CONF-810606--45

ANEMOS: A Code to Calculate Radionuclide Concentrations in Air

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SUMMARY

Authority to regulate radioactive airborne effluents was given to the U. S. Environmental Protection Agency (EPA) by the 1977 amendments to the Clean Air Act. A computerized methodology for performing an interim assessment of airborne radionuclide releases as the basis for regulatory action has been supplied to EPA.[1] Efforts are now underway to develop a more comprehensive consistent methodology that can be the continuing basis for EPA assessments and radiation standards development. The ANEMOS computer code is being developed as part of this effort.

The purpose of the ANEMOS code is to estimate concentrations in air and ground deposition rates for Atmospheric Nuclides Emitted from Multiple Operating Sources. A schematic representation of the code is shown in Figure 1. ANEMOS is designed to be used for continuous rather than acute radionuclide releases. Atmospheric dispersion estimates are made using a modified straight-line Gaussian plume model.[2] The ground level concentration for the 22.5° sector-averaged form of this model is given by

$$\chi = \frac{Q}{0.16\pi\ \sigma_z u\ x} \exp\left[-\tfrac{1}{2}\left(\frac{H}{\sigma_z}\right)^2\right] \qquad (1)$$

where

χ = concentration in air at x meters downwind (Bq/m³),

Q = uniform emission rate from stack (Bq/s),

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u = mean wind speed (m/s),

σ_z = vertical dispersion coefficient (m),

H = effective stack height (m).

The Gaussian model is the most widely used atmospheric dispersion model for assessment purposes.[3] However, the ANEMOS code outlined in Fig. 1 incorporates several features that have not been widely used for assessment purposes, among them: (1) adjustment of wind speeds for height, (2) dependence of plume rise on downwind distance, and (3) explicit consideration of the ingrowth of radionuclide daughter products during downwind plume transport.

In the Gaussian model, Eq. (1), air concentration is inversely proportional to the wind speed, u. Wind speed information available from the National Weather Service for use in radiological assessments is generally measured at a height of 10 m above ground. For release heights greater than 10 m, however, these wind speeds should be adjusted to the height of release for use in the model. This adjustment can be made using the wind profile power-law[4]

$$u(z) = u_{10} \left(\frac{z}{10}\right)^n \qquad (2)$$

where

$u(z)$ = wind speed (m/s) at height $z > 10$ m,

u_{10} = wind speed (m/s) measured at a height of 10 m,

n = power-law exponent.

Values of n are usually specified as a function of atmospheric stability. ANEMOS, however, incorporates values of n that are a function of both Pasquill atmospheric stability class (seven classes) and surface roughness length (six classes).[4] It has been shown that adjustment of the wind speed for the height of release can improve the accuracy of the Gaussian plume model.[5]

The effective stack height, H, of a plume with momentum and/or thermal buoyancy is the sum of the physical stack height and the plume rise. Often, the maximum plume rise is calculated for assessment purposes.[1] In reality, however, plume rise is often a function of downwind distance until the maximum value is reached. ANEMOS allows the user to calculate either the maximum value of plume rise or a distance-dependent plume rise.[6] The latter may be especially important when calculating the external finite overhead plume gamma dose near the point of release. Use of the maximum plume rise values in such calculations could lead to an underestimation of the dose for certain combinations of downwind location, release height, meteorological conditions, and gamma ray energy.

It is common to correct air concentrations of emitted radionuclides for radiological decay during downwind transport. However, the treatment of the ingrowth and radiological decay of daughter products often involves manipulations external to the main code itself.[1] ANEMOS includes an efficient matrix methodology for explicitly treating the buildup and decay of all daughter products resulting from the emission of any given radionuclide.[7,8] This is an especially important procedure when estimating the dose from emitted nuclides that are members of long chains such as the uranium and thorium series.

The air concentrations and ground deposition rates calculated by ANEMOS will serve as inputs to other parts of the radiological risk investigation methodology being implemented for use by EPA. The features of ANEMOS discussed above, as well as other aspects of this risk investigation procedure, encompass more details than are often used in radiological assessment activities today. However, in our judgement, these methods represent improvements in assessment methodology based on the best scientific evidence available. As a result, we believe this implementation should provide EPA with a reasonable assessment methodology for its regulatory needs.

ACKNOWLEDGEMENT

This research was sponsored by the Office of Radiation Programs, U. S. Environmental Protection Agency, under Interagency Agreement EPA-78-D-X0394 under Union Carbide Corporation contract W-7405-eng-26 with the U. S. Department of Energy.

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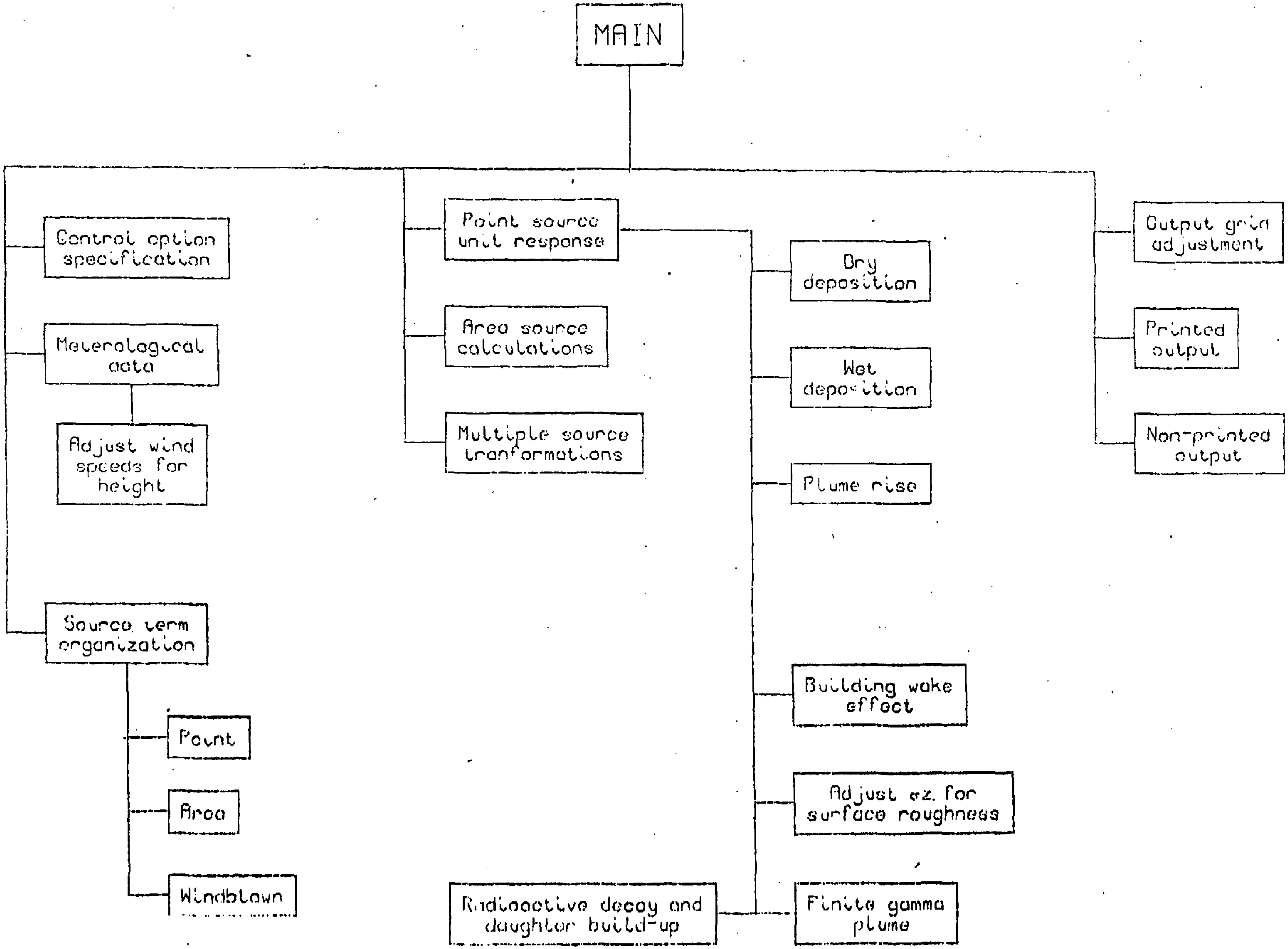

Figure 1. Schematic representation of the ANEMOS computer code.