A COMPUTER MODEL FOR THE CALCULATION OF DERIVED EMISSION LIMITS FOR THE NORMAL OPERATION OF NUCLEAR FACILITIES

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This paper presents a computer program for calculating derived emission limits for the normal operation of nuclear facilities. The environmental transfer model is discussed, in particular plume depletion effects, the effective height of release, sensitivity analysis, and the importance of the atmosphere to surface water pathway. When the receiving body of water receives only airborne effluent, this pathway has been found to be significant for long lived radionuclides and HTO.

INTRODUCTION:

In order to ensure that no member of the public receives a dose higher than the regulatory limit, upper limits to the rate of release of radionuclides to the atmosphere and to surface waters must be known. This paper presents an overview of the computer program "DELPro" which has been developed to calculate such upper limits, usually known as derived emission limits (DEL), for the normal operation of nuclear facilities.

This paper is subdivided in two main sections. First, the methodology for calculating DELs is examined. The environmental transfer model (ETM), its applicability to other nuclear facilities as well as its limitations are discussed. In a second section, the program per se is described briefly, giving particular attention to modifications brought to the ETM[1]; ie, the inclusion of atmospheric plume depletion effects, effects of building entrainment, and the addition of the atmosphere to surface water pathway. The sensitivity analysis routine is also discussed in this section.

METHODOLOGY:

The DEL is defined as the rate of release which is such that the group of maximally exposed individuals, the critical group, will not receive a dose higher than the regulatory dose limit.The critical group must also be relatively homogeneous with respect to those factors which affect doses received (eg, diet, age, behaviour). The methodology for determining DELs has three parts. First, the behaviour of the release must be known. Two modes of release are considered in the model[1]; atmospheric and aquatic. A gaussian plume model is used for describing releases to the atmosphere. It assumes continuous release of radioactive material. A model[2] for reduction of the effective height of release due to plume entrainment in the wake of neighbouring buildings (downdraught) and in the wake of the stack itself (downwash) has been added to the initial model[1]. Also added to the initial model is the effect of plume depletion (wet and dry deposition)[2,3].

Due to the high complexity of liquid dispersion in large bodies of water and its dependence on site-specific characteristics (eg, bottom topography, wind induced currents, seasonal variations in water

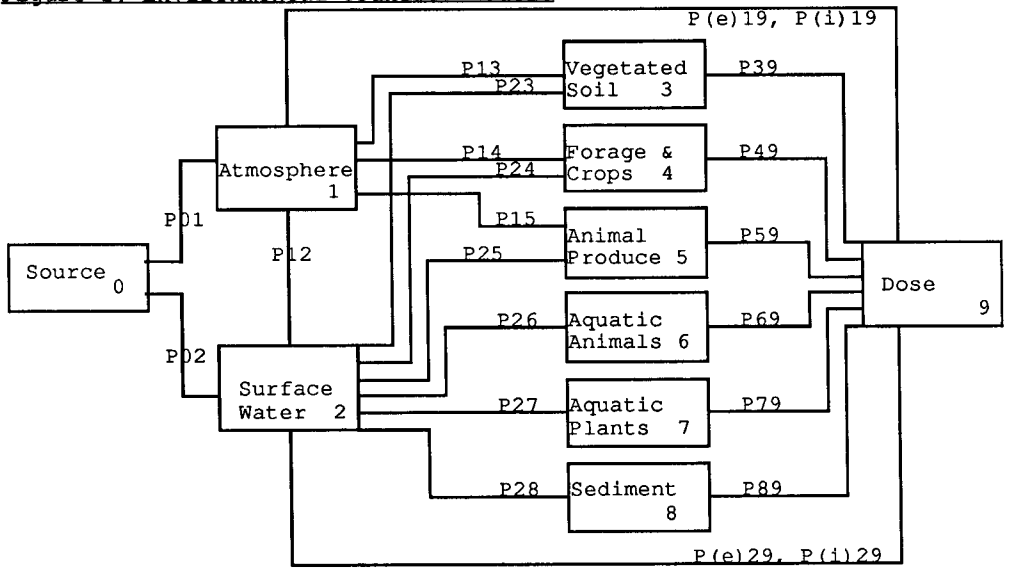
temperature) no general aquatic dilution model is used. Instead, site-specific concentrations are used. Also, since a DEL is calculated for each radionuclide released, the composition of the release must be known. This is achieved through effluent monitoring.

Second, the passage of radioactive material from the source through the environment to man must be analyzed. The environmental transfer model (ETM) used for this purpose is presented by the Canadian Standards Association[1], and can be seen in figure 1. Each compartment in the ETM is numbered. The quantity of radioactive material in compartment i is denoted X_i. A transfer parameter P_{ij} characterizes the transfer of material from compartment i to a compartment j such that

$$X_j = \Sigma_i P_{ij} X_i. \qquad (1)$$

All P_{ij} assume the system (ETM) to be in steady state, and are preferably calculated from site-specific data rather than from canadian averages.

Figure 1: Environmental Transfer Model:



The atmosphere to water pathway (P_{12}) is not included in CSA[1] but it is in the Gorman[4] model. In fig.1 the atmosphere to dose (P_{19}) and surface to dose (P_{29}) pathways both have two components. The external exposure component is denoted by (e) and the inhalation/ingestion component by (i). The DEL is defined as:

$$DEL = ADL/[X_9/X_0] \qquad (2)$$

where ADL is the annual dose limit for members of the public. DELs must be calculated separately for the stochastic and deterministic

dose limits, the most restrictive value being retained as the DEL for that radionuclide. X_9/X_0 is determined from equation 1, for the pathways and radionuclides significant to the critical group in question. To ensure that the critical group is not exposed beyond the ADL, for a multi-facility site, when more than one radionuclide is released, or when more than one mode of release exists (air or water), the following criterion must be satisfied:

$$\Sigma_i \Sigma_j \Sigma_k \, Q_{ijk}/DEL_{ijk} \leq 1 \qquad (3)$$

where Q_{ijk} is the actual release of radionuclide i from release mode j (air or water), and source facility k; DEL_{ijk} is the DEL for radionuclide i, release mode j, and facility k.

The model applies to many facilities such as research reactors, incinerators, and radioisotope-processing facilities. The model does not apply to facilities involving area sources and releases to the ground (eg, uranium mine tailings and mills, fuel fabrication plants and refineries, and in-ground waste storage facilities).

THE PROGRAM:

DELPro is a 207 KB Microsoft Excel macro which can run on PC or MAC type microcomputers. It uses pull down menus to select actions (eg, select emission type, etc...) and dialogue boxes allow the user to enter site-specific information about the critical group. Doses to the critical group may also be calculated.Results of the calculations can be saved and printed.

When released from a stack, some of the material may be drawn downward into the low pressure region on the lee side of the stack. This process, known as downwash, causes the height of release to be lower than the stack height. This effect is usually present when the efflux velocity is similar or smaller than the mean windspeed at the stack height[2,4]. The effective stack height may be further reduced if the emitted material is entrained in the wake of a nearby building. This effect, known as downdraught, occurs when the downwash corrected stack height is between 1 and 2.5 times the height of the nearby building, and when the mean windspeed is above 5 m/s [2, 4].

Although the air to water pathway (P_{12}) is negligible when the receiving body of water also receives liquid emissions[4],it may be important when radioactive material deposits onto standing ponds. These land ponds, receiving no liquid emissions, may be used for irrigation of crops and/or drinking water for livestock. To examine the importance of P_{12}, DELs were calculated using Canadian averages for all transfer parameters, with all realistic pathways selected. DELs for about 31 out of a total of 78 radionuclides decreased by a factor of two or more when P_{12} was selected. The most significant decrease was for ^{238}U; when the pond was used for drinking by livestock the ^{238}U DEL went down 9 orders of magnitude. Such a decrease was predictable since P_{12} is proportional to the half-life of the radionuclide[4] (^{238}U half-life = 4.5E+9 years). The DEL for HTO went down by a factor of 6. A sensitivity analysis has shown that the atmosphere-pond-livestock-man pathway contributes 99% of the dose to

man for ^{135}Cs, ^{234}U, ^{235}U, ^{238}U, ^{237}Np, and ^{244}Pu when all airborne emission pathways are present. This same pathway contributed 79% of the dose for HTO.

The effect of dry deposition on plume depletion is accounted for by multiplying the atmospheric dispersion coefficient by the ratio of concentration of activity in the air taking into account dry deposition to the concentration of activity ignoring deposition[3]. Dry deposition reduces plume concentration significantly in stable conditions and at long distances from the source (> 10km). To account for wet deposition the atmospheric dispersion coefficient is multiplied by the factor $e^{-\Lambda t_1}$. Values of the washout coefficient, Λ, for rain and snow, and for various precipitation rates are suggested in reference 2; t_1 is the time during which the plume is being depleted by precipitation.

Each pathway's contribution, C_{ijk}, to the critical group dose is evaluated for each pathway i, radiation effect j (eg, stochastic dose to adults), and radionuclide k, and can be written as:

$$C_{ijk} = (X_9/X_0)_{ijk}/\Sigma_n (X_9/X_0)_{njk} \qquad (4)$$

where m is the total number of significant pathways, $1 \leq n \leq m$, and X_0 and X_9 are from equation (2).

CONCLUSION:

The addition of the air to water pathway, accounting for downdraught and downwash, and the inclusion of plume depletion effects increase the versatility of DELPro. The next task now is to obtain a better understanding of the uncertainties associated with DELs and doses calculated using this model. Also, increasing the processing speed of the program by upgrading it to a compiled version would make it easier to run complex simulations.

REFERENCES:

1. Canadian Standards Association, "Guidelines for Calculating Derived Emission Limits for the Radioactive Material in Airborne and Liquid Effluents for Normal Operation of Nuclear Facilities", CSA/CSA N288.1, August 1987.

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4. Gorman, D.J., "The Basis for the Derived Limits for the Emission of Radionuclides in Airborne and Liquid Effluents from Ontario Hydro's Nuclear Facilities", SSD-HSD-86-3, 1986

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