}2\ \exp\,[-0.0013 * (t_i - 34)^2]\}_{\text{previous calendar month avg}} +$$
$$\{D_{pg}\,(t_i)\ 9.8E\text{-}2\ \exp\,[-0.0013 * (t_i - 34)^2]\}_{\text{current calendar month avg}} +$$
$$(C_s * B_v / S_w)$$

Dairy and beef cows body burden:

$$A_{b\ \text{Current step}} = A_{b\ \text{Previous step}} * \exp\,(-\lambda_r * dt) +$$
$$U_g * C_g + U_{pg} * C_{pg} + U_{s\ \text{dairy cow only}} * C_{sw\ \text{dairy cow only}}) * f_{food} * dt +$$
$$U_a * C_a * f_{breath} * dt$$

- Milk and beef concentrations:
- $C = F_{\text{milk from activity in cow}} * A_b$

Mathematical Description (continued)

- Similarly calculates concentration in other meat products
- Calculates ingestion doses from all food products
- Calculates inhalation, immersion and groundshine doses in a manner similar to other models

Parameter Values

- To do the uncertainty analysis, CHERPAC is coupled with the LHS code (Iman and Shortencarier, NUREG/CR-3624, 1984)
- There are several types of distributions (i.e. normal, lognormal, uniform, triangular and user) used for parameters in CHERPAC
- Correlation coefficients between parameters are also used
- Distributions are defined for the parameters related to agricultural pathways, plants, animals (some parameters are nuclide specific)

Preparing input files (distribution type, best estimate value, and limits)

- Suppose, there were 70 values (A1, A2, A3,…,A70) found for a parameter
- These values were used to plot a histogram
- Histogram indicated Log Normal distribution
- Natural Logarithm a1 = ln(A1), a2 = ln(A2), a3 = ln(A3), …, a70 = ln(A70) were calculated.
- Mean(a1,a2,a3,…,a70) and Standard Deviation(a1,a2,a3,…,a70) were calculated
- Geometric Mean = Exp (Mean) was calculated and used as a best estimate in most cases.
- 0.01 Percentile = Exp (Mean - 3.09 * Standard Deviation) was calculated and used as lower limit
- 99.9 Percentile = Exp (Mean + 3.09 * Standard Deviation) was calculated and used as upper limit.

Sensitivity Analysis

- CHERPAC is also coupled with the PCCSRC code (Iman et al 1985) which ranks the importance of the input parameters to variation in the output
- Sensitivity analyses results are always scenario-specific and time-dependent
- Based on past work with CHERPAC, there is a high probability that the model output will be sensitive to parameters such as dry deposition velocity and washout ratio
- It is planned that the sensitivity analysis will be done for the Agricultural Environment scenario of this Working Group using some parameter values and distributions already present in CHERPAC and by adding some new parameter values, as required

Validation and Usage of CHERPAC

- CB scenario
- VAMP S scenario
- User-specific modelling uncertainties scenario

Acknowledgement

- Contribution of Ring Petersen, prior to retiring from AECL in 1998, to CHERPAC development and documentation is gratefully acknowledged.

AECL EACL